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Environmental Geochemical Assessment of Air Quality in Areas Influenced by Petroleum Activities

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Abstract: This study assessed ambient air quality using selected gaseous and particulate pollutants across twelve sampling locations within the investigated environment. The parameters evaluated included nitrogen dioxide (NO_2), sulphur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter ($PM_{2.5}$ and PM_{10}), methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen sulphide (H_2S), and ozone (O_3). The measurements were undertaken to characterize the spatial distribution of atmospheric pollutants and evaluate the general environmental quality of the study area. The results showed generally low concentrations of NO_2, VOCs, $PM_{2.5}$ and PM_{10} across most locations. Carbon monoxide was predominantly not detected, while H_2S was also absent at most locations, although a detectable value was recorded at Location 10. SO_2 was consistently detected, with values generally ranging from 0.3 to 0.4, while ozone concentrations varied among the sampling locations. Methane was detected at several locations, with concentrations varying spatially, indicating possible influence from hydrocarbon-related sources. Carbon dioxide concentrations generally ranged from approximately 520 to 590 ppm, suggesting localized atmospheric enrichment relative to normal outdoor background levels. The relatively low particulate concentrations indicate limited particulate pollution during the sampling period, whereas the detection of SO_2, CH_4, VOCs and elevated CO_2 suggests contributions from combustion, petroleum-related activities, gas flaring or other anthropogenic sources. Overall, the study indicates relatively low particulate and combustion-related pollution but demonstrates localized gaseous emissions requiring continued monitoring. The findings provide useful baseline information for environmental management, pollution-control planning and assessment of potential impacts of petroleum-related activities on ambient air quality and public health.

Keywords: Gas, Flaring, Air, Quality

INTRODUCTION

Air quality is an important component of environmental health because the atmosphere serves as a major pathway through which pollutants are transported and ultimately exposed to humans, vegetation, animals and other components of the environment. Atmospheric pollution may originate from natural processes as well as anthropogenic activities, including industrial operations, transportation, waste burning, petroleum exploration and production, and gas flaring. Continuous or intermittent emissions from these activities can alter the chemical composition of ambient air and contribute to environmental degradation and potential health risks. The World Health Organization (WHO) recognizes air pollution as a major global environmental health concern, with exposure associated with respiratory and cardiovascular diseases and other adverse health outcomes (WHO, 2021).

The assessment of ambient air quality commonly involves the measurement of gaseous pollutants and particulate matter. In this study, important air-quality parameters

investigated include nitrogen dioxide (NO_2), sulphur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter ($PM_{2.5}$ and PM_{10}), methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen sulphide (H_2S) and ozone (O_3). These parameters provide useful information for evaluating atmospheric conditions and identifying possible emission sources. $PM_{2.5}$ and PM_{10} are particularly important because fine and coarse particles can penetrate the respiratory system, with smaller particles capable of reaching deeper regions of the lungs.

Gaseous pollutants also provide important indicators of atmospheric contamination. NO_2 is commonly associated with combustion processes, while SO_2 may originate from the combustion of sulphur-containing fuels and petroleum-related activities. Ozone is a secondary pollutant formed through atmospheric photochemical reactions involving precursor gases. Carbon monoxide is primarily associated with incomplete combustion, whereas VOCs comprise a diverse group of organic compounds that may be released from petroleum operations, fuel handling and combustion processes. WHO (2021) established health-based guideline levels for major pollutants including NO_2, SO_2, O_3, $PM_{2.5}$, PM_{10} and CO.

Methane and carbon dioxide are also important parameters in environmental investigations, particularly in areas influenced by petroleum activities and gas flaring. Methane is a major component of natural gas and may indicate hydrocarbon emissions when detected in the ambient environment. Carbon dioxide is naturally present in the atmosphere but may increase locally because of combustion, gas flaring, traffic and other human activities. Hydrogen sulphide is another important parameter because it can originate from petroleum-related processes and has toxicological significance even at relatively low concentrations.

In Nigeria, environmental air-quality assessment is particularly relevant in petroleum-producing regions where oil and gas activities may influence atmospheric conditions. The National Environmental Standards and Regulations Enforcement Agency (NESREA) provides ambient air-quality standards for pollutants including SO_2, NO_2, CO and particulate matter, providing a national framework for evaluating environmental conditions (NESREA, 2025).

Therefore, this study evaluates the concentrations and spatial variations of NO_2, SO_2, VOCs, $PM_{2.5}$, PM_{10}, CH_4, CO_2, CO, H_2S and O_3 across the investigated locations. The results provide baseline information for assessing the prevailing ambient air-quality conditions and identifying possible influences of petroleum-related and other anthropogenic activities. The findings may also contribute to environmental management, pollution-control planning and protection of human and ecosystem health.

GEOLOGIC SETTING

The study area(Igruita) is within the Niger Delta Basin. The basin developed as a result of the separation of the African and South American plates during the opening of the South Atlantic Ocean from the Cretaceous to Early Tertiary periods.The geological succession of the Niger Delta is generally divided into three major formations: the Akata Formation, Agbada Formation, and Benin Formation. The Akata Formation constitutes the oldest unit and consists predominantly of marine shale, deposited in relatively deep-water

environments. It is rich in organic matter and serves as the principal source rock for petroleum generation in the Niger Delta.Overlying the Akata Formation is the Agbada Formation, which consists of alternating sequences of sandstone and shale. These sediments were deposited mainly in delta-front, distributary-channel, and coastal environments. The sandstone units commonly serve as important reservoir rocks, while the interbedded shale provides seals and, in some cases, source material. The youngest major unit is the Benin Formation, composed predominantly of coarse- to medium-grained continental sands with minor shale and clay. It was deposited mainly in fluvial and upper deltaic environments and forms much of the exposed surface geology of the onshore Niger Delta.

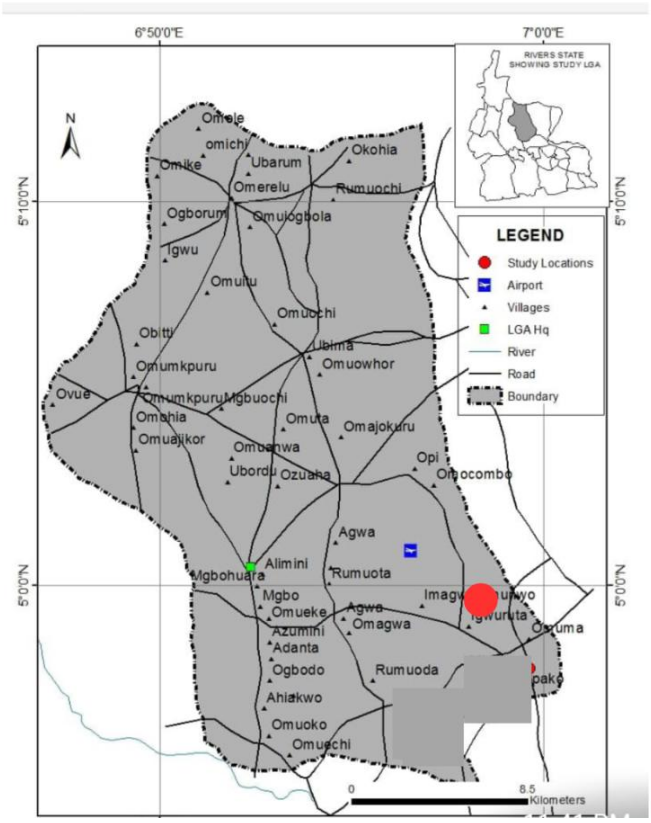

Figure 1: Map of the study location and Environ.

SAMPLING PROCEDURES AND METHODOLOGY

Ambient air quality assessment was carried out to determine the concentrations and spatial distribution of selected gaseous and particulate pollutants within the study area. Twelve sampling locations were selected to provide representative coverage of the investigated environment, with consideration given to proximity to potential emission sources, accessibility, prevailing environmental conditions, and spatial distribution. At each location, measurements were taken for nitrogen dioxide (NO_2), sulphur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter ($PM_{2.5}$ and PM_{10}), methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen sulphide (H_2S), and ozone (O_3).

A portable multi-parameter air-quality monitoring instrument was used for field measurements. Before sampling, the instrument was switched on and allowed to stabilize according to the manufacturer's recommended procedure. Where applicable, the instrument was calibrated or zero-checked before measurements to minimize instrumental errors. At

each sampling station, the instrument was positioned in open ambient air and operated for a sufficient period to obtain stable readings. Care was taken to avoid direct obstruction of the sensor inlet and interference from immediate sources such as exhaust pipes or other localized emissions. The concentrations displayed by the instrument were recorded for all measured parameters at each sampling location. Particular attention was given to $PM_{2.5}$ and PM_{10} as indicators of particulate pollution, while NO_2, SO_2, CO, H_2S, VOCs, CH_4 and O_3 were used to characterize gaseous atmospheric contamination. CO_2 was also measured as an indicator of atmospheric carbon dioxide enrichment and possible influence from combustion and other local activities. The recorded data were subsequently tabulated and subjected to descriptive and comparative analysis to determine spatial variations among the twelve locations. The measured concentrations were interpreted against relevant WHO. nbThe results were used to evaluate the overall ambient air-quality status and identify potential areas of elevated pollution within the study area.

RESULTS AND DISCUSSIONS

Description of Air Quality Parameters from Locations 1–12 Ambient air quality assessment was conducted at twelve sampling locations using ten parameters: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), volatile organic compounds (VOCs), particulate matter with aerodynamic diameters of less than 2.5 μm ($PM_{2.5}$) and 10 μm (PM_{10}), methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen sulphide (H_2S), and ozone (O_3). The results provide information on the spatial variability of gaseous and particulate pollutants within the study area and are useful for assessing possible influences of anthropogenic and petroleum-related activities.

Nitrogen dioxide (NO_2) concentrations across the locations were generally very low, with several locations recording zero or near-zero values. The highest recorded values were still relatively small, indicating limited atmospheric accumulation of nitrogen dioxide during the sampling period. NO_2 is commonly associated with combustion processes, including vehicular emissions, industrial activities and gas flaring. Its generally low concentration suggests that nitrogen-oxide pollution was not a major contributor to the observed air-quality conditions.

Sulphur dioxide (SO_2) was detected at most sampling locations, with values generally ranging between 0.3 and 0.4. The relatively consistent concentrations indicate a widespread but relatively uniform presence of sulphur dioxide across the investigated area. In petroleum-producing environments, SO_2 may be associated with the combustion of sulphur-containing hydrocarbons during gas flaring and other petroleum-processing activities.

The measured **VOCs** (Volatile organic compound) showed relatively low concentrations, generally ranging from approximately 0.0 to 0.7. Location 1 recorded a comparatively higher VOC value of 0.7, while Location 12 recorded no detectable VOCs. VOCs may originate from petroleum evaporation, incomplete combustion, fuel handling, industrial activities and natural sources. Their spatial variation may therefore reflect differences in proximity to emission sources and atmospheric dispersion.

$PM_{2.5}$ and PM_{10} concentrations were generally very low throughout the twelve locations. $PM_{2.5}$ values ranged approximately from 0.001 to 0.005, while PM_{10} values

generally ranged from 0.002 to 0.015 based on the available measurements. Location 1 recorded a relatively higher PM_{10} concentration of 0.015. Overall, the low particulate concentrations suggest limited particulate accumulation during the sampling period. However, particulate pollution can vary considerably with wind speed, traffic, weather conditions, industrial activities and other local factors.

Methane (CH_4) was detected at all reported locations, with concentrations varying spatially. Values included approximately 1 at Location 10, 2 at Location 11, and 4 at Locations 9 and 12, while some locations recorded higher values. The detection of methane is particularly significant in an oil- and gas-producing environment because methane is a major constituent of natural gas. Elevated concentrations may indicate leakage, incomplete combustion, gas-processing activities or influence from gas flaring.

Carbon dioxide (CO_2) showed a relatively consistent but elevated pattern, with measured values generally ranging from approximately 520 to 590 ppm. Location 11 recorded 585 ppm, while other locations recorded values around 520–566 ppm. These values are above typical outdoor atmospheric background levels and may reflect contributions from combustion, gas flaring, vehicular activities, human activities and natural respiration. The spatial variation in CO_2 may also be influenced by atmospheric circulation and proximity to emission sources.

Carbon monoxide (CO) was generally recorded as zero across the locations. The absence or non-detection of CO suggests limited accumulation of carbon monoxide during the monitoring period. Nevertheless, CO concentrations can fluctuate depending on combustion efficiency, traffic intensity and atmospheric dispersion.

Hydrogen sulphide (H_2S) was not detected at most locations. However, Location 10 recorded H_2S = 1, making it particularly important for further investigation. H_2S can originate from petroleum-related activities and anaerobic decomposition and is environmentally significant because of its toxicity and characteristic odour.

Samples	No_2ppm	So_2ppm	VOCppm	PM2.5ppm	PM10ppm	CH_4ppm	CO_2ppm	COppm	H_2Sppm	O_3ppm
1	0.003	0.3	0.7	0.003	0.014	9	550	0.00	0	0.07
2	0.00	0.4	0.1	1.00	1.00	6	550	0	0	0.06
3	0.00	0.4	0.1	0.01	0.01	7	532	0	0	0.08
4	0.00	0.4	0.00	0.001	0.002	2	544	1.4	0	0.7
5	0.00	0.4	0.1	0.002	0.004	2	590	0	2	0.7
6	0.00	0.4	0.1	0.003	0.004	1	586	0.006	0	0.06
7	0.004	0.4	0.2	0.005	0.010	6	560	1	0	0.07
8	0.001	0.4	0.5	0.004	0.010	2	548	0	0	0.06
9	0.00	0.4	0.1	0.003	0.004	4	520	0	0	0.08
10	0.00	0.4	0.4	0.001	0.002	1	566	0	1	0.04
11	0.00	0.3	0.1	0.002	0.01	2	585	0.000	0	0.006
12	0.002	0.3	0.00	0.001	0.002	4	560	0	0	0.07
Range	0.00-0.004	0.3-0.4	0.0-0.7	0.001 - 0.005	0.002 - 0.015	1-9	520 -590	0-1.4	0-2	.04-0.7
W.H.O	0.013	0.015	-	15 µg/m^3	45 µg/m^3	-	<1000	4ppm	-	

Finally, ozone (O_3) was detected across the locations, with reported values generally between 0.04 and 0.08. Location 9 recorded 0.08, while Location 10 recorded 0.04. Ozone is a secondary pollutant formed through photochemical reactions involving precursor pollutants such as NO_x and VOCs.

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