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Assessment of the Impact of Gas Flaring on Air Quality in Isoko South Lga of Delta State

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ABSTRACT
*This study examined in detail the effect of gas flaring on air quality in Olomoro and Igbide communities, all in Isoko South Local Government Area of Delta State, which is located in the oil rich region in Niger Delta, Nigeria. lying on longitude 6^0 10' 24.4''N and latitudes 5^0 27' 25'' E as low exposure sites **(LES)** and longitudes 6^0 08' 39'' E and latitudes 5^0 30' 54''N as medium exposure sites (MES) with all communities housing flow stations. This study took into consideration NOx, SO_2, CO, CH_4, VOC, $PM_{2.5}$, & $PM_{10,}$ in achieving this, the air quality sampling was done in LES and MES locations totaling six (6) different sample points, the sampling was done with the use of industrial scientific corporation IBRID MX6 multi gas monitor with different range of detection and resolution of different gases according to standard. The results showed a daily average concentration of SO_2, CO, CH_4, VOCs, in the LES sites as 0.55, 0.45, 2.25, and 1.02ppm respectively and the MES experienced more pollutants including NH_3, H_2S, SO_2, CO, CH_4, VOCs with daily average concentration of 0.05, 2.00, 0.213, 2.10, 2.00 and 1.25ppm as against the international annual mean of N/S, 0.005, 0.005, 9.00, N/S,0.00053ppm, both results from the LES and MES study areas exceeded the local and international permissible limits. The MES area, there is the presence of H_2S and NH_3. The research has helped to monitor, audit and examine the daily concentration level of pollutants in order to avert the danger of spread or outbreak of diseases, more so the study can be used as a base line study or decision tool in regulatory bodies.*
Keywords: Air quality, Gas flares, environmental monitoring, WHO permissible limits, daily environmental investigation.

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I. INRODUCTION

Gas flaring is the burning of natural gas linked to oil production. This approach is prevalent in oil-producing areas when the infrastructure for capturing and using natural gas is inadequate or absent. Gas flaring is conducted for several reasons, including safety, operational efficiency, and the absence of a market for the generated natural gas [1]. Nigeria is among the leading nations globally regarding gas flaring quantities. Delta State, being a major oil-producing state, experiences significant levels of gas flaring. Despite legal frameworks aimed at reducing gas flaring, enforcement remains a challenge, leading to continued environmental degradation. Some of the pollutants emitted by gas flaring include: Carbon Dioxide (CO_2), Methane (CH_4), Nitrogen Oxides NOx, Sulphur Dioxide (SO_2), volatile Organic Compounds VOCs, smog and Particulate Matter (this causes global warming and climate change). Methane (CH4): is a powerful greenhouse gas with a greater global warming potential than CO_2. Nitrogen Oxides (NOx): May cause breathing issues and cause the ground-level ozone that is an initiator of the process. Sulfur Dioxide (SO_2): Leads to acid rain and breathing problems. Volatile Organic Compounds (VOCs): Have the potential to cause ground-level ozone and smog. Particulate Matter (PM): Causes respiratory and cardiovascular diseases: This article investigated the correlation between gas flaring and air quality in the Niger Delta and found significant rises in particulate matter, CO2 and other pollutants in the area of the flares. Nevertheless, no real-time monitoring data was included in the study, and thus, a temporal variability assessment was lacking due to higher concentrations of NOx and SOx. They emphasized much on health effects but never considered the long-term air quality effects of gas flaring in Nigeria, and the emission of the greenhouse gases and volatile organic compounds was measured [4]. Nevertheless, their models were locally-based therefore limiting the general application of the study to other gas-flaring regions. The study by [5] estimated air pollution by gas flaring in the Niger Delta and reported that there were high levels of particulate matter and other toxic gases. However, the study did not include the investigation of the long-term environmental degradation, which is a significant gap in the knowledge of the effects of long-term exposure.

In a study on environmental impact of gas flaring, [6] revealed that it contributes greatly to acid rain and degradation of air quality in the Niger Delta. This study has a gap as it does not incorporate seasonal changes in the level of pollution. The article [7] examined the impacts of gas flaring on human health and air quality in Nigeria and concluded that the air quality was seriously deteriorated with rising respiratory problems. Nevertheless, the research has failed to fully address mitigation measures and thus there is insufficiency in solution-based research. [8] investigated the health hazards and environmental impacts of gas flaring and reported that at the locations of flares, carbon monoxide and sulfur dioxide concentrations were high. The weakness of this research is that the geographical area was narrow since the study encompassed a single region. [9] studied the distribution of pollutants emitted by gas flaring and their effects on air quality, revealing that air quality is devastated in the areas near gas-flaring stations. Their model however did not consider the transboundary air pollution and thus it was a gap in the overall atmospheric impact assessment.

The effects of gas flaring on the air quality of the Niger Delta were reported and confirmed in a case study by [10], which showed high levels of nitrogen dioxide and volatile organic compounds. The research established a vacuum in the evaluation of the ground-based ozone formation as a result of gas flaring. [11] examined the effects of gas flaring on air quality, and on flora in the area and discovered that there is a close relationship between flaring and degradation of air quality. Although the research findings were very detailed, it failed to fill the gap in the knowledge of how flaring affects the ozone layer or global warming. According to a study by [12], the communities in the Niger Delta around gas flaring sites had high rates of respiratory and skin diseases. In another study, [13] pointed out that the concentrations of particulate matter and other pollutants are high in flaring regions and they are above WHO air quality standards. [14]; they used Geographic Information System (GIS) and remote sensing to examine spatial and temporal variations of air quality in their study. The research concluded that there are time variations in the concentration of the pollutants with greater quantity in the dry seasons. The research lacked a research gap of having ground-truth data to confirm remote sensing findings. [15]; in air sampling and analysis of criteria pollutants (e.g., NO_2, SO_2, CO, PM) and survey of health outcomes in the local population. In their findings, they also reported that high levels of pollutants were observed and reported health problems among residents in terms of eye irritation, skin problems and respiratory problems were preeminent with a small geographic area and brief time span of investigation. A study by [16] in a combined air quality measurements with health impact surveys in communities near gas flaring sites also recorded the higher levels of CO, NO_2, SO_2, and PM_{10}, their health surveys recorded higher prevalence of respiratory issues among the residents. They also had little time range and lack of chemical speciation.

Moreover, research by [17]; employed portable air quality monitoring instruments and GIS software to measure spatial distributions of pollution. There was a substantial air pollution at the locations of flares with adverse effects on the quality of air and plants in the area. In their analysis they failed to consider long term health effects or compounding effects of several flare locations. Research by [18]; literature review and synthesis of literature on gas flaring impacts. A detailed outline of negative environmental and health impacts, air pollution, acid rain, and respiratory illnesses. Lacks primary data gathering and is based on secondary data.

Study by [19] which was also a review of existing literature, combined with field data on environmental pollutants including air quality parameters. Detailed evaluation of different pollutants due to oil industry operations, such as gas flaring. Brings to the fore high levels of air quality degradation. Primarily a review that lacks much new empirical evidence; requires more field measurements that are more local and up to date. [20]; in their cross-sectional survey relying on health survey and medical records analysis to correlate air quality data with health effects, they report high occurrence of respiratory illness, eye irritations and skin diseases among communities living around gas flares. The cross-sectional design did not provide the ability to make causal inferences; longitudinal studies were required. Research work by [21]; the use of biomonitoring to determine the level of pollutants in the human tissues along with air quality measurement and health survey indicated high concentration of pollutants like benzene and toluene in the blood of the residents, which was associated with higher incidences of cancer and respiratory diseases. They were concerned with health outcomes but not with detailed spatial and temporal air quality data. In another study by [22]; environmental impact assessment through air sampling, soil sampling and vegetation analysis, the researchers noted high concentrations of CO, NOx and hydrocarbons in the area around the gas plant resulting in damage of vegetation and acidification of the soil. Restricted to a particular location, which would need more geographical coverage to obtain in-depth knowledge. The literature review on [23]; in their research, they carried out a field study, a thorough field study in Warri South West LGA, a combination of qualitative and quantitative research. They gathered air quality measurements of some of the gas flaring locations in the area and concentrated on important pollutants, including particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs). The researchers also interviewed the locals to obtain anecdotal data of health effects and socio-economic disturbances caused by gas flaring. The results of the study were alarming as the concentrations of air pollutants in the areas around the gas flaring sites were extremely high and were much higher than the national and international air quality standards. The mean concentration of PM2.5, in particular, was discovered to be more than triple the recommended amount by the WHO. On the same note, the amount of sulfur dioxide and nitrogen oxides was also extremely high, which is extremely dangerous to the health of local residents. Although the study by [23-26] contributes greatly, it also finds that there are a number of gaps in the existing knowledge of the effects of gas flaring. A significant loophole is the fact that no long-term health research has been conducted to determine the direct causation between gas flaring and certain health effects. The research was based on a self-reported health problem, which, although indicative, cannot give conclusive evidence of causality.

II. PLLUTANTS IN THE AIR

Gas flaring produces particulate matter (PM), especially fine particles like $PM_{2.5}$ (particles with a diameter of 2.5 micrometers or less) and PM_{10} (particles with a diameter of 10 micrometers or less). The particles are the result of incomplete burning processes when flaring occurs and may take a long duration in the air causing bad air quality. PM has the ability to get deep into the lungs and get into the bloodstream leading to respiratory and cardiovascular illnesses.

Black Carbon:
Black carbon or soot is a major constituent of gas flaring particulate matter. Black carbon is a powerful short-lived climatic pollutant contributing to global warming since it absorbs sunlight and decreases the reflectivity of ice and snow. As it is deposited on ice, it increases the melting, which leads to climate change.

Volatile Organic Compounds (VOCs):
Gas flaming emits volatile organic compounds (VOCs) that are organic substances that readily escape into the air. Frequent flaring VOCs are benzene, toluene, ethylbenzene, and xylene (also referred to as BTEX). They can create ground-level ozone (smog) and are dangerous air pollutants, some of which are carcinogenic (e.g., benzene).

Sulfur Dioxide (SO_2):
During flaring, the sulfur-containing compounds present in the natural gas are burned to produce sulfur dioxide. SO_2 may interact in the atmosphere to produce fine sulfate particles which are pollutants of $PM_{2.5}$. It may as well cause acid rain which destroys ecosystems, buildings and water bodies.

Nitrogen Oxides (NOx):
Natural gas is burnt in the high temperature to produce nitrogen oxides (NO and NO_2). NOx can react with VOCs in the presence of sunlight to form ground-level ozone, a harmful air pollutant. Ozone may lead to lung conditions, decrease lung activity and worsen diseases such as asthma.

Carbon Monoxide (CO):
Carbon monoxide is produced from the incomplete combustion also of hydrocarbons during gas flaring. CO is a colorless and odorless gas, which can be a threat to human health, especially by decreasing the oxygen carrying capacity of blood, causing cardiovascular and neurological outcomes.

Greenhouse Gases (GHGs):
Gas flaring releases high levels of carbon dioxide (CO_2) and methane (CH_4), which are both important greenhouse gases. Other gases such as methane which are not wholly burned during flaring can be emitted into the atmosphere, causing global warming. Of particular concern is methane, which has been shown to have a greater global warming potential relative to CO_2 in a 20-year period.

III. IMPACT ON LOCAL AND REGIONAL AIR QUALITY

Air Quality Deterioration:
Discharge of pollutants during gas flaring negatively affects the quality of air around the flaring location and the effect may spread wider distances, depending on the wind direction and weather conditions. Societies residing around gas flaring location usually record high quantity of contaminants that surpass country-wide and worldwide standards of air quality [23-26].

Formation of Ground-Level Ozone:
NOx and VOCs from gas flaring can react in the presence of sunlight to produce ground-level ozone, a major component of smog. Ground-level ozone is harmful to human health, causing respiratory problems, aggravating asthma, and reducing lung function. It destroys crops and ecosystems as well by interfering with photosynthesis and decreasing agricultural products.

Long term environmental and health impact:
The gases produced in gas flaring are reported to lead to respiratory and cardiovascular diseases in the local people. Research on air quality assists in determining the health hazards and developing measures to counteract such impacts. The research brings awareness of health hazards of poor air quality. This data is essential in the efforts by the public health officials, local communities and policymakers to undertake preventive and remedial actions. Gas flaring, including PM, VOCs, SO_2 and NOx, exposure is associated with various health issues. In the long term, respiratory diseases, cardiovascular diseases and a higher risk of lung cancer may occur. Specifically

vulnerable populations, including children, older populations, and people with underlying health issues, are at risk.

Environmental Impacts:

The SO_2 and NOx emissions cause acid rain, which may cause acidic soils and water bodies, resulting in the loss of biodiversity, forest destruction, and worsening of aquatic habitats. Particulates such as black carbon may be deposited on vegetation, which suppresses photosynthesis and has an impact on plant health. The emission of greenhouse gases like CO_2 and methane from gas flaring contributes to global climate change. Methane, specifically, is a highly-effective greenhouse gas, which has a strong effect on global warming in the short term. The situation is further aggravated by the contribution of black carbon to the climate change due to its effect on the albedo of snow and ice. Although the effects of gas flaring are known, regulation and enforcement are tough in most areas. Poor gas capture and use infrastructure, and laxity in regulations, continue to result in flaring. Measures to minimize flaring are through tighter regulations, investment in gas capture and processing facilities and encouraging alternative uses of associated gas.

Pollution and Ecosystem Health

Ecosystem health is the totality and functioning of an ecosystem, and includes its physical, chemical and biological aspects. A healthy ecosystem is strong, sustainable and retains its natural processes and functions that sustain biodiversity and offer vital services to human beings and wild animals.

Ecosystem health is impacted in various ways, including:

i. Destruction and fragmentation of habitats: Human activities such as deforestation, urbanization, and development of infrastructures contribute to habitat loss and fragmentation which interferes with the interactions of species and their ecosystem processes.
ii. Pollution: Emission of chemicals, plastics, industrial waste changes the chemistry of the ecosystem, damages species, and interferes with the nutrient cycle.
iii. Climate change: Changing patterns of precipitation, higher temperatures, and more extreme weather events put pressure on ecosystems and alter the distribution of species and upset delicate balances. (iv) Invasive species: Introductions of non-native species may outcompete native species, distort food webs, and disrupt ecosystem processes.
iv. Excessive resource exploitation: Overhunting, overfishing and overharvesting of resources causes population depletion of species, affecting food webs and ecosystems.
v. Soil degradation: Soil erosion, nutrient depletion and salinization impairs the productivity and fertility of the ecosystem.
vi. Water shortage and pollution: Alterations in water supply and quality affect aquatic ecosystems and have effects on species survival, and ecosystem processes.
vii. Water scarcity and pollution: Changes in water availability and quality impact aquatic ecosystems, affecting species survival and ecosystem processes.
viii. Human population and pattern of consumption: Growing population and consumption of resources, energy, and land results in the degradation and loss of biodiversity.

Impacts of Cascading Effects

Cascading effect results in loss of biodiversity, lower ecosystem resilience, broken nutrient cycles and diminished ecosystem services (e.g. clean air and water, soil formation).

IV. MATERIALS AND METHOD

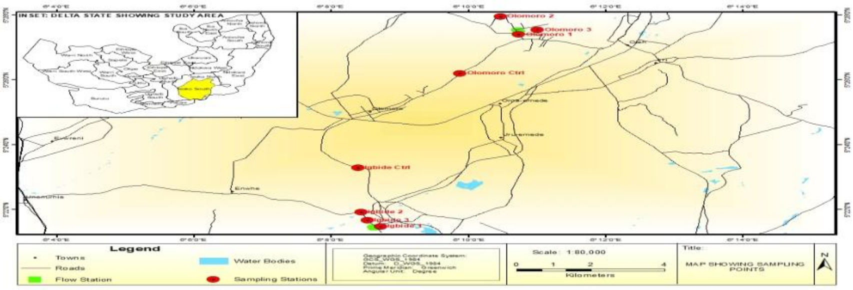

Figure 1 MAP OF STUDY AREA

Study Area:

Isoko South LGA of Delta State, in oil rich Niger Delta region in Nigeria, is a significant oil producing region. The state is marked by a high number of gas flaring locations related to oil extraction. The research concentrated on some of the communities near these flare locations in order to record the changes in air quality. With Olomoro Flow Station lying on longitude 6^0 10' 24.4''N and latitudes5^0 27' 25'' E for **Low Exposure Site (LES)** and Igbide Flow Station lying on longitude 6^0 08' 39'' E and latitude 5^0 30' 54''N and – **Medium Exposure Site (MES).** Exploration and exploitation of crude oil has been the backbone of the economies of the region. Nonetheless, these operations have severe environmental consequences, especially on air quality, as a result of gas flaring. This is a practice that emits numerous types of pollutants into the atmosphere, which is negatively impacting the atmosphere and endangering the health of the surrounding communities. One of the areas of special interest to environmental and health issues in the Niger Delta region has been the Isoko South LGA of Delta State, which is highly involved in oil mining and the resulting gas flaring.

V. Methodology

Sampling sites was selected based on proximity to gas flare sites, population density, and accessibility. Two categories of sites were identified: **Moderate Exposure Sites (MES)**: Communities 1-5 km away from gas flare sites, **Low Exposure Sites (LES)**: Communities more than 5 km away from gas flare sites. A total of 2 sites were visited, with three sampling points in each exposure category. Air quality measurements were conducted in each site, according to standard.

The Air quality was monitored using portable air quality monitors with Aeroqual; model no 500 series. The measured parameters are Sulfur Dioxide (SO_2), Nitrogen Oxides (NOx), Carbon Monoxide (CO), Volatile Organic Compounds (VOCs), and Particulate Matter ($PM_{2.5}$ and PM_{10}). A collection of portable air quality monitoring devices was used to assess the air quality of the designated research region. Sampling was conducted for eight hours daily, with all parameters measured bi-hourly. The eight-hour monitoring interval was adjusted daily to capture results from early morning to late night throughout the monitoring duration. Three measurements were obtained for each sample site, and the average for each location was recorded.The measurements were conducted by positioning the sensors of the different air quality monitoring devices at an elevation of about two meters, oriented towards the prevailing wind, while values were recorded under stable conditions.

During the execution of fieldwork, the subsequent air quality and meteorological indicators were observed. Specifically, Carbon Monoxide (CO), Nitrogen Dioxide (NOx), Sulphur Dioxide (SOx), Hydrogen Sulphide (H2S), Volatile Organic Compounds (VOCs), Ammonia (NH3), Methane (CH4), and total suspended particulates. Additional factors include relative humidity, ambient temperature, noise levels, wind speed, and wind direction were also determined

Carbon monoxide (CO):
The detection of CO was carried out using an IBRID MX6 multi-gas monitor manufactured by Industrial Scientific Corporation. An electrochemical sensor that produces a signal that is directly proportional to the concentration of CO is used by the apparatus to detect the gas. There is a sensitivity of 1 ppm and a detection range of 0–999 ppm. The sensor was held at a height of about two meters in the direction of the prevailing wind to take data while remaining stable.

Sulphur oxides (SO_x):
The detection of SO2 was carried out using an IBRID MX6 multi-gas monitor manufactured by Industrial Scientific Corporation. The alarm set points are 10 and 15 ppm, respectively, and the detection range is 0 to 499 ppm with a precision of 1 ppm. The sensor was held at a height of about two meters in the direction of the prevailing wind to take data while remaining stable.

Ammonia (NH_3):
The detection of NH3 was carried out using an IBRID MX6 multi-gas monitor manufactured by Industrial Scientific Corporation. The alarm set points are 10 and 15 ppm, respectively, and the detection range is 0 to 499 ppm with a precision of 1 ppm. The sensor was held at a height of about two meters in the direction of the prevailing wind to take data while remaining stable.

Nitrogen oxides (NO_x):
The detection of NO_2 was carried out using an IBRID MX6 multi-gas monitor manufactured by Industrial Scientific Corporation. With a precision of 0.1 ppm, the detection range is 0 to 99.9 ppm. The sensor was held at a height of about two meters in the direction of the prevailing wind to take data while remaining stable.

Hydrogen Sulphide (H_2S):
H_2S was detected using an IBRID MX6 multi-gas monitor from Industrial Scientific Corporation. The detection range is 0 to 499 ppm, with a precision of 1 ppm, with alert thresholds set at 10 ppm for low and 15 ppm for high.

Measurements were conducted by positioning the sensor at an approximate height of two meters in alignment with the prevailing wind, and data were documented under stable condition

Methane (CH_4):

The detection of CH4 was carried out using an IBRID MX6 multi-gas monitor manufactured by Industrial Scientific Corporation. With a resolution of 0.01%, the detection range is 0 to 50%. The sensor was held at a height of about two meters in the direction of the prevailing wind to take data while remaining stab

Volatile Organic Carbons (VOC)/Methane:

The organic vapors were monitored using an IBRID MX6 Multi-Gas monitor from Industrial Scientific Corporation. It uses a gas discharge lamp with a photo-ionization detector (PID) that operates at either 10.6 eV or 11.7 eV. It has a built-in sample pump, a diaphragm pump that can provide a flow rate of around 250 cc/min when set to its highest level. The first range covers 0–200 ppm with a 0.1 ppm resolution, while the second range covers 200–2,000 ppm with a 1 ppm resolution for volatile organic compound measurement.

Total Suspended Particulates:

The total suspended particles were measured using an Aerosol Mass Monitor Model GT-531 from Met One Instrument, Inc. In addition to continuously monitoring particles, this Ambient Particulate Monitor with Recorder also captures "real-time" data on the concentration of airborne particles. The package includes a laser optical sensor that can detect and measure particle concentrations as low as 1 mg/m². The digital recorder, flow system, and laser sensor are all housed in a watertight casing. Additionally, it has a password security system, an 8 x 40 character LCD, and automated alarms that notify the user of dangerous situations. Air quality assessments, sampling of pollutants, workplace monitoring, and filter testing are all made easier with this handheld mass monitor. Unlike competing monitors, this one measures individual particles by analyzing light scatter rather than clouds. Next, the particle data is categorized according to size, and in two minutes at a flow rate of 2.83 L/min, the mass concentration is transformed into the following measurement ranges:

<1 micron, PM 1 mass concentration.

<2.5 micron, PM 2.5 mass concentration.

<7 micron, PM 7 mass concentration.

<10 micron, PM 10 mass concentration.

The equipment also measures Total Suspended Particulates (TSP).

VI. RESULTS AND DISCUSSION

The results presented below are the data collected from air quality measurements conducted in various locations across Isoko South, Delta State. The findings are presented in the form of tables, presenting the concentration levels of the major air pollutants, including Carbon monoxide (CO), Nitrogen dioxide (NOx), Sulphur dioxide (SOx), Hydrogen Sulphide (H_2S), Volatile Organic Compounds (VOCs), Ammonia (NH_3), Methane (CH_4) and total suspended particulate. The choice of these pollutants followed the relevance to air quality and is known to associate with gas flaring activities. The data is presented for each sampling location, including areas in proximity to gas flaring sites and a control location further away from the gas flare stacks.

Pollutant	Guideline Level (ppm)	Averaging Time
Carbon Monoxide (CO)	9 ppm	8-hour mean
	25 ppm	1-hour mean
Nitrogen Dioxide (NO_2)	0.012 ppm	Annual mean
	0.021 ppm	1-hour mean

Sulfur Dioxide (SO_2)	0.005 ppm	24-hour mean
	0.175 ppm	10-minute mean
Hydrogen Sulfide (H_2S)	0.005 ppm	24-hour mean (WHO ambient guideline)
Volatile Organic Compounds (VOCs)	Varies by compound (e.g., Benzene: 0.00053 ppm)	Annual mean (Benzene)
Ammonia (NH_3)	No specific guideline by WHO	Not specified
Methane (CH_4)	No specific guideline by WHO	Not applicable

Table 1 WHO Air Quality Standards (ppm) for Various Pollutants

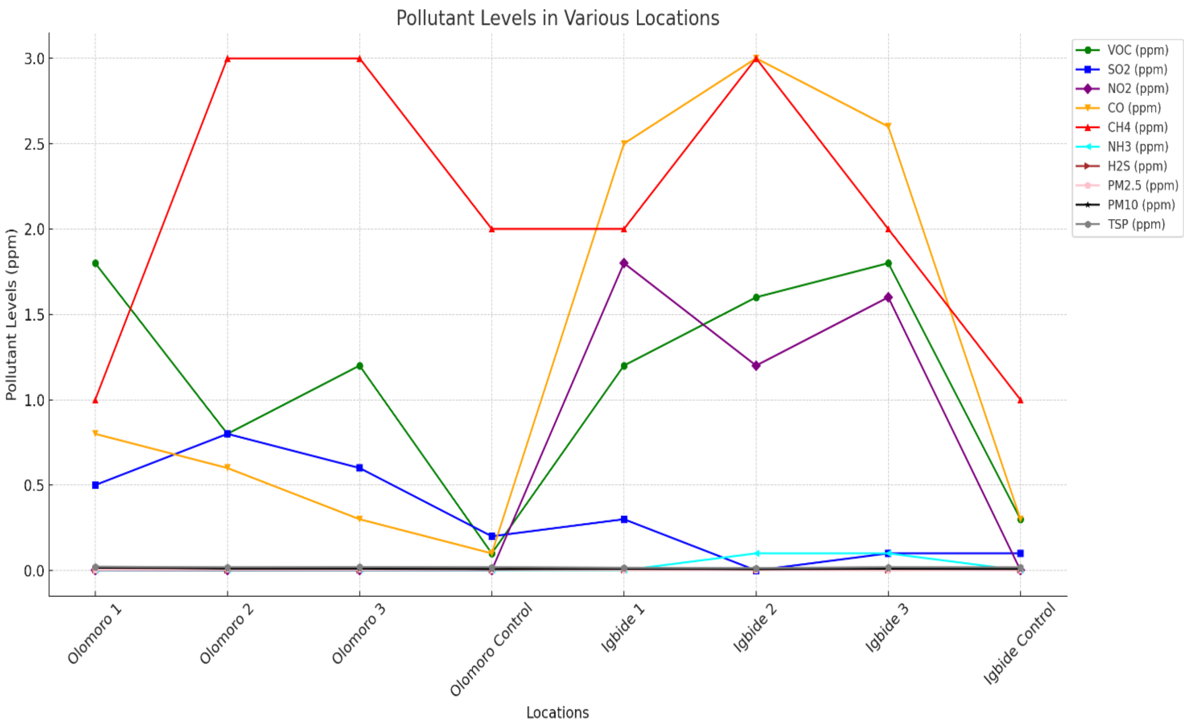

Figure 2 Showing Pollutant Levels of VOCs, SO2, NO2, CO, CH4, NH3, H2S, PM2.5, PM10and TSP (ppm),

Figure 2 Graph showing variations in pollutant levels in Study Areas. CO levels in both **Olomoro** and **Igbide** are well **below** the WHO limit of 9 ppm. The highest CO level is found in Igbide 2 (3.0 ppm), but this is still within safe limits. From the results, in figure 2, it is observed that VOC levels in both Olomoro and Igbide sampling sites were relatively high, especially in **Olomoro 1 (1.8 ppm)** and **Igbide 3 (1.8 ppm)**. Although WHO does not provide a specific overall VOC limit, these levels indicate a significant presence of VOCs, which could pose long-term health risks.

The results also showed that **SO_2 levels in Olomoro 2 was** (up to 0.8 ppm) which are **significantly** higher than the WHO standard presented in tables 1 as (0.005 ppm), particularly in Olomoro 2. This suggests serious air pollution concerns. In **Igbide** sample sites, SO_2 levels were seen to be lower in the control station, which was (up to 0.3 ppm) still well above the WHO standard of 0.005ppm, indicating that both areas experience SO_2 pollution which is not safe in the studied environment.

Findings showed that NO_2 levels in **Olomoro** were below 0.001 ppm, which is much lower than the WHO limit of 0.021ppm. However, in **Igbide**, the NO_2 levels were significantly higher than (1.8 ppm in Igbide 1 and 1.6 ppm in Igbide 3). These values greatly exceed the WHO guideline, indicating a potential air quality issue related to NO_2 in Igbide.Also, the results in figure 2 for CO levels in both **Olomoro** and **Igbide** were all well below the WHO limit of 9 ppm. The highest CO level that was seen in Igbide 2 was (3.0 ppm), this is still within WHO permissible limits of 9ppm.

Further results in figure 3 for Methane (CH_4), Ammonia (NH_3), and Hydrogen Sulfide (H_2S): whose WHO standards: has no specific limits for CH_4, NH_3, or H_2S in ambient air quality. Results from figure3 showed that: CH_4 levels are high in overall, with the highest being 3 ppm in Igbide 2 and Olomoro 2. This seems not to be a health concern under normal conditions. NH_3 levels are mostly negligible, except in **Igbide 2 and Igbide 3**, where it reaches 0.1 ppm. Though WHO does not provide a limit, such levels could still contribute to air quality issues. H_2S levels are extremely low and do not pose a threat in either location.

Implication of Findings from the results.

These findings highlight the impact of gas flaring on air quality in Isoko South, Delta State, particularly in areas closer to the flare stack. Air quality monitoring in Olomoro and Igbide demonstrates that the concentration of the major air pollutants can significantly differ, whereas the fact that the WHO does not specify the level of total VOCs is, nevertheless, alarming because it can lead to the formation of ozone in the air and its correlation with carcinogens like benzene. The chronic exposure to high levels of VOCs may augment the possibility of long-term health effects such as cancer and central nervous system damages. This underscores the importance of having stricter control of VOC emissions around gas flaring facilities.

High concentrations of SO_2 can lead to respiratory irritation and aggravate existing heart and lung diseases. The high SO_2 concentration indicates that gas flaring is also contributing to sulfur emission especially in the areas near the flaring sites in the study area. This finding aligns with other studies conducted in the Niger Delta region, where SO_2 levels around flare sites often exceed safe limits, also in the reviews studies iterated that air pollution is the second most important factor in Non-Communicable disease, also stating that PM, Ozone (O_3), Nitrogen dioxide (NO_3), Sulphur dioxide (SO_2), metals and polyaromatic hydrocarbon (PAH). Their analysis revealed that SO_2 has negative health impact on the respiratory, cardiovascular and nervous systems of human beings and also leads to type 2 diabetic and noon-accidental death [27, 28]. The spatial variation indicates that areas closer to gas flaring sites/stacks, such as Igbide, tends to have higher CO levels than those farther away, this result was also in line with the study carried out by [29].

The levels of $PM_{2.5}$ and PM_{10} in both Olomoro and Igbide were within the WHO limits, with the highest $PM_{2.5}$ level recorded as 0.005 ppm in Olomoro 2. The current levels are not beyond the standards, but the level of particulate matter is a significant issue as it can penetrate deep into the lungs and bloodstream and lead to cardiovascular and respiratory diseases. Even low levels of exposure can be dangerous in the long run, particularly to individuals residing near gas flaring facilities.

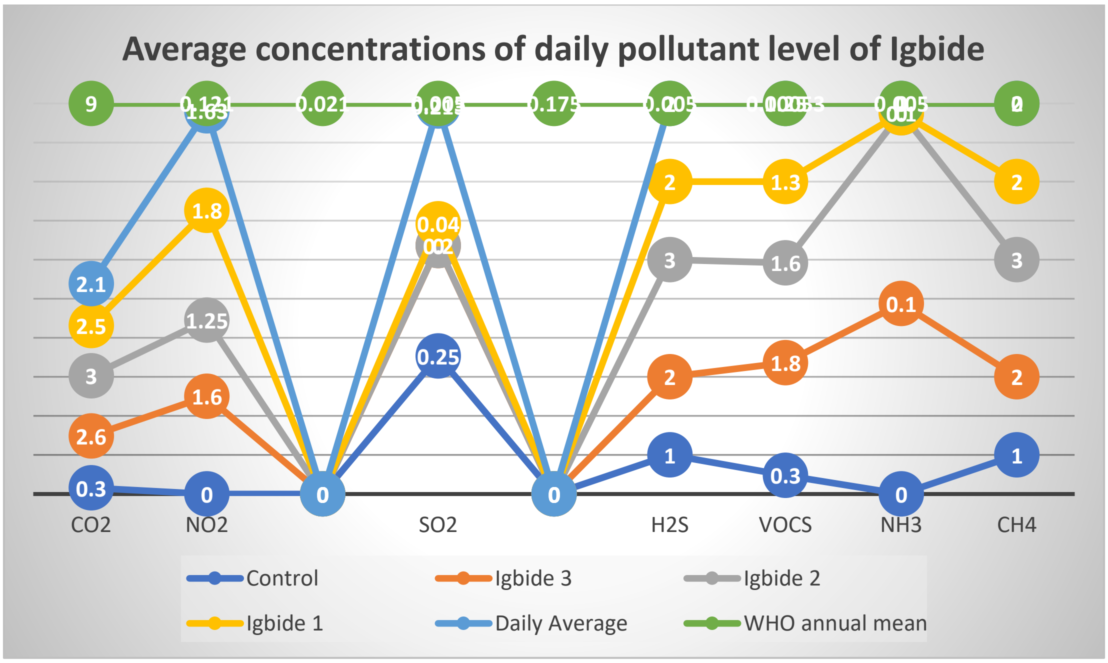

Figure 3: Graph Showing Daily Average conc. Of pollutant levels in Igbide (MES)

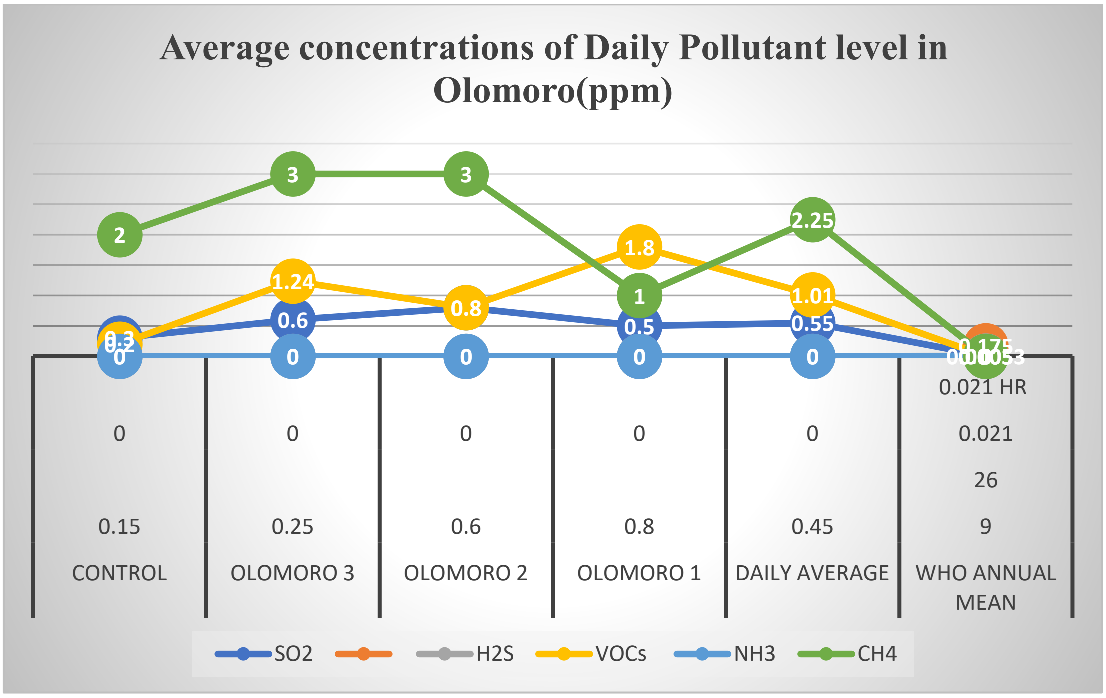

Figure 4. Graph showing Average Conc. of pollutant in Olomoro (LES)

From our findings it was observed in figure 3 that CO_2, NO_2, SO_2, H_2S and CH_4 had averages of 2.10, 1.163, 0.21, 2.00, 1.25, 0.05 and 2.00ppm, which exceeded the WHO permissible limit of 9.00 annul mean, which when divided by 365days was 0.0246ppm, 0.021,0.005,0.005, 0.00053ppm. This is indeed was not really good for the habitats in that environment. In addition to causing severe global warming and ocean rise, the high levels of CH4 in the study area are a precursor to ground level ozone (smog). The study also notes that symptoms such as rapid breathing and changes in heart rate can lead to suffocation. Furthermore, the daily average of the LES study area in figure 4 show results of relatively high CO_2 SO_2, VOCs and CH_4 with value 0.45, 0.00,1.02 and 2.25ppm as against the WHO standards of 0.0246, 0.005,0.00053, N/S. All the LES and MES are contaminated with pollutants and so it is recommended that immediate action be taken as it is not conducive to health of the environment and its habitat.

IV. CONCLUTION

The results of this research have shown that there is a great difference in the concentration of pollutants in the two study locations. Some of the most important pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_3) were detected to be higher than WHO standards, particularly in Igbide. The article noted high levels of volatile organic compounds (VOCs) and particulate matter ($PM_{2.5}$ and PM_{10}) which may have long-term health effects. This also affected the overall air quality since harmful pollutants were present, although the CO levels were within safe limits, which has led to concerns about respiratory and heart health among the residents. Air pollution due to gas flaring activities in Isoko South is a serious problem, which suggests that there is an urgent necessity to implement the regulations and public health interventions to protect the well-being of the local population

RECOMMENDATION

1.) This paper emphasizes the importance of increased regulation of emissions around flaring locations of gas.

2.) Improved Air Quality Measures, Tougher laws and penalties on Gas Flaring, Public Education, Cleaner energy source encouragement, and Health Impact Assessments should be adopted,

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