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Seasonal variations of atmospheric pollutants in Oil producing communities of Rivers State using Satellite application.

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Abstract
This study is aimed at demonstrating the application of satellite data in analysing the seasonal pattern of air pollution in the Oil producing communities in Rivers State with a view of providing valuable information for effective adaptation mechanisms to the residents. Air quality satellite data was collected from NASA Goddard Earth Sciences database using the ground coordinates of the study areas (Ebocha, Mgbede and Okwuzi) which was got from field work. Parameters of concern for which data were collected are SO_2, PM2.5 and VOC as Formaldehyde (HCHO) from December, 2018, January and February, 2019 for the dry season while June, July and August 2019 for the wet (rainy) season. The data were extracted from the dataset using python programming language. The analytical techniques were descriptive using tables and percentages and trend analysis. In this study, hot spots are areas with high perceived level of air pollution whereas cold spots are with perceived low level of air pollution. Ebocha community is mostly polluted among the three communities during the dry season with values of SO_2=1.65378E-06kg/m^2,1.15342E-06 kg/m^2,9.15046E-07 kg/m^2 , PM2.5 = 2.08793E-05 kg/m2, 2.99876E-06 kg/m2,3.62596E-06 kg/m2, and HCHO= -7.68E+17 molec/cm^2,-1.29E+18 molec/cm^2,-8.58E+17 molec/cm^2 while Okwuzi is most polluted during the wet (rainy) season with SO_2 levels = 8.94634E-08 kg/m^2, 8.5244E-12 kg/m^2 ,7.81415E-08 kg/m^2, PM2.5= 1.25707E-05 kg/m2, 6.01465E-06 kg/m2, 2.86769E-06 kg/m2 and HCHO= -2.68E+17 molec/cm^2 -3.08E+17 molec/cm^2 -4.92E+17 molec/cm^2 . In both seasons, pollutants in Mgbede community are lowest. Ebocha and Okwuzi communities are known as the pollution hot spots while Mgbede community as the pollution cold spot in the study area. It is therefore recommended that real time air quality monitoring facilities and alert systems should be installed across the study area and environmental education strengthened as ways of adaptation during the peak pollution periods.

Keywords: Pollutants, Concentration, BTEX, Simulation, Satellite data and Communities Introduction

Introduction

The concentration of atmospheric pollutants is not homogenous. Several studies have been carried out to emphasize the seasonal variations associated with atmospheric pollutants. Miri, Derakhshan, Allahabadi, Ahmadi, Conti, Ferrante and Aval (2016) investigated outdoor concentration variations, sources, spatial distribution and risk assessment in Tehran, the capital of Iran. The aim of the study was to measure Benzene, Toluene, Ethyl benzene and Xylene (BTEX) concentration and determine their seasonal variations and probable sources. Their concentrations were measured using a continuous monitoring device which is installed in seven stations around the city. Spatial mapping was carried out using the Inverse Distance Weighting (IDW) method while Monte Carlo simulation was used to assess the carcinogenic and non-carcinogenic risks imposed by BTEX. Result shows that spatial distribution of BTEX pollution indicated that the highest concentrations were found along the major roads because of heavy traffic.

Owoadea, Philip, Hopkeb, Olisea, Olanisun, Adewolec, Olusegun, and Fawolea, (2016) carried out a study in Ile-Ife, South Western Nigeria to determine the influence of regional and local sources of fine and coarse fractions of air borne particulate matter. A total of 216 samples were collected between 2006, 2007, 2010 and 2013 across wet and dry seasons using low volume gent samplers. Most result exceeds the annual National Ambient Air quality standards (NAAQS). The authors applied Positive Matrix Factorization (PMF) to identify and apportion the sources of PM. For $PM_{2.5}$ the sources identified were soil (44%), Savannah burning (26%), Scrap processing (18%) and vehicular emission (72%). While for PM_{10} the sources identified were soil and biomass burning (71%), Sea salt (22%), Scrap processing (5%) and vehicle emissions (tyre wear) (2%). The author concluded that the major source of PM in the area was anthropogenic with the highest concentrations linked to the north westerly wind from the urbanized areas of Ile-Ife.

Liu *et al.* (2017) applied Principal Component Analysis to identify the sources of volatile organic compounds (VOCs) collected from July to October, 2014 in Kunming. Findings revealed that during the summer 40.60%, 19.33%, 19.19%, 10.22% and 8.34% of total VOC concentrations where sourced from biogenic emissions, industrial process, vehicular emissions, solvent usage, fuel leakage and evaporation and industrial production respectively. While in the autumn, 39.73% of total VOC concentrations were attributed to industrial production, 27.69% to solvent usage, 21.26% to vehicle emissions while 8.12% to various evaporations or leakages from fuel.

He , Gong, Yu, Wu, Mao , Song,, Zhao, Liu, Li, and Li, (2017) on the other hand, undertook a study to analyze the characteristics of air pollution in relation to multi-Scale meteorological conditions during 2014-2015 in 31 provincial capital cities of China. Results showed that the average concentrations of CO, NO_2, PM_{10}, $PM_{2.5}$ and SO_2 decreased in 2015 but increased for O_3. It was found that meteorological conditions across China were the Primary factor determining the daily concentrations of atmospheric pollutants in China. The condition (meteorological) in China was more adverse in 2015 for pollutant dispersion than in 2014.

Okoro (2010) noted that non point source of air pollution originates from various processes and fugitive emissions such as combustion processes and other anthropogenic processes. These non point sources according to the author are difficult to quantify and its control depends on a very careful industrial practices, effective monitoring and awareness programmes.

According to Murkherjee (2000), physical characteristics of the point source such as stack, plays significant role in the dispersion and impact of pollutants on the environment. Pires, Sousa, Pereira, Alvim-Ferraz, and Martins (2008) carried out a study in the Metropolitan Area of Oporto to identify city areas with similar air pollution behaviours and locate various sources of emissions. The statistical techniques of Principal Components Analysis (PCA) and cluster analysis were applied on a collected data from January 2003 to December, 2005. Results showed that only one emission source of SO_2 associated with wind direction was found. While, in the case of particulate matter, three emission sources were identified.

In this study area of Ebocha, Mgbede and Okwuzi communities of Rivers State, seasonal concentration of atmospheric pollutants are collected from satellite data and analyzed with a view to highlighting seasonal variations and proffering appropriate measures for mitigation and adaptation to air pollution episodes in the area. Fig. 1 is the map showing the study area.

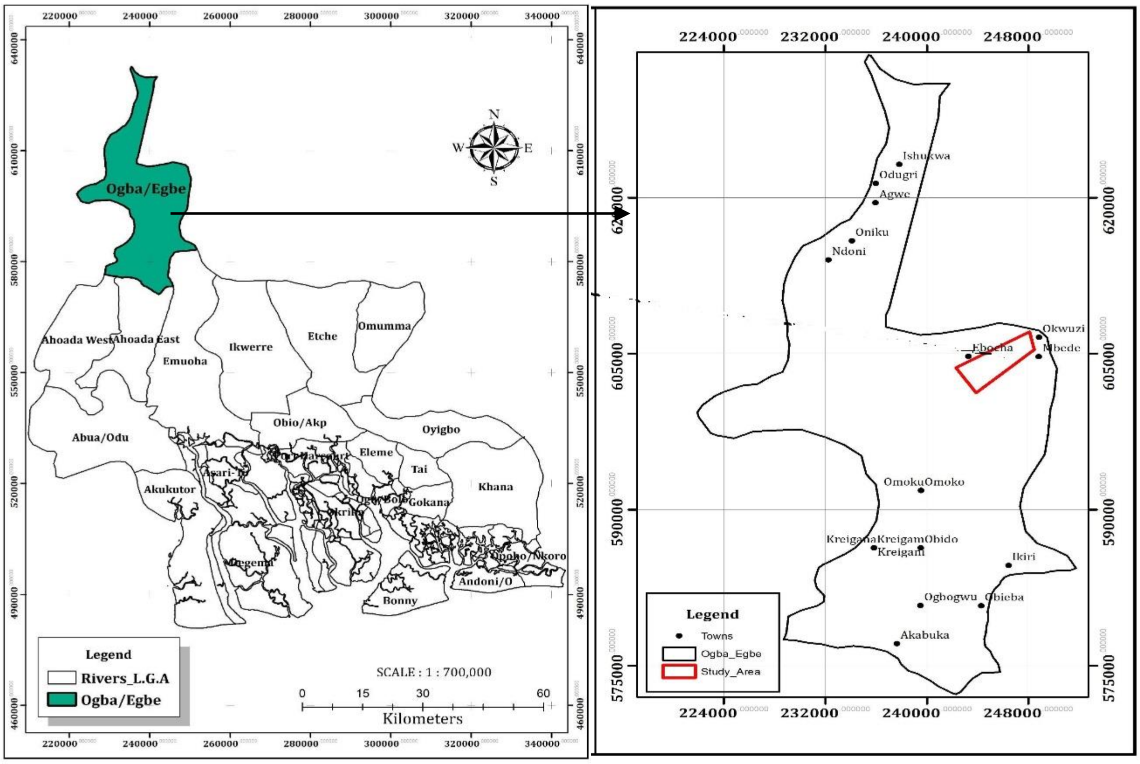


Fig. 1: The study area.

Methodology

Air quality data was collected sequentially from secondary source of the satellite imagery in NASA database. The satellite data revealed the concentration of atmospheric pollutants in each of the communities. These data were analyzed using descriptive analysis as well as trend analysis for two seasons. Also, geospatial analysis such as hot spot analysis and space-time analysis were carried out to identify the spatial hot and cold spots. Procedure for collecting data of pollutants' concentrations involved going to the field to determine coordinates of the study area and browsing through website of NASA using known coordinates to access their database where concentration of the pollutants is stored.

Satellite data was collected from NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC) database as shown on plates Plate 1, 2, 3 and 4.

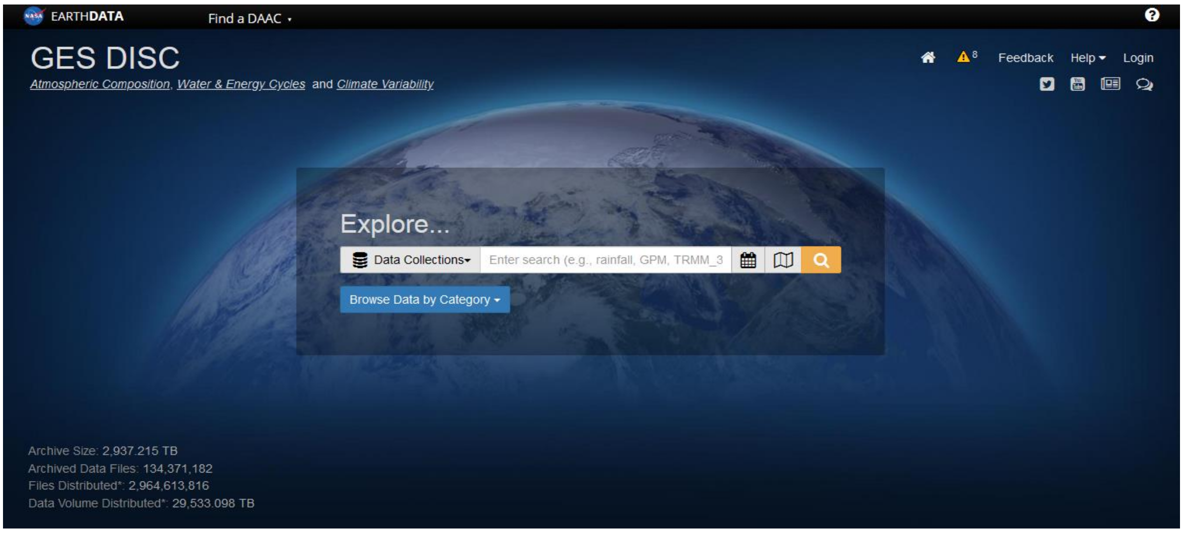
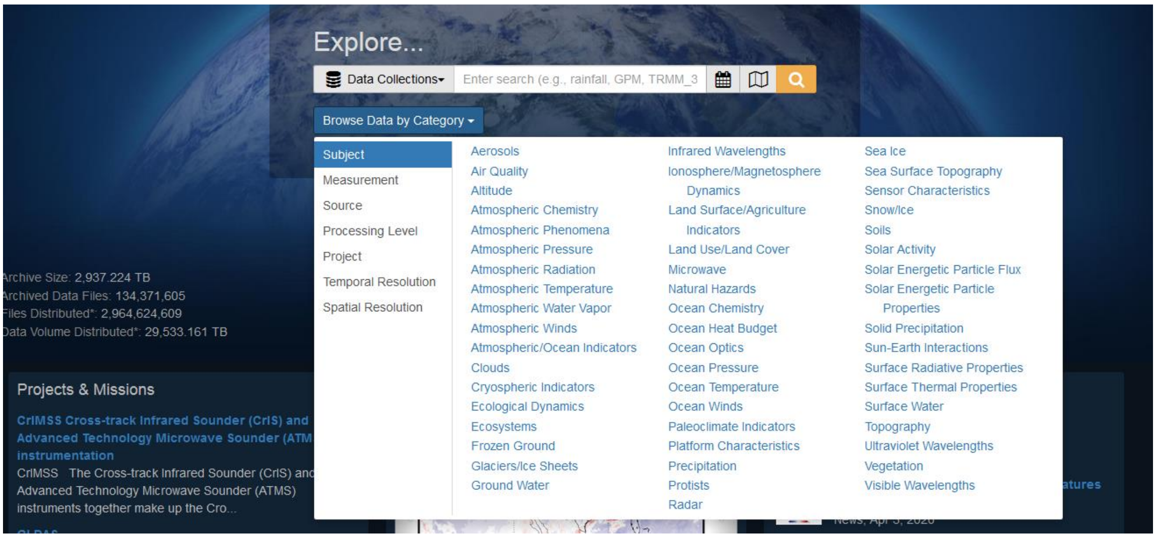
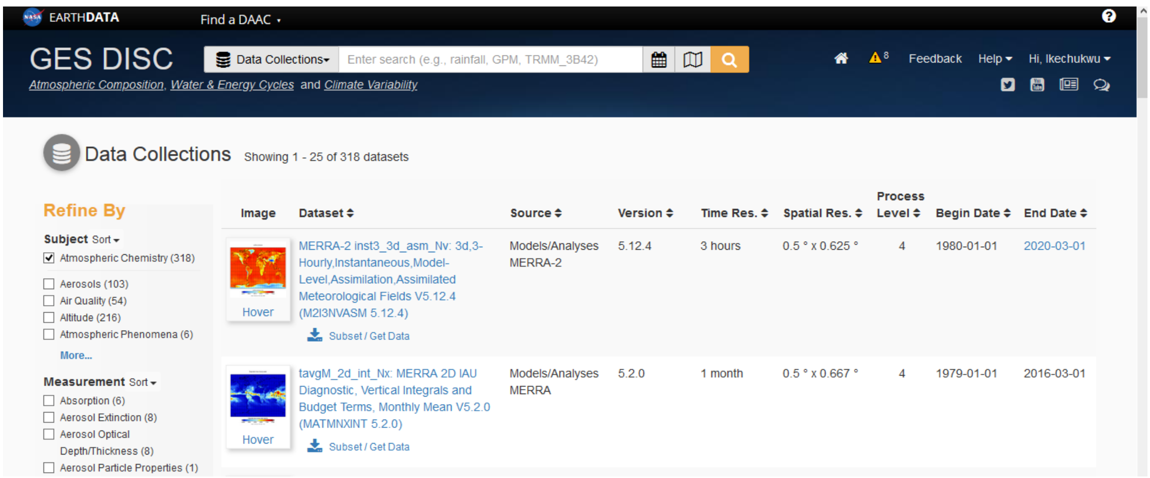


Plate 1: Landing Web page for NASA GES DISC

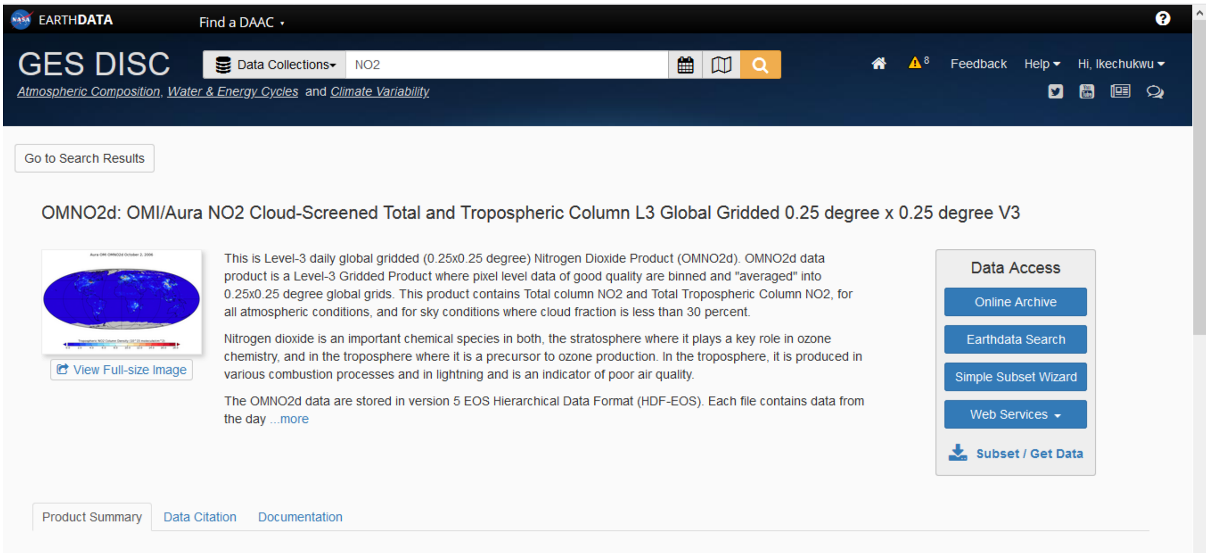
Registration was done before the site was accessed for pollutants information. After registration, the login details was used to acces the site.



Then the pollutant of interest was selected from the filter. For this research, interest was on Atmospheric Chemistry.



From this web page, pollutants of interest (Sulphur iv Oxide (SO_2), Formaldehyde (VOC) and particulate matter (PM2.5) were choosen. Also, spatial region of interest and time range was selected.



This page presents a brief description of the data and download link at the right side of the page. The longitude, latitude and concentration of the data were extracted from the dataset using python programming language. Data format encountered in this research are netcdf4, he5, and hdf.

Results

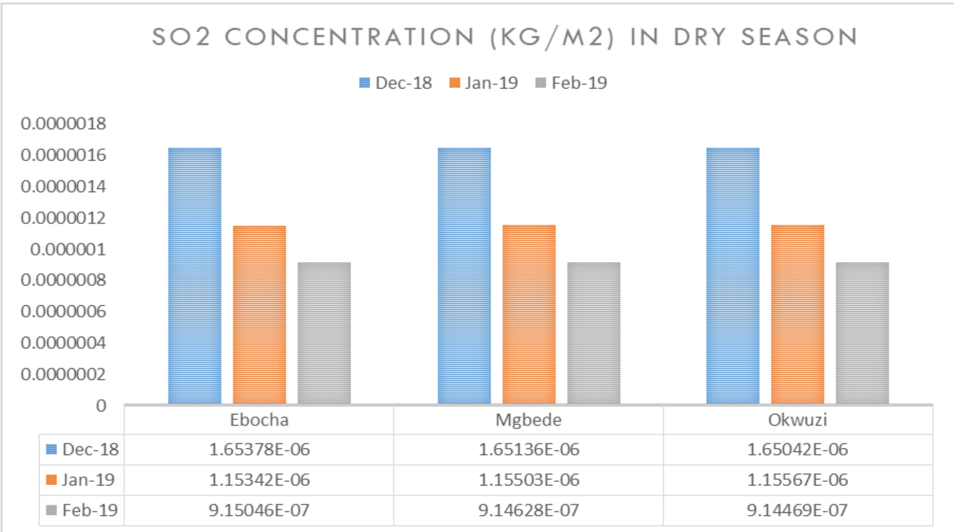


Fig. 2: SO_2 concentration in Ebocha, Mgbede and Okwuzi between December and January 2019 (Dry Season).

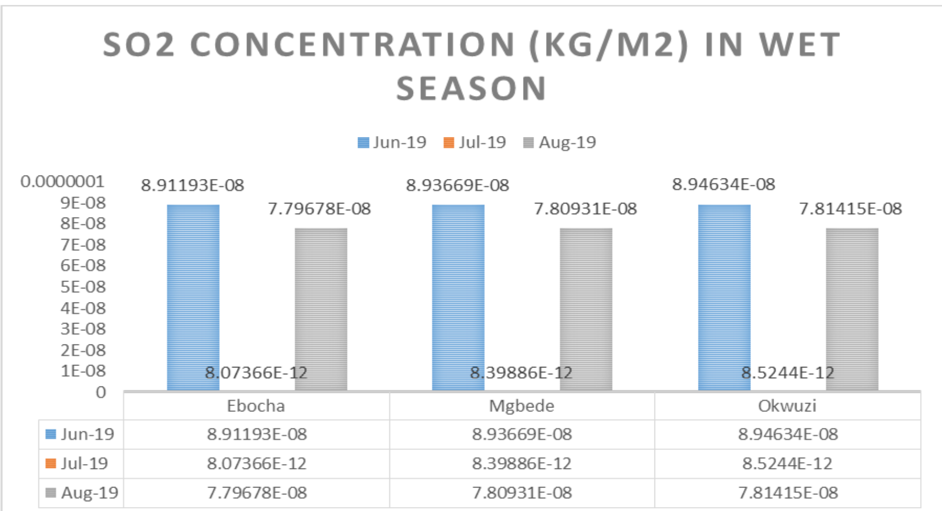


Fig. 3: SO_2 concentration in Ebocha, Mgbede and Okwuzi between June and August 2019 (Wet Season)

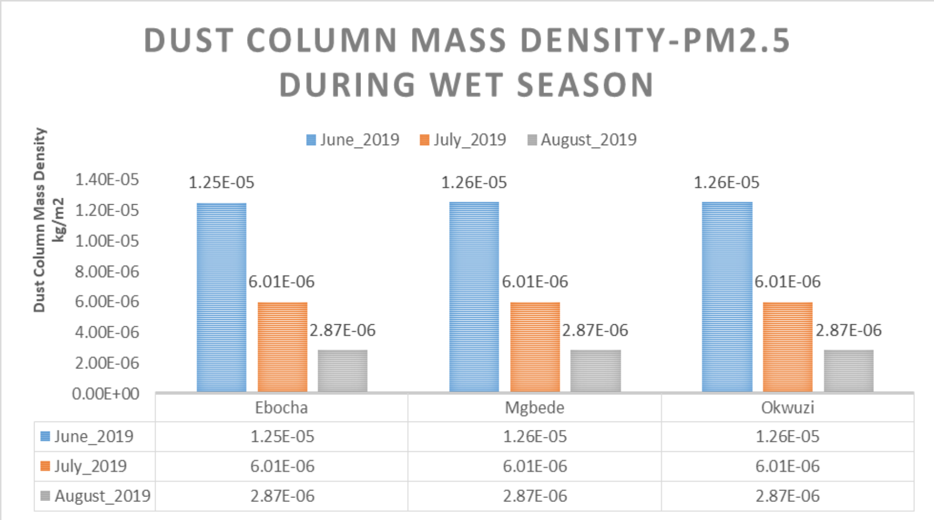


Fig. 4: Dust Column Mass Density-PM2.5 in Ebocha, Mgbede and Okwuzi in June 2019, July 2019 and August 2019 (Wet Season).

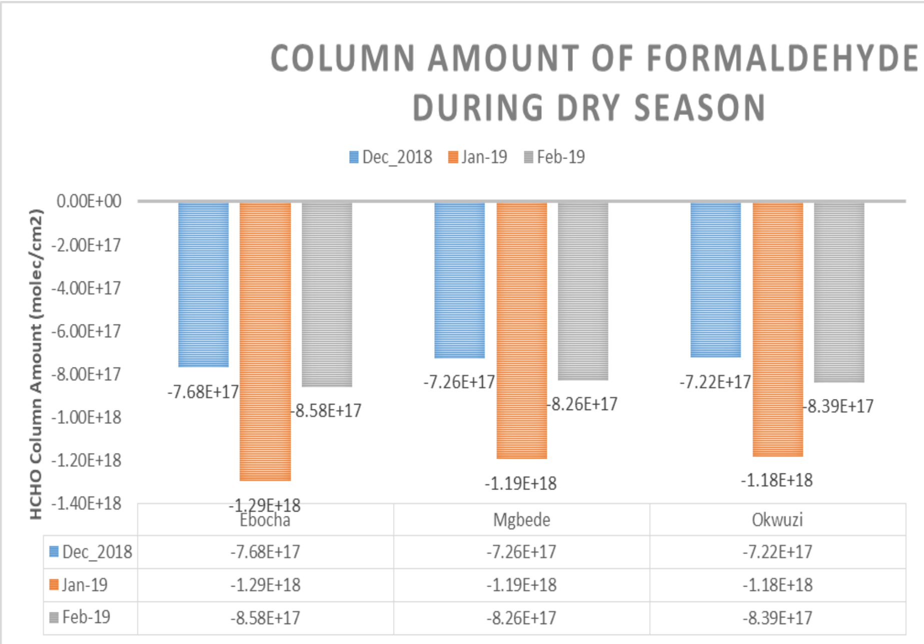


Fig. 5: Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi between Dec 2018 and Feb 2019.

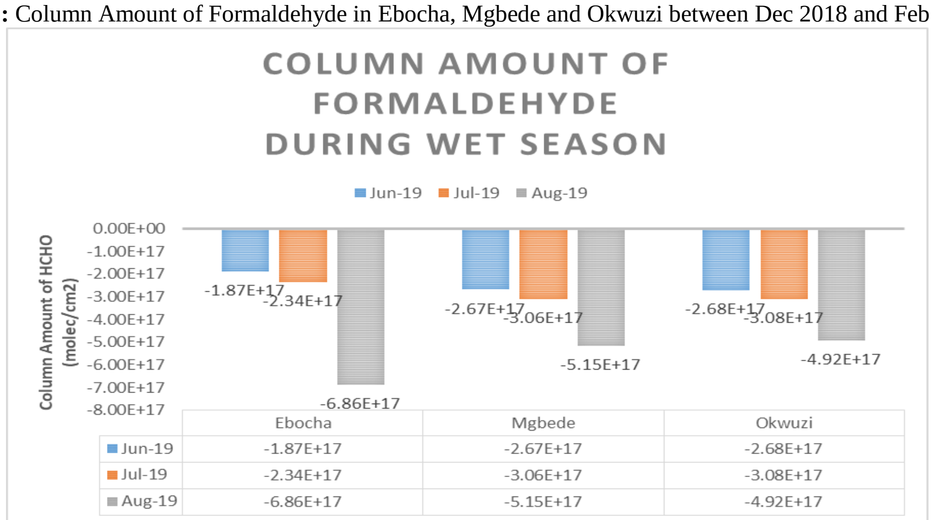


Fig. 6: Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi between June and August 2019.

Discussions

Spatial Concentration of SO_2 in Dry Season

During the dry season period, from December and February, it was discovered that in December, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 1.65378E-06 kg/m^2, 1.65136E-06 kg/m^2, 1.65042E-06 kg/m^2 respectively; this indicated that Ebocha community had the highest concentration of SO_2 in December. In January, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 1.15342E-06 kg/m^2, 1.15503E-06 kg/m^2, 1.15567E-06 kg/m^2 respectively; this also showed that Okwuzi had the highest concentration of SO_2 in January. In February, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 9.15046E-07 kg/m^2, 9.14628E-07 kg/m^2, 9.14469E-07 kg/m^2 respectively which equally indicated that Ebocha had the highest concentration of SO_2 in February as demonstrated in fig. 2.

Spatial Concentration of SO_2 in Wet Season

During the wet season period of June, July and August, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 8.91193E-08 kg/m^2, 8.93669E-08 kg/m^2, 8.94634E-08 kg/m^2 respectively, this indicated that Okwuzi community had the highest concentration of SO_2 in June. In July, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 8.07366E-12 kg/m^2, 8.39886E-12 kg/m^2, 8.5244E-12 kg/m^2 respectively which also indicated that Okwuzi had the highest concentration of SO_2 in July. In August, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 7.79678E-08 kg/m^2, 7.80931E-08 kg/m^2, 7.81415E-08 kg/m^2 respectively, this also indicated that Okwuzi had the highest concentration of SO_2 in August, this trend is illustrated in fig. 3.

Dust Column Mass Density PM 2.5 during Wet Season

During the wet season period; June to August using a five day monthly average, it was discovered that Ebocha, Mgbede and Okwuzi had Dust Column Mass Density of 1.25289E-05 kg/m2, 1.2559E-05 kg/m2, 1.25707E-05 kg/m2 respectively in June, showing that Okwuzi community had the highest amount of Dust Column Mass Density – PM2.5 in June. In July, Ebocha, Mgbede and Okwuzi had Dust Column Mass Density - PM2.5 of 6.01017E-06 kg/m2, 6.01339E-06 kg/m2 , 6.01465E-06 kg/m2 respectively, this also showed that Okwuzi had the highest amount of Dust Column Mass Density -PM2.5 in July while in August, Ebocha, Mgbede and Okwuzi had Dust Column Mass Density of 2.87289E-06kg/m2, 2.86918E-06 kg/m2, 2.86769E-06 kg/m2 respectively, this indicated that Ebocha had the highest amount of Dust Column Mass Density-PM2.5 in August as demonstrated in fig. 4.

Column Amount of Formaldehyde (HCHO) during Dry Season

Formaldehyde (HCHO) is one of the most common Volatile organic compounds VOCs. It is colorless with sharp bitter taste. Formaldehyde is a known carcinogen (Subesi, 2020). During the dry season, between December 2018 and February 2019, it was discovered that Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -7.68E+17 molec/cm^2, -7.26E+17 molec/cm^2, and -7.26E+17 molec/cm^2 respectively in December, this showed that Ebocha community had the highest Column Amount of HCHO in December. In January 2019, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -1.29E+18 molec/cm^2, -1.19E+18 molec/cm^2, and 1.18E+18 molec/cm^2 respectively indicating that Ebocha had the highest Column Amount of HCHO. In February 2019, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -8.58E+17 molec/cm^2, -8.26E+17 molec/cm^2, and -8.39E+17 molec/cm^2 respectively, this equally indicated that Ebocha had the highest Column Amount of HCHO in February. This implies that Ebocha had the highest amount of HCHO during the dry season as shown in fig. 5.

Column Amount of Formaldehyde (HCHO) during Wet Season

During the Wet season period, June, July and August 2019, it was observed that Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -1.87E+17 molec/cm^2, -2.67E+17 molec/cm^2, and -2.68E+17 molec/cm^2 respectively – an indication that Ebocha community had the highest Column Amount of HCHO in June 2019.

In July, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -2.34E+17 molec/cm^2, -3.06E+17 molec/cm^2, and -3.08E+17 molec/cm^2 respectively; this indicated that Ebocha had the highest Column Amount of HCHO while in August 2019, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -6.86E+17 molec/cm^2, -5.15E+17 molec/cm^2, and -4.92E+17 molec/cm^2 respectively which also showed that Okwuzi had the highest Column Amount of HCHO in August as seen in fig. 6.

From results obtained in this study, anthropogenic origin is the dominant source of atmospheric pollution in the study area while seasonal winds have a strong distribution effect in rainy and dry seasons. The map of the study area in Fig. 1 above, revealed the locations of Ebocha, Mgbede and Okwuzi and from the map, it is clear that Ebocha and Okwuzi lie tangentially in opposite direction. In this study area, two major seasonal winds known as the NE trade wind and the SE Trade wind blow across the area. The NE trade wind which occurs during the dry season blows across Okwuzi towards Ebocha into the Atlantic Ocean. On the other hand, the SE Trade wind which blows from the Atlantic Ocean, bringing about rainy season and reverses wind direction or pollutants from Ebocha towards Okwuzi community.

It could be deduced that Ebocha and Okwuzi communities are mostly polluted in the area while Mgbede community recorded an average level of pollutants. Generally, Ebocha is the hot spot of pollution in the study area during dry seasons and Okwuzi the hot Spot during the rainy seasons, while Mgbede is classified as the cold spot of pollution both in dry and wet seasons.

This agrees with the work of Kim, Kwon, Lee, Seo and Choi (2019) that seasonal wind patterns play a role in the distribution of pollutants in the city of Korea. Similarly, in Tibet, China, Chen, Kang, Yang, Pu, Li, Guo and Tripathee (2019) affirm that the seasonal variations of $PM_{2.5}$, SO_2, NO_2 and CO concentrations in six different locations are linked to wind direction. Also, Okoro (2004) revealed that acid deposition increases from Ebocha where gas flaring dominates towards Okwuzi which serves as the receptor.

Another significant factor accounting for the distribution of pollutants in each of the communities is human activities. For instance, the major source of formaldehyde in the study area is gas flaring. It is formed in the troposphere through the oxidation of hydrocarbons (Subesi, 2020). Formaldehyde recorded the highest amount (-7.68E+17 molec/cm^2, -1.29E+18 molec/cm^{2,} -8.58E+17 molec/cm^2) in Ebocha community. Also, the distribution of $PM_{2.5}$ is linked to trash burning by farmers during farming seasons in the area which occurs in the dry season especially from

January to February. This agreed with the study carried out Pozzer, Tsimpidi, Karydis, Meil and Lelieveld (2017) which revealed that human activities, especially agriculture, are the sources of atmospheric pollutants in the environment as such, a primary determinant of pollutant concentration in an area.

Conclusion

- Human activities (farming, gas flaring, and palm oil processing) and wind greatly influenced distribution of pollutants in the study area.
- Among the three communities, Mgbede is the pollution cold spot region in both seasons while Ebocha is a hot spot region during the dry season and Okwuzi a hot spot region during rainy season.
- It was also discovered that the concentration of some pollutants such as HCHO increased across the three communities during wet seasons. Concentration of $PM_{2.5}$ decreased across the three communities during wet seasons. On the other hand, concentration of SO_2 across the three communities decreased during dry seasons.
- Finally, results from this study indicated that strategic installation of air pollution monitoring stations and public enlightenment programmes would mitigate the problem of pollution , enhance adaptation and provide employment for the teeming unemployed youths in the oil producing region.

Recommendations

- Environmental education and enlightenment on various adaptive measures should be strengthened in the communities. The residents of Ebocha community should adapt by reducing their exposure during the dry season. Wearing of face masks by the residents could be very important not only as a protection against the spread of COVID-19 but also as a preventive measure against the inhalation of atmospheric contaminants.
- On the other hand, during the wet season, Okwuzi residents should reduce their exposure to rains. This will reduce their physical contact with soluble SO_2 which is high during the rainy season.
- Also, Government and Multinational oil companies operating in the area should install 24hr real time air quality devices in the area to collect regular data and alert systems to inform the people as soon as the level of pollutants poses danger to their health. This is particularly important as formaldehyde is a known carcinogen.
- Gas flaring in Ebocha community is a 24hr operation since the 1960s. The residents who are less than 60 years old and are confined to Ebocha community never know how dark night used to be through their life! Gas flaring is a major contributor to VOC, CO, CH_4 and other deleterious gases. This activity is suicidal and should be discontinued.

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