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ATMOSPHERIC IMPLICATIONS OF INFORMAL PETROLEUM REFINING IN THE NIGER DELTA: A SATELLITE-BASED TROPOSPHERIC STUDY

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Abstract

Nigeria is Africa's largest oil producer and a major global crude oil exporter, producing about 1.36 million barrels per day as of 2021. The Niger Delta region, the largest river delta in Africa, serves as the center of the country's petroleum industry and plays a vital role in its economy. The downstream petroleum sector is particularly important for refining crude oil into usable products that support transportation, industry, and domestic energy needs.Despite its importance, the sector faces major challenges such as low refinery capacity utilization, outdated infrastructure, and heavy reliance on imported refined products. Although Nigeria has four refineries with a combined installed capacity of about 445,000 barrels per day, actual output remains far below expectations due to operational and technical inefficiencies.This study highlights the significance of the downstream petroleum sector in the Niger Delta and examines the constraints limiting refinery performance. It emphasizes the need for improved infrastructure, better management practices, and policy reforms to enhance efficiency and promote energy self-sufficiency in Nigeria.

Keywords: Downstream petroleum sector, Niger Delta, refineries, oil production, energy security

INTRODUCTION

Nigeria is currently ranked as the largest oil producer in Africa and fifteenth largest producer in the world, in which as at 2021 produces about 1.36 million bpd. It is the energy giant of Africa and the most prolific crude oil producing nation in the continent (Olumide and Ayodele, 2017). The Niger Delta, endowed with vast natural resources is the key oil producing region of Nigeria, it is also the largest river delta in Africa (Ndidi et al., 2015). The downstream sector of the Petroleum industry of Nigeria is key in the economy of the country and its sustenance. This region is equipped with four refineries which by design is to have a combined refining capacity of 445,000 (bpd) barrels per day (Ogbon et al., 2018).

Nigeria has over eight (8) major and more than three hundred and fifty (350) Independent Petroleum Product Marketers, all active in the marketing business that distribute and retail refined products in Nigeria (Onigbinde, 2014). It is ironic to state that as richly endowed as Nigeria, direct exportation of its petroleum (Crude oil and natural gas) is the main foreign exchange earner of the country. Nigeria lacks effective domestic refining capacity and as opined by many this phenomenon is caused by sabotage in the petroleum sectors which has influenced importation of refined products to meet local need (Nkaginieme, 2005).

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The consistent insufficient supply of useable energy due to poor development and management of the energy sector is a major problem facing the country which the government is sincerely bordered about on ways to cub this distressing seasonal occurrences. In the year 2017, the consumption of refined products in Nigeria was put at about 24 billion liters per annum and products utilized include: Dual Purpose Kerosene (DPK), Automotive Gas Oil (AGO), Premium Motor Spirit (PMS) and Aviation Turbine Kerosene (ATK).

To the detriment of the nation's earnings, most of these products are imported from other sources and imports account for more than 80% of the products supply in the country, bringing about a huge potential for domestic refining (Olumide and Ayodele, 2017; Nathaniel, 2018). The effect of this insufficient and shortage of this reusable energy is severely felt in the country, especially in the Niger Delta region. Consequently, in a quest to bridge the gap between production and consumption of refined petroleum products, some Nigerians have discovered an indigenous local way of refining petroleum products using local technology (Social Action, 2014; Akeredolu and Sonibare, 2015).

The process and practice of artisanal refining activity is not new, it was used during the Niger delta agitation struggle as a local means of refining fuel from crude oil for the use of the militants, but since the end of the militant crisis in Nigeria in 2009, the scale has doubled and grown beyond control. The inefficiency of this illegal refining process is so high such that it is most likely that as much as 80% of the heavy end of the crude oil cannot be refined and are just discharged into the lands, wetlands, mangroves, rivers and creeks in our environment.

This technology employs simple and local distillery process to achieve refined products by subjecting the distilleries with crude oil content to heat from open fire. The refining process yields Petrol, Kerosene and diesel. Materials deployed for the operation are indigenously constructed and acquired, including: drilling machines, drums, Cotonou boats, dugout canoes, pipes, fire woods, crude oil, pumping machines, rubber hose, dried wood, storage facilities, among others. This operation does not require a large workforce, just a few personnel can conveniently and effectively manage the whole process. It does not require a lot of capital out lay to setup, depending on the choice of processing capacity adopted or entrepreneurial capability. The refinery is simple, averagely efficient and cheap to set up. It’s relatively low cost in setting up makes it an easy-going business for local private investors (Asuru and Amadi, 2016). This is the situation of the Niger Delta region where over 20,000 artisanal refineries have been setup by private investors who take advantage of the cheap labour and availability of raw materials in the area (Akeredolu and Sonibare, 2015).

Innovations in any form has its specific challenges of which this local illegal refining is a kind. According to several scholars, the artisanal petroleum refineries in the Niger delta region have been discovered to negatively impact its environment; (Obenade and Amangabara (2014a, b) of which presently the very core states at the bottom of the Niger delta are the most affected and as such suffering the attendant negative consequences and impact of these illegal artisanal petroleum refining activities and the chain of other oil and gas industry activities (Zabbey et al., 2017).

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Satellite investigations have proven to be a very useful tool in unravelling trends in virtually every aspect of science in our modern times, hence the use of portfolios and data derivable from globally recognized and well authenticated sources such as that provided by NASA Giovanni and other related satellite enabled platforms. These satellite signatures are explored in this study to compliment and validate ground data, research and investigations carried out by other research methods.

Considering the current disturbing trends of activities of illegal refineries springing up in the Niger Delta region of Nigeria of which easy access to most of these sites is hindered because of their locations, which most times is located in the coastal area or very deep into the rain forest in remote communities. Also with particular concerns on flash points states such as Rivers state, Bayelsa state and Imo State in the region, it becomes very important to study the levels of concentration of gaseous pollutants in these areas occasioned by these illegal artisanal refining activities on the atmosphere chemistry in the concerned states which by extension would give a picture of the entire region.

At the same time not undermining the fact that there are other activities from related sources such as fossil fuel usage, bush burning, air emissions from industrial machineries and other anthropogenic activities that could also add up to the loading of these gases on the atmosphere of the region.

The Problem

The extent and impact of devastation done to the air quality index of the atmosphere by the activities and continuous increase of artisanal petroleum refining across the Niger Delta Region is on the rise, hence the need for a continuous investigation as to quantify and characterize these trends in which satellite signatures retrieved from Giovanni platforms have proven over the years to be of immense assistance. Consequently, some research conducted on air pollution in Nigeria gave indication of air pollution exceeding WHO guidelines in some cities in Nigeria. (Ana, 2011; Abam & Unachukwu, 2009; Weli, 2014a; Weli, 2014b; Weli and Adekunle, 2014; Weli and Kobah, 2014; Weli and Ayoade, 2014; Weli and Itam, 2016; Weli and Adegoke, 2016; Weli, et al, 2017; Shaibu and Weli, 2017)

On a global scale a quantitative comparison of the aerosol optical properties over Durban using ground and satellite based instrumentation a study carried out by (Singh et al., 2017), it was discovered that there was a high extent of fine mode aerosols present throughout the year for Skukuza, indicating that urban industrial emissions from the South African Highveld region can also contribute to aerosol loads in the region. In another research work in which Nasa Giovanni interface was deployed aimed at evaluating spatial distribution of carbon dioxide (CO_2) pollutant concentration in Abuja the Capital City of Nigeria by (Salami et al., 2019), their results and analyses reveals a steady rise in concentration of carbon dioxide from 376.6 parts per million to 402.2 parts per million (ppm) in the Study area caused by human inducement.

Similarly, a study by (Ijeoma, et al., 2020) which investigated surface concentration of carbon monoxide (CO) across Nigeria as a region from the year 2007 to 2016 using remote sensing data from NASA GIOVANNI air quality platform confirms higher surface concentrations of CO recorded in Southern cities than cities in the

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Northern cities which largely is due to man's anthropogenic activities, vehicular emission, industrialization, bush burning, deforestation, burning of refuse dump sites and artisanal petroleum refining to mention a few. Mores, a study conducted by (Chukwudobe, et. al., 2021) also establishes elevated and decreasing levels of aerosols concentrations such as CH_4, NO_x, CO, SO_4 across the selected areas under study at different seasons and location in the year.

Other studies in other regions and urban cities equally recorded pollution level exceeding WHO guidelines. These issues necessitate this study to assess the levels of impact of the emission of these poisonous gases into the lower troposphere which also could affect climate change and cause diver's health issues across the area under study. Using remote satellite sources and platform to observe these changes and impacts provides for us incontrovertible globally authenticated background data, for predicting and mitigating environmental impacts to which subsequently, monitoring and evaluation with ground data could be compared with to draw holistic inferences and conclusions.

The aim of this paper is to examine the impact of artisanal refining of petroleum on the lower tropospheric chemistry of the Niger delta region of Nigeria using Giovanni satellite platform. To achieve this aim, the following specific objectives were pursued.

The specific objectives of this study include the following;

1. Determine atmospheric concentrations of the oxides of Cabon (CO, CO_2) across the states under study.
2. Unravel the atmospheric loading of the concentrations of Methane (CH_4) in the study area. 3. Determine the atmospheric dose of oxides of Nitrogen (NO_2)
4. Identify the levels of atmospheric concentrations of oxides of Sulphur (SOx) across the selected states in Niger Delta of Nigeria.
5. Determine the atmospheric concentration of Organic Carbon
6. Determine the concentration levels of the pollutants across the selected states
7. Compare the level of concentration of these pollutants with WHO standards for air quality

Study Area

There are two major area of study in this work. Firstly, three states in the Niger Delta Region namely; Rivers state, Bayelsa state and Imo state, these three states are focused upon as key states where these artisanal petroleum refining activities are very ubiquitous, and secondly Bornu state; a state in the North-Eastern part of the country where artisanal petroleum refining activities is not practiced as control

The Niger Delta region (NDR) of Nigeria, located in the southern part of the country, stretches over an area of about 75,000 sq. km, between longitude 5^o E to 8^o E and latitude 4^O N to 7^o N (Adagunodo et al., 2017). The region is made up of nine administrative states with diverse ethnic groups (Odalonu, 2016) which are Edo, Delta, Bayelsa, Ondo, Abia, Akwa Ibom, Imo, Rivers, and Cross River. These are the oil producing states in Nigeria (Odalonu, 2016) as illustrated in Figure 3.1. However, as stated above the critical study areas in the NDR are (1) Rivers State located on a latitude of 4.8396^0N, longitude 7.0588^0E and an area covering 11.077km^2, (2) Bayelsa

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state located on a latitude of 4.7719^{0}N, longitude 6.0699^{0}E and an area covering 10.773km^2 (3) Imo state located on a latitude of 5.5720^{0}N, longitude 7 and an area covering 5.530km^2, as illustrated in (Figure 1).

These three states under study are bounded together as immediate geographic neighboring states, while five other states form border states directly to the North, East and the West around them in the region with the Atlantic Ocean borders the south of Rivers and Bayelsa states. Rivers state shares border with Abia and Akwa Ibom States to the East; Bayelsa State is bordered to the NorthWest with Delta State while Imo State is bordered to North with Anambra and Enugu State and to the East with Abia state.

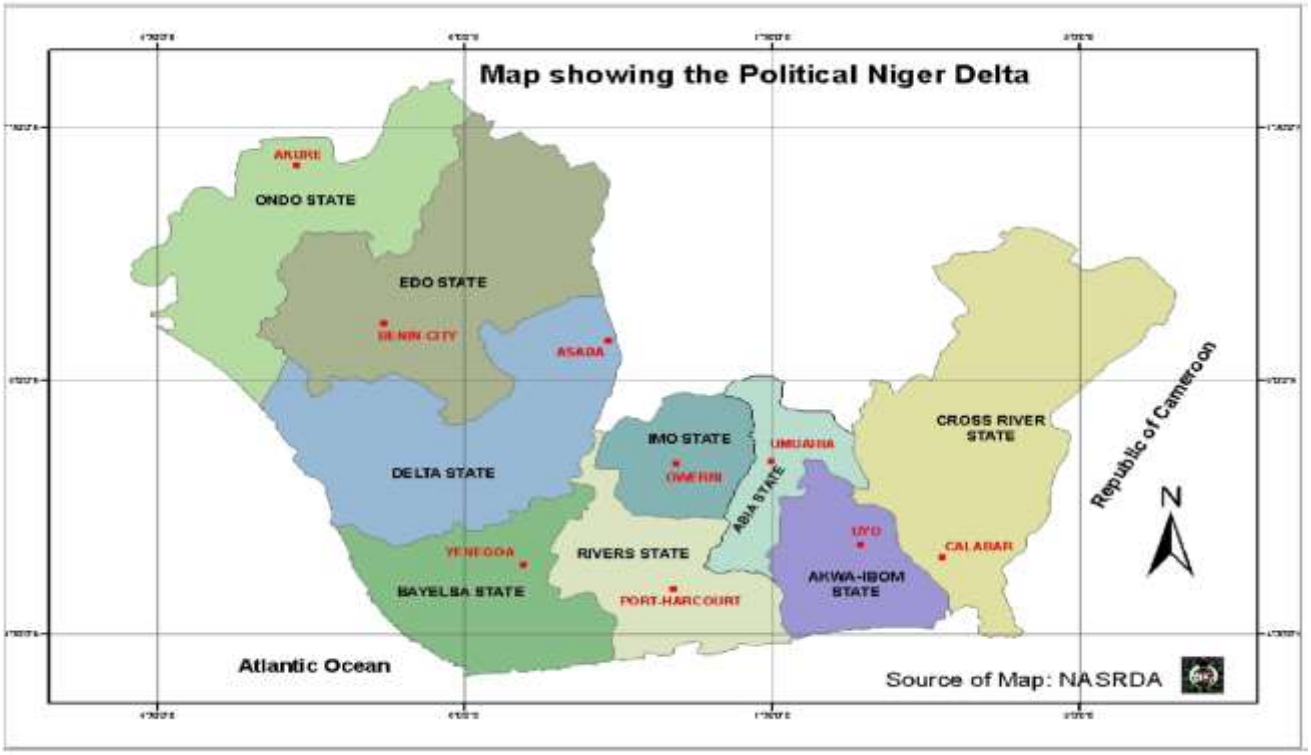

Figure 1: Map of the Niger Delta Region of Nigeria showing the Nine Niger Delta states.

Secondly, Bornu State (fig 2) being the fourth state is located on a latitude of 11^0 30^l N, longitude 13^0 00^{l}E and an area covering 70,898km^2. It is a state in the North-East geopolitical zone of Nigeria, bordered by Yobe to the west, Gombe to the southwest, and Adamawa to the south while its eastern border forms part of the national border with Cameroon, its northern border forms part of the national border with Niger, and its North-Eastern border forms all of the national border with Chad, being the only Nigerian state to border three foreign countries.

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Figure 2. Map showing all North-Eastern States and Bornu state Nigeria

Population of the study area

The total estimated population of the Niger Delta region is 42,637,086. The population of three states of the area of interest/study in the NDR is about 14,990,641. Rivers state which is the six most populated State in the country is the most populated state in the region with an estimated population of 7,303,923, Imo State stands as the fifteenth most populated State in the country and the fourth in the region has a population of 5,408,756, Bayelsa State coincidentally is the State with the least population both in the nation and the Niger delta region ,it has an estimated population of 2,277,961 while Bornu State stands as the state with the second largest land area, the eleventh most populated State in the country with a population of 5,860,183 persons. All the states have vast ethnicities and culture though with lots of similarities.

Conceptual Clarifications

Artisanal Refining

Artisanal refining also known as "Kpofire" as colloquially called is a small-scale or subsistent distillation of crude petroleum over a specific range of boiling points, to produce useable products such as kerosene, fuel and diesel (Ikanone et al., 2014). These artisanal refineries were developed to satisfy local demands for combustible energy in the face of an unreliable national grid, high costs and sporadic scarcity of consumer fuels, it can be likened to modular refineries in the United States of America and other parts of the world though of a less advanced and crude technology

(Chigbo, 2009). Petroleum products which are products gotten from these artisanal refining are fuels made from crude oil and hydrocarbons contained in natural gas such as butane, diesel fuel, fuel oil, gasoline, kerosene, LPG, LNG etc. (Walther, et al., 2005).

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This is the major satellite remote sensing platform used in this study, it is a web-based application developed by the Goddard Earth Sciences Data and Information Services Center (GES DISC) that provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data (although data downloads are also supported). Giovanni is an acronym for the Geospatial Interactive Online Visualization and analysis Infrastructure, it is also a Web interface that allows users to analyze NASA's gridded data from various satellite and surface observations. The NASA Giovanni data analysis system has been recognized as a useful tool to access and analyze many different types of remote sensing data for an illustration, the " Regional Assessment of Ozone across Nigeria, from 2005 to 2018 using NASAGIOVANNI Air Quality" by David-Okoro, et al (2018). The variety of environmental data types has allowed the use of Giovanni for different application areas, such as agriculture, hydrology, and air quality research etc. James, Radiner etal., (2014), in their study deployed the use of Giovanni for researching connections between public health issues and Earth's environment and climate, potentially exacerbated by anthropogenic influence. The study also provided a case study of the use of remote sensing data from Giovanni in assessing the associations between seasonal influenza and meteorological parameters. Giovanni data analysis system has significant capabilities for oceanographic education and independent research utilizing ocean color radiometry data products (Acker.,2007). Data Visualization and analysis for climate studies using Nasa Giovanni online system has also become relevant and a tool in remote sensing meteorological and climatological researches (Hualan, et. al., 2009).

The use of Nasa Giovanni data visualization, observation and analysis has found expression in almost every critical sector in Earth science. A study carried out by David- Okoro, et.al., (2020), investigating surface concentration of carbon monoxide (CO) across Nigeria as a region from the year 2007 to 2016 using remote sensing data from NASA GIOVANNI air quality platform. They established by their research that Nigeria's air quality is attracting enormous growing public concerns because some cities recorded very dangerous concentration of criteria pollutants like Particulate matter (Pm) in the year 2016. From this study, higher surface concentrations of CO were recorded in Southern cities than cities in the North. Similarly, in a research carried out using Nasa Giovanni earth data platforms on Black carbon pollution simulations by Oluleye and Folorunsho (2020), it was posited that " The increasing sources of black carbon (BC) emission into the atmosphere have made BC a major air pollutant that could contribute significantly and alter the global atmospheric radiation budget.

METHODOLOGY

This section aims to provide an overview of the methodology and datasets employed in this research. The chapter details the preliminary steps taken at characterizing, scaling and identifying specific states and the difficulties encountered. A description of the study area, satellite spatial sampling method and comparative analysis following. Furthermore, the chapter explains the attributes of the satellite data utilized and the various computational procedures applied. Although this section gives an overview of the general methodology of this research, specific methods applied to unique datasets are discussed in subsequent sections

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Previously published research works that were undertaken in the areas bordering on the topic of interest in this dissertation were qualitatively and quantitatively reviewed, evaluated side by side and other available data were also assessed for extraction of important and relevant information, while exploring and gathering data via satellite imagery and signatures, using accurate and well plotted shape files and portfolios to describe location/study area, accompanied with critical evaluation, observation and interpretation of downloaded profiles as to adequately convey the specific aims and objectives of the study. Analyses and visualizations used in this study were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC."

Satellite derived data sets and images representing specific atmospheric conditions of air emissions within the region and area of interest/study were generated and accessed by remote sensing from Earth data sources of NASA GESDISC DATA ARCHIVE via the Nasa Giovanni platform. The geographical map of the entire Niger delta region was first pbtained, then with the aid of Google earth, the maps of the three states of interest is isolated as shape files. Two amongst the three states namely Rivers state and Bayelsa states are identified as areas of greater prevalence of activities of artisanal refining, while Imo states serves as the state where less of these artisanal refining takes place (Figure 2). Bornu states serves as the control state where the activities of artisanal petroleum refining are not being practiced.

Satellite signatures of specific atmospheric gases such as oxides of Nitrogen (NO_x), oxides of carbon (CO, COx), methane(CH_4), oxides of sulphur (SOx) and Organic carbons (OC_s) are then retrieved from Earth Data satellite sources by launching into Nasa Giovanni platform and exploring satellite imagery from satellites such as (Modern-Era Retrospective analysis for Research and Applications-2 (MERRA-2),Atmospheric Infrared Souner (AIRS),Moderate Resolution Imaging Spectro radiometer (MODIS-Aqua and MODIS-Terra, Ozone Monitoring Instrument (OMI) NASA's Aura satellite). Eight (8) data sets each were retrieved representing the three states of the Niger Delta Region and also the North eastern Bornu state of Time Average Map with each parameter treated independently and one (1) Time series Area average each was also plotted for each time range of between (January 1997 to February 1999, January 2012 to January 2022, January 2002 to February 2005, January 2014 to February 2015 and January 2017 to February 2022) as the case applies for the two areas of study. Information or data retrieved for any variable is based on available data on the satellite that has been generated and preserved in their archive for the variable being investigated. All procedures followed at retrieving of data from the Nasa Giovanni Earth Data platform were in accordance with official protocols in retrieving data from the platform, which will be listed stepwise in course of the study. Final satellite signatures were downloaded in KMZ GIS file format directly via Google Earth and saved as an image for analytical/illustrative purposes.

Geospatial satellite signatures on the Atmospheric Chemistry of the area under study retrieved from Earth science data sources using the Nasa Giovanni platform as instrument of observation. Two channels were used; firstly, Time Average Map and secondly Time series area average of the specific air emissions under observation in the study area.

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Time Average Map.

Time average map (TAM) is the default visualization type of plot in Giovanni, it shows data values for each grid cell within the user-specified area. TAM was used to average any data variable time increment (hourly, 3-hourly, weekly, monthly). Bounding boxes or shape files can be used for the study area. Three (3) representative Time Average Map data sets with shape files were plotted for each of the air emission being investigated with a clipping-in of specific shape files for the purposes of identifying the states as to ascertain the level of pollution/emissions in each specific state for proper analysis, comparisons, conclusions and recommendations.

These four satellites namely (MERRA-2, AIRS, OMI, MODIS-Aqua and MODIS-Terra) were the major satellite source of our Geospatial data sets.

Time Series Area Average (TSAA) spatial plot/graph

Time series area average is another earth science data select plotting tool used for several geo spatial remote sensing analytical comparisons which was deployed in the study. It is stated that "The standard Giovanni time-series plot was produced by computing spatial averages over the user-selected area of a given variable for each time step within the user's range". Fill values do not contribute to the spatial averages for each average value is plotted against time to create the timeseries output.

Table 1: Geo spatial satellite signatures summary of Time Average maps (TAM)

S/N	Measurement /variables	Satellite source/details	No of State(s)	Date range	No of satellite signature(s)
1	NO_2 (Tropospheric column)	OMI	4states impacted & 1 control) (3	(January 2020 to February 2020) & (January 2022 to February 2022)	3.
2	CO (surface concentration)	MERRA – MODEL 2	4states impacted & 1 control) (3	(January 1997 to January 1998) & (January2017 to February 2022)	3

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3	CO_2 (mole fraction in free troposphere)	AIRS		4 states (3 impacted & 1 control)	(Sept 2002 to February 2012) & to February 2012 to January 2017	3
4	SO_2 (Biomass Burning Emission)	MERRA – MODEL	2	4 states(3 impacted & 1 control)	(January 1997 to January 1998) & (February2017 to Aug 2022)	3
5	SO_2 (Surface Mass Concentration)	MERRA – MODEL	2	4 states(3 impacted & 1 control)	(January 1997 to January 1998) & (February2017 to Aug 2022)	3
6	SO_4 (Production from SO_2 gaseous oxidation column)	MERRA – MODEL	2	4 states(3 impacted & 1 control)	(January 1997 to January 1998) & (January 2017 to January 2022)	3
7	CH_4 (Methane)Mole fraction in Air (Day time Ascending)	AIRS		4 states (3 impacted & 1 control)	(Sept 2002 to January 2005) & (January 2015 to January 2016)	3
8	OCs (Organic carbons Anthropogenic Emission)	MERRA – MODEL	2	4 states (3 impacted & 1 control)	January 1996 to January 1999) & (January 2017 to January 2022)	3

Source: Author's field work from Nasa Giovanni platform, 2023.

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Table 2: Time Series Area Average Plot

S/N	Measurement /variables	Satellite source/de tails	No of State(s)	Date range	No of plot(s)
1	NO_2 (Tropospheric column)	OMI	3 impacted & 1 control	(January 2020 to February 2020) & (January 2022 to February 2022)	1 & 1 respectively.
2	CO (surface concentration)	MERRA – 2 MODEL	3 impacted & 1 control	(January 1997 to January 2000) & (January2012 to February 2021)	1 & 1 respectively
3	CO_2 (mole fraction in free troposphere)	AIRS	3 impacted & 1 control	(Sept 2002 to February 2005) & (February 2012 to January 2017)	1 & 1 respectively
4	SO_2 (Biomass Burning Emission)	MERRA – 2 MODEL	3 impacted & 1 control	(January 1996 to January 1999) & (February2012 to Aug 2021)	1 & 1 respectively
5	SO_2 (Surface Mass Concentration)	MERRA – 2 MODEL	3 impacted & 1 control	(January 1996 to January 1999) & January2017 (January 2022) to	1 & 1 respectively
6	SO_4 (Production from SO_2 gaseous oxidation column)	MERRA – 2 MODEL	3 impacted & 1 control	(January 1992 to January 2000) & (January 2017 to January 2022)	1 & 1 respectively
7	CH_4 (Methane)Mole fraction in Air (Day time Ascending)	AIRS	3 impacted & 1 control	(Sept 2002 to January 2005) & (January 2013 to January 2017)	1 & 1 respectively
8	OCs(Organic carbons Anthropogenic Emission)	MERRA – 2 MODEL	3 impacted & 1 control	January 1996 to January 1999) & (January 2017 to January 2022)	1 & 1 respectively

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Source: Author's field work from Nasa Giovanni platform, 2023

Table 3: Geo spatial Locations and Bounding Region

S/N	States	Latitude	Longitude	Select Region (Bounding Box/Shape)
1	Rivers state	4.872904^0	6.839260^0	6.3116,4.3756,8.7946,7.342
2	Bayelsa state	4.769236^0	6.031305^0	5.6525,4.0461,7.5201,7.276
3	Imo state	5.537830^0	7.061776^0	6.289,4.9164,7.207,5.5096
4	Bornu state	$11^030^!$	$13^000^!$	6.289,4.9164,7.207,5.5096

Source: Author's field work from Nasa Giovanni platform, 2023.

All the satellite signatures/profiles indicated in Table 1 and Table 2 for Time Average Map and Time series area average were retrieved and downloaded from specific satellite platform (NASA Giovanni platforms) which has provided a wide range of earth science data in its archives for over several decades and are still generating every passing moment with bigger satellites being launched.

RESULTS AND DISCUSSION OF FINDINGS

Study showed that Bornu state had CO concentration ranging between (125.8 - 209.1) ppbv with Imo state having the highest concentration range at (172.1 - 206.2) ppbv; Rivers state (135.1 - 172.5) ppbv ; Bayelsa State (135.1- 162.9) ppbv, while Bornu state showed the least concentration range at (94.5 – 121.8) ppbv.. For methane (CH_4) concentration, mole fraction in air (day time/ascending) for the period 2015 January – 2016 January for the area under study shows methane concentrations in air with variations between the states ranging from (1784.0 -1820.0) ppbv. Bayelsa state had the highest atmospheric loading of (CH_4) at (1810.0 – 1815.0) ppbv > Rivers state with concentration at (1810.0 – 1813.0) ppbv; Imo state (1788.0 - 1806.0) ppbv; however, no concentration in all the states exceeded its globally rated occurrence of about 1900.0ppb. For Bornu state at the north-eastern part of the country time average map profile data was not available on the [AIRS AIRX3STM v006]-satellite source.

Selected atmospheric gaseous emissions which included-(CO, CO_2, NO_2, CH_4, SO_2, SO_4 and Organic carbons) for some selected states such as; Bayelsa state, Rivers state and Imo state in the Niger Delta region and one state of the northern region – (Bornu state) as control for analytical comparisons of satellite retrieved data using satellite signatures retrieved from Nasa Giovanni platforms and other Earth data/GES DISC sources between time gaps of an average of (1 - 20) years apart, so as to determine atmospheric pollution levels of these pollutants within the time periods.

Time average maps were plotted and downloaded across the selected states from Nasa Giovanni platform using google earth and ArcGIS images, to further illustrate relationship and accuracy of the data generated, result's data is compared with Time series area average plots with same set up also from same source, which also corresponded with the profile images retrieved from Time average maps.

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The oxides of carbon result data generated for Carbon monoxide (CO) - surface concentration shows the Niger delta states have a higher atmospheric concentration of CO pollution level when compared to Bornu state in the north-eastern region. Imo State in both time periods had the highest atmospheric concentration level of CO pollution in the region at about 85% higher than the atmospheric concentration level of CO in Bornu state.

Carbon Dioxide (CO_2) mole fraction in free troposphere shows a reverse in concentration of atmospheric pollution levels of CO_2 between the two-time periods under review. In 2002 to 2005,

CO_2 mole fraction in free troposphere generated from available satellite atmospheric data and signatures showed that the Niger Delta region had higher tropospheric pollution levels than Bornu state, whereas the reverse from satellite signatures and data retrieved from same source for the period (2007 to 2012) in which Bornu state in the North experienced a higher level of atmospheric concentration of CO_2 in free troposphere. However, all atmospheric concentrations levels were within air quality index of safe and clean air not exceeding 500ppm (WHO/FMEnv limits).

Methane (CH_4) and Oxides of Nitrogen (NO_2) showed a higher atmospheric concentration in the states of the Niger delta region than Bornu state within the periods under observation (2002 – 2005) and (2007 – 2012) respectively. It was observed that Satellite signature were retrievable for the Niger delta region but unavailable for the whole northern regions of the country where our control state Bornu state is located.

Sulphur oxides (SO_2 and SO_4) are emitted or produced when sulfur containing fuels such as petroleum, coal etc are burnt which includes artisanal petroleum refining. We observed from the satellite data and signatures retrieved that the SO_2 surface mass concentrations shows the atmospheric concentration of SO_2 in the Niger delta much higher than that in Bornu state, while satellite profiles for SO_2 Biomass Burning emission within the same time periods of (1997 January to 1998 January and 2017 January to 2022 January) respectively, show a complete opposite with Bornu State having atmospheric pollution due to SO_2 Biomass Burning emission much higher than the Niger delta states at levels above 400% to 800% respectively. We also observed a direct relationship with SO_4 production from SO_2 oxidation in which the Niger delta states had a much higher air pollution level of oxides of sulphur (SO_4) as compared to the much lower atmospheric concentration level in Bornu state. Organic Carbon (OC) due to Anthropogenic emission was also investigated and results from satellite retrieved data was also consistent with the trend of the Niger delta states having a higher pollution level of Organic carbons than the north-eastern state of Bornu state.

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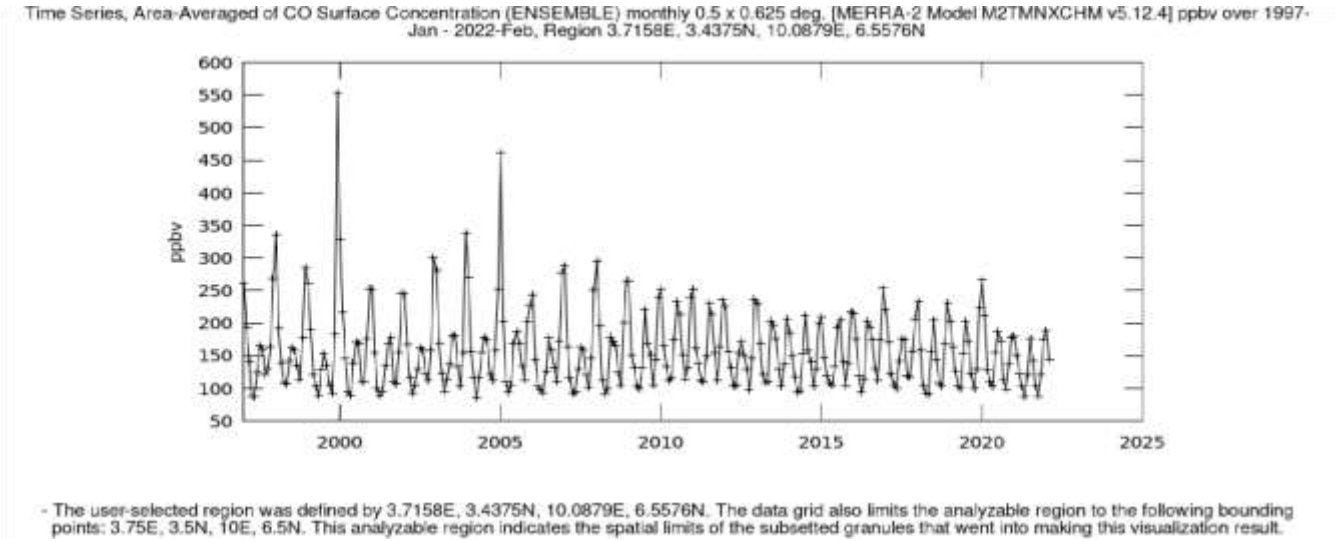

Figure 3: Time Series, Area-Averaged of CO Surface Concentration (ENSEMBLE) for Bayelsa, Rivers and Imo states

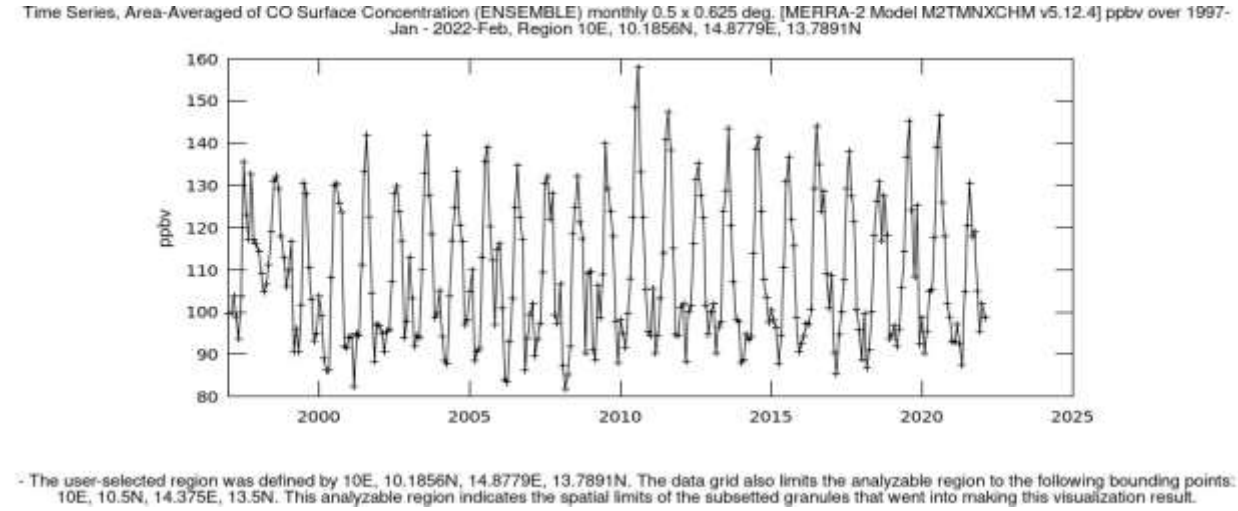

Figure 4: Time Series, Area-Averaged of CO Surface Concentration (ENSEMBLE) for Bornu state

The Time Series Area Average (TSAA) graph for atmospheric CO Surface Concentration for an average of twenty-two (22) years period, ranging from 1997-January to 2022-February, for the NDR under review reveals an inconsistent flow of concentration within the years under observation, in which the year 2000 showed the highest atmospheric CO Surface Concentration at 500ppbv, which is an average of 250 ppbv above the other years under observation across the Niger Delta region (NDR) See (Fig. 3). While retrieved plotted data for Bornu state showed an average of 55% difference below the atmospheric CO surface concentration levels at between (90 to 160)ppbv across the state in the north. See (Fig. 4)

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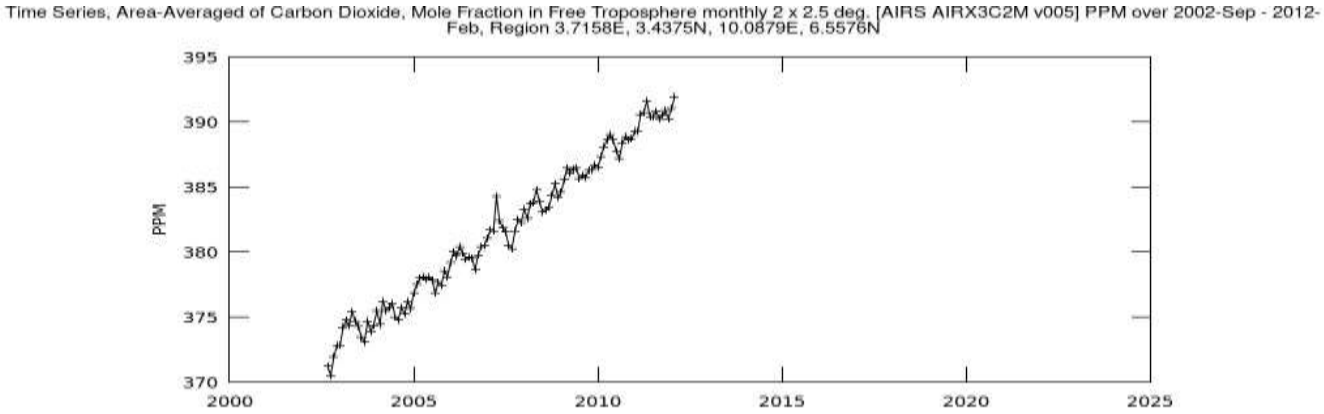

Figure 5: Time Series, Area-Averaged (TSAA) of Carbon Dioxide, Mole Fraction in Free Troposphere for Bayelsa, Rivers and Imo state.

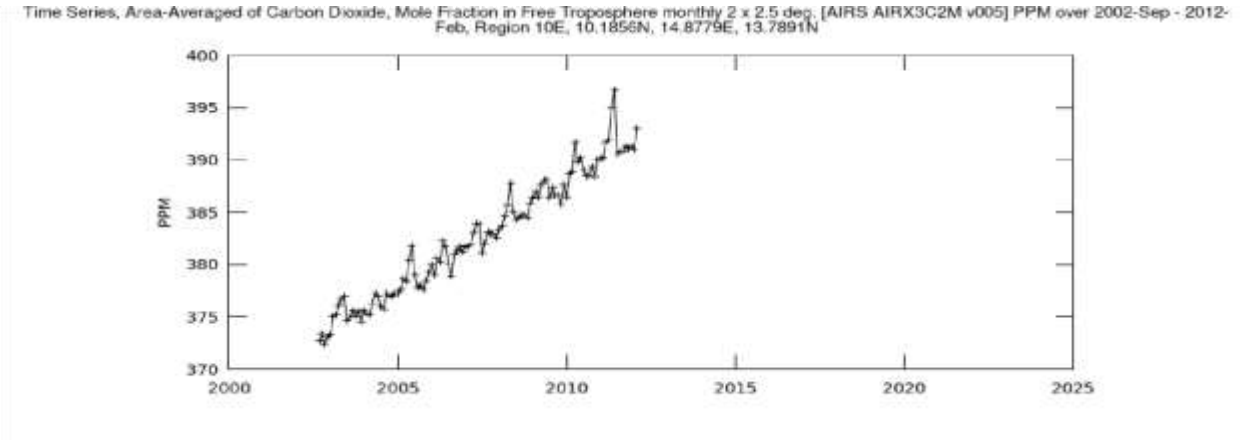

Figure 6: Time Series, Area-Averaged of Carbon Dioxide, Mole Fraction in Free Troposphere for Bornu state.

The Time Series Area Average (TSAA) profile plot of CO_2 mole fraction in free troposphere for the NDR states and Bornu state under observation for the ten year (10) time range of 2002September to 2012 February reveals a steady continuous upward rise of concentrations of CO_2 in free troposphere within the Niger delta region and in Bornu State. (Fig. 5 and Fig. 6).

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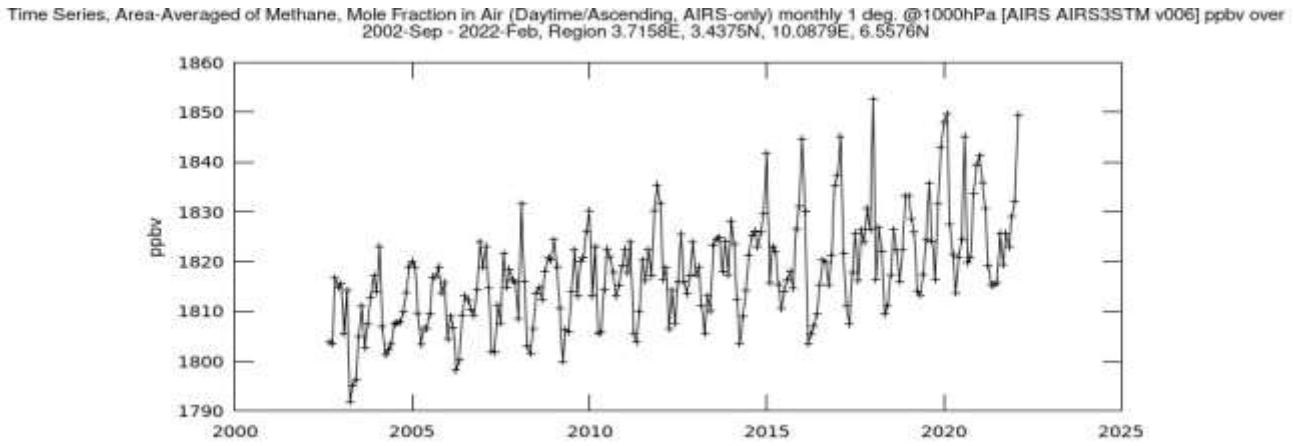

Figure7: Time Series, Area-Averaged of Methane, Mole Fraction in for the Niger Delta Region

From the available Earth satellite data fromNasa Giovanni, the graph above for Time Series Area Average of Methane (CH_4) mole fraction in air (Day time/Ascending AIRS Only) also reveals a graduaul steady rise in concentrations of Methane in the Atmospheric chemistry of the NDR study area within the ten year (10) period under review (2002-September to 2022-February). (Fig. 7) . This is an indication of

CONCLUSIONS

Nigeria with a rapidly growing population and a massive oil and gas exploration sector regrettably has little information available about the direct impact on its air quality and atmospheric chemistry by the activities of oil exploration/exploitation, biomass emissions and other industrial activities to its environment. In this study, an ensemble of satellite observations of atmospheric compositions is used to better the understanding of the pollution levels across the Niger delta region focusing on selected states. From the results of satellite data generated we observed that for all variables studied such as CO, SO_2, SO_4, CH_4 and organic carbons (OC), the Niger delta states had much higher concentration of gaseous pollutants in the nation than the control state of (Bornu State) located in the northern region . Conversely, it was only observed when evaluating SO_2 due to biomass burning and CO_2 in free troposphere that Bornu state had a higher atmospheric concentration level of SO_2 and CO_2 than the Niger delta states under review. This study conclusively finds evidence that artisanal refining of petroleum negatively impacts the atmospheric chemistry of the Niger delta and is a major contributor to the atmospheric loading of these gaseous pollutants emitted from such activities across the region.

Recommendations

Government should as a matter of great concern, take conscious steps to cubing the involvement of those in this illegal crude oil refining activities by adopting some measures such as;

1. Proper funding of governmental agencies saddled with the responsibility of orienting the public on the negative consequences of these illegal activities to our atmosphere and environment in general to carry out proper continuous public enlightenment.

2. To ensure other relevant authorities/agencies of government whose constitutional duties includes protection of oil facilities and pipelines against vandalism and enforcement of environmental protection laws to be up their task.

3. To seize illegally refined products and hand over same to NNPC for proper refining and thereafter systematically dismantle of all illegal refineries where these artisanal refining is being perpetrated so as to discourage its continuity.

4. Government and well-meaning citizens to create job opportunities for these teaming youth so as to keep them actively busy and able to take care of themselves so as to keep off such negative vices.

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