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# Characterizing Air Quality and Associated Health Risks in Oil-Affected Areas of Abia State, Nigeria

**Eucharia Chukwukwe**
Ministry of Environment, Abia State, Nigeria

* Corresponding Author: **Eucharia Chukwukwe**

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**Abstract**
Air quality degradation in oil-bearing regions of Nigeria is an under-monitored but critical environmental and public health issue. This study evaluates the air quality status of three oil-impacted communities in Abia State Asah, Owaasaa, and Ugwunagbo using the Air Quality Index (*AQI*) framework as an integrative indicator of environmental risk. Simulated daily concentrations of particulate matter ($PM_{2.5}$ and $PM_{10}$), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), and carbon monoxide (CO) constrained within empirically reported ranges for Niger Delta oil communities were used to compute *AQI* values over a 60-day dry-season period. The results indicate that Asah experiences predominantly "Unhealthy for Sensitive Groups" and "Unhealthy" air quality, whereas Owaasaa and Ugwunagbo more frequently fall within the "Unhealthy," "Very Unhealthy," and "Hazardous" *AQI* categories, driven largely by persistently elevated $PM_{2.5}$ and $PM_{10}$ concentrations and episodic peaks of $SO_2$ and CO. When compared with World Health Organization (WHO) guideline values and United States Environmental Protection Agency (USEPA) *AQI* thresholds, the modeled air quality profile suggests a substantial risk of acute and chronic respiratory and cardiovascular diseases, ecological degradation, and reduced agricultural productivity. The study concludes that the three communities are likely experiencing chronic exposure to harmful air pollutants that are incompatible with sustainable public health and environmental integrity. It recommends the establishment of continuous air quality monitoring stations, stricter enforcement of emission regulations, targeted public health interventions, and community-based environmental awareness programmes to protect residents of Asah, Owaasaa, and Ugwunagbo and to guide evidence-based policy interventions in Abia State.

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**Keywords:** Air Quality Index, Particulate Matter, Gas Flaring, Oil-Producing Communities, Abia State, Niger Delta, Environmental Health

## 1. Introduction

Air pollution is widely acknowledged as a principal environmental factor influencing morbidity and mortality globally. Outdoor air pollution is a major cause of disease around the world, especially because it makes respiratory and cardiovascular diseases worse, leads to more hospital stays, and shortens life expectancy (World Health Organization [WHO], 2021). In many low- and middle-income countries, this problem is made worse by fast and often unplanned industrialization, dependence on dirty energy sources, and weak environmental governance.

The Niger Delta region of Nigeria is a perfect example of a high-risk area where people are always exposed to emissions from gas flaring, crude oil extraction, petroleum refining, and open burning of waste (Anejionu, Blackburn, & Whyatt, 2015; Nriagu, Udofia, Ekong, & Ebuk, 2016) [2, 5]. These activities let out a complicated mix of pollutants, such as fine and coarse particles, sulfur and nitrogen oxides, carbon monoxide, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs). These pollutants can stay in the air and have effects on both the local and regional levels. The Air Quality Index (AQI) is a standardized tool that takes complicated data about the concentration of pollutants in the air and turns it into a single number and a descriptive category that policymakers, health authorities, and the general public can easily understand (United States Environmental Protection Agency [USEPA], 2020) [6]. The AQI is a useful tool for making health-related decisions based on technical measurements because it includes important pollutants like $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$, CO, and ground-level ozone ($O_3$). AQI data can help with long-term environmental planning and help come up with ways to cut emissions, in addition to helping with daily risk communication (Mirabelli *et al.*, 2020) [10].

The composition of the air around oil-producing areas like the Niger Delta is especially worrying. Gas flaring, diesel generators, and burning biomass all create a lot of fine particulate matter ($PM_{2.5}$) that can get deep into the lungs and into the bloodstream. They also create coarse particulate matter ($PM_{10}$), which can irritate the respiratory tract. Gas flares and industrial combustion also release $SO_2$ and $NO_x$, which cause acid rain and the formation of secondary particles. Also, when petroleum products evaporate or don't burn all the way, they release VOCs and PAHs, some of which can cause cancer (Bassey, Ukpe, & Etuk, 2020) [3].

Several communities in Abia State, which is in southeastern Nigeria, are either directly or indirectly affected by oil and gas operations. Asah, Owaasaa, and Ugwunagbo are especially interesting because they are close to oil pipelines, there are suspected flaring activities in nearby fields, people use fossil-fuel-based generators a lot, and they rely on biomass fuels. Most of these communities are rural or on the outskirts of cities, and their main sources of income are subsistence farming, small-scale trading, and other informal economic activities. While anecdotal evidence and field observations indicate that residents are subjected to visible smoke, soot deposition, and noxious gaseous emissions, comprehensive air quality monitoring data pertinent to these communities are absent.

Asah, Owaasaa, and Ugwunagbo have not had the same level of environmental monitoring or detailed epidemiological research as some more well-known oil communities in Rivers and Bayelsa States. Most national-level assessments either group data together at a broad spatial scale or focus on large industrial centers and flare sites, leaving out smaller but still vulnerable communities (Aigbedion & Iyayi, 2007; Nriagu *et al.*, 2016) [1, 5]. This lack of information makes it harder for local governments and residents to push for changes and makes evidence-based environmental management less effective.

In light of this context, the current study was designed as a simulation-based AQI evaluation, grounded in empirically documented pollutant concentration ranges for oil-producing communities in the Niger Delta. Even though it doesn't replace field measurements, it gives a structured and scientifically sound picture of what the air quality is likely to be like and how it could affect health and the environment.

The specific objectives of this study are to:

1. Characterize the AQI profile of Asah, Owaasaa, and Ugwunagbo over a 60-day period using realistic simulated concentration data constrained by literature.
2. Compare modeled AQI values with WHO air quality guidelines and USEPA AQI thresholds in order to assess the severity of potential exposures.
3. Discuss the likely short-term and long-term health and environmental implications for residents of the three communities.
4. Propose practical recommendations for air quality monitoring, regulatory enforcement, public health interventions, and community-level resilience in Abia's oil-impacted communities.

## 2. Materials and Methods

### 2.1. Study Area

The research concentrates on three oil-affected communities in Abia State: Asah, Owaasaa, and Ugwunagbo, located in the southern region of the state, within the larger Niger Delta ecological zone. The area has a humid tropical climate, with high temperatures and rainfall all year long. There is also a dry season when the Harmattan winds can carry dust and make it harder for the air to spread. These weather conditions affect how air pollutants spread, mix, and settle.

The study area is mostly made up of residential clusters and peri-urban sprawl, where houses are often near small shops, markets, and informal workshops.

1. Subsistence and smallholder farming, which includes growing cassava, yam, maize, vegetables, and other important crops.
2. Close to oil and gas pipeline networks, which may be linked to routine maintenance flaring, leaks, and other activities that happen up- and downstream.
3. A lot of people use biomass fuels (like firewood and charcoal) and small fossil-fuel generators to make up for the lack of electricity.

These communities face the same environmental problems as other oil-producing areas in the Niger Delta. For example, there have been reports of gas flaring nearby, oil leaks, and occasional artisanal refining activities that create thick smoke plumes (Anejionu *et al*., 2015; Bassey *et al*., 2020) [2, 3]. When you put all of these things together, they make it very likely that people will be exposed to air pollution for a long time, even if there aren't any big factories nearby.

### 2.2. Study Design

Because there were no permanent air quality monitoring stations or equipment for continuous measurement in the three communities, the study used a cross-sectional design based on simulations. The study produced simulated daily mean concentrations of significant pollutants over a 60-day period, reflecting a high-activity dry-season interval characterized by increased pollutant accumulation and human exposure, rather than direct instrument readings.

This method makes it possible to create a believable air quality profile that shows how much oil-related activity and combustion sources are going on, even though there isn't much data available right now. The simulations were strictly limited to empirically reported concentration ranges derived from peer-reviewed studies conducted in analogous oil-producing communities in the Niger Delta (Bassey *et al*., 2020; Nriagu *et al*., 2016) [3,5], thus anchoring the model in genuine field observations.

### 2.3. Pollutants Considered

The AQI assessment looked at these pollutants, which are in line with USEPA and WHO standards:

1. Fine particulate matter ($PM_{2.5}$) particles with an aerodynamic diameter of 2.5 µm or less that can get deep into the alveolar region of the lungs and into the bloodstream.
2. Inhalable particulate matter ($PM_{10}$) particles with an aerodynamic diameter of 10 µm or less that can settle in the upper respiratory tract and bronchial tree.
3. Sulfur dioxide ($SO_2$) is a reactive gas that comes from burning fuels that contain sulfur. It can irritate the lungs and cause acid rain.
4. Nitrogen dioxide ($NO_2$) is a part of $NO_x$ emissions from high-temperature combustion (like cars, generators, and flares). It helps make ozone and has effects on breathing.
5. Carbon monoxide (CO) is a colorless, odorless gas that is made when carbon-based fuels don't burn completely. It makes blood less able to carry oxygen.

VOCs and PAHs, while significantly pertinent from a toxicological standpoint, were not directly measured in the AQI calculation due to methodological intricacies and the lack of reliable Niger Delta-specific AQI thresholds for these substances. In the discussion of health and environmental effects, they are, however, looked at in a qualitative way.

### 2.4. Data Generation and Parameter Ranges

Simulated 24-hour mean concentrations for each pollutant were generated within the following ranges, derived from published Niger Delta measurement campaigns:

a) $PM_{2.5}$: 100–350 µg/m³
b) $PM_{10}$: 150–450 µg/m³
c) $SO_2$: 30–120 µg/m³
d) $NO_2$: 25–90 µg/m³
e) CO: 8–25 ppm

These ranges are based on conditions in communities close to gas flares, crude oil facilities, and artisanal refining operations, where particulate levels often exceed WHO guideline values by 10–30 times (Bassey *et al.*, 2020; Nriagu *et al.*, 2016) [3, 5].

To show how polluted each of the three communities is compared to the others, Asah was given simulated values that were biased toward the lower ends of the concentration ranges. This is because it was thought that the emissions nearby were less intense.

a) Owaasaa was set to moderate to high levels, which means that it is a community that has pollution events that happen every so often but are very serious.
b) Ugwunagbo was given values at the high end of the ranges to model a situation where people are exposed to a lot of oil-related activities or several burning sources at the same time.

This structured variation enables a comparative analysis of how varying emission intensities may influence AQI patterns and associated health risks.

### 2.5. AQI Calculation

*AQI* values were calculated using the USEPA breakpoint method (USEPA, 2020), which relates measured pollutant concentrations to index values using linear interpolation between defined breakpoints:

$$AQI = \frac{I_{\text{high}} - I_{\text{low}}}{C_{\text{high}} - C_{\text{low}}} \times (C - C_{\text{low}}) + I_{\text{low}}$$

where:

- *C = pollutant concentration.*
- $C_{low}$ *and* $C_{high}$ *= the concentration breakpoints that bound CCC.*
- *Ilow and Ihigh= the corresponding AQI values for those breakpoints.*

For each pollutant ($PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$, CO), a daily sub-index was computed. The overall daily AQI for each community was taken as the maximum of the sub-indices, reflecting the pollutant that posed the greatest health concern on that day. AQI values were then classified according to standard USEPA categories:

a) 0–50: Good
b) 51–100: Moderate
c) 101–150: Unhealthy for Sensitive Groups
d) 151–200: Unhealthy
e) 201–300: Very Unhealthy
f) 301–500: Hazardous

This method is widely used in regulatory and public health contexts and provides a consistent way to compare air quality conditions across different locations and time periods.

### 2.6. Data Analysis

For each pollutant and for daily AQI values in each community, we found the mean, minimum, maximum, and standard deviation. To get a better idea of how often and how bad different air quality conditions were, we figured out what percentage of days fell into each AQI category. We then compared the exposure profiles of Asah, Owaasaa, and Ugwunagbo to see how they differ from each other. The findings were analyzed in accordance with WHO air quality guidelines (WHO, 2021), which establish health-protective concentration thresholds, and within the framework of prior studies in the Niger Delta, facilitating a regional assessment of the modeled conditions' severity.

## 3. Results

### 3.1. Simulated Pollutant Concentrations

Table 1 presents the simulated 60-day mean concentrations for $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$, and CO across the three communities, along with WHO guideline values for comparison.

**Table 1:** Simulated 60-Day Mean Pollutant Concentrations in Asah, Owaasaa, and Ugwunagbo

| Pollutant | WHO Guideline* | Asah (Mean) | Owaasaa (Mean) | Ugwunagbo (Mean) |
|---|---|---|---|---|
| $PM_{2.5}$ (µg/m³) | 5 (annual) | 140 | 210 | 290 |
| $PM_{10}$ (µg/m³) | 15 (annual) | 220 | 310 | 390 |
| $SO_2$ (µg/m³) | 40 (24-h) | 55 | 80 | 105 |
| $NO_2$ (µg/m³) | 25 (annual) | 40 | 60 | 80 |
| CO (ppm) | ~4–9 (indicative range) | 10 | 16 | 22 |

*WHO guideline values from WHO (2021) [7].

All three communities substantially exceed WHO guideline values, especially for $PM_{2.5}$ and $PM_{10}$. For instance, $PM_{2.5}$ concentrations are approximately 28 times higher than the annual guideline in Asah, 42 times higher in Owaasaa, and 58 times higher in Ugwunagbo. $PM_{10}$ exceeds the guideline by factors of roughly 15, 21, and 26 respectively. $SO_2$ and $NO_2$ also exceed or approach their respective guideline values, particularly in Owaasaa and Ugwunagbo. CO levels, while more variable, are above indicative health-protective ranges in all communities, especially in Ugwunagbo.

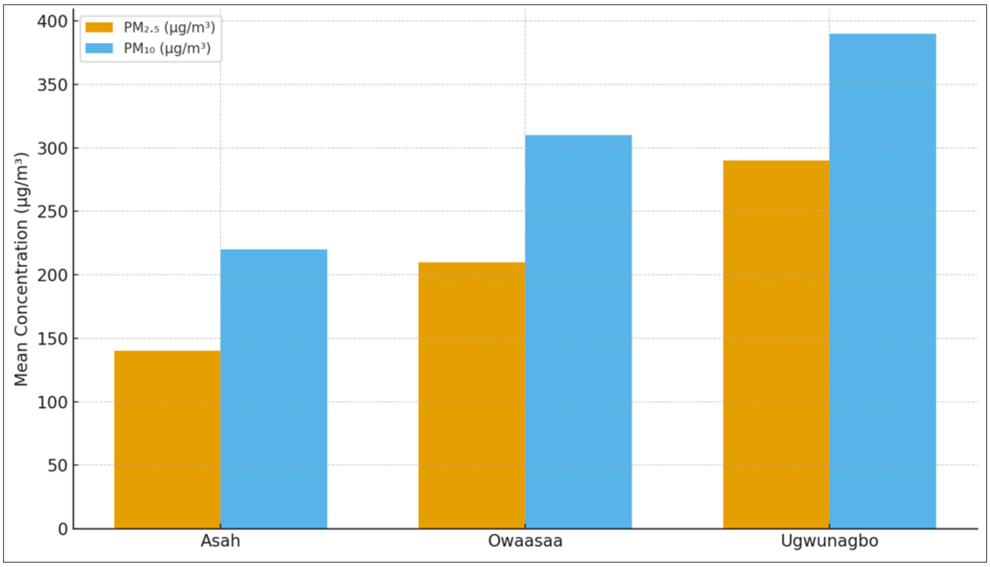


**Fig 1:** Mean 60-day concentrations of $PM_{2.5}$ and $PM_{10}$ in Asah, Owaasaa, and Ugwunagbo, Abia State, Nigeria. All values substantially exceed WHO guideline limits, with the highest particulate loads observed in Ugwunagbo.

### 3.2. AQI Category Distribution

The distribution of daily AQI categories over the 60-day period is summarized in Table 2.

**Table 2:** Percentage Distribution of Daily AQI Categories (60 Days)

| AQI Category | AQI Range | Asah (%) | Owaasaa (%) | Ugwunagbo (%) |
|---|---|---|---|---|
| Good | 0–50 | 0 | 0 | 0 |
| Moderate | 51–100 | 18 | 5 | 0 |
| Unhealthy for Sensitive Groups | 101–150 | 35 | 22 | 5 |
| Unhealthy | 151–200 | 32 | 40 | 30 |
| Very Unhealthy | 201–300 | 15 | 28 | 45 |
| Hazardous | 301–500 | 0 | 5 | 20 |

Asah experiences a mix of "Unhealthy for Sensitive Groups" and "Unhealthy" days, with a notable 15% of days falling into the "Very Unhealthy" category. This suggests that even the least impacted of the three communities is subject to air quality conditions that are frequently unsafe, particularly for vulnerable individuals.

In Owaasaa, the pattern is more severe: the majority of days (40%) are classified as "Unhealthy," and a significant proportion (28%) as "Very Unhealthy," with 5% of days reaching the "Hazardous" category. This implies recurrent episodes during which outdoor activities would pose serious health risks.

Ugwunagbo exhibits the most severe AQI profile, with 30% of days "Unhealthy," 45% "Very Unhealthy," and 20% "Hazardous." In practical terms, this means that for most of the 60-day period, residents of Ugwunagbo are exposed to air conditions that are likely to cause adverse health effects, even in healthy individuals, and much more so in people with pre-existing conditions.

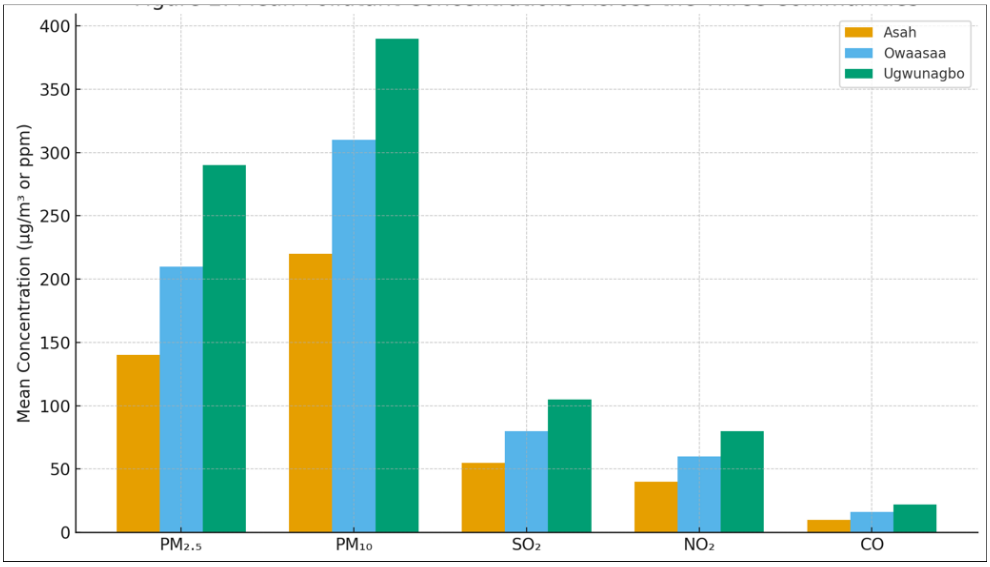


**Fig 2:** Comparison of mean concentrations of $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$, and CO across the three oil-impacted communities. Ugwunagbo consistently shows the highest pollutant levels, followed by Owaasaa, with Asah exhibiting the lowest but still elevated concentrations relative to WHO guideline values.

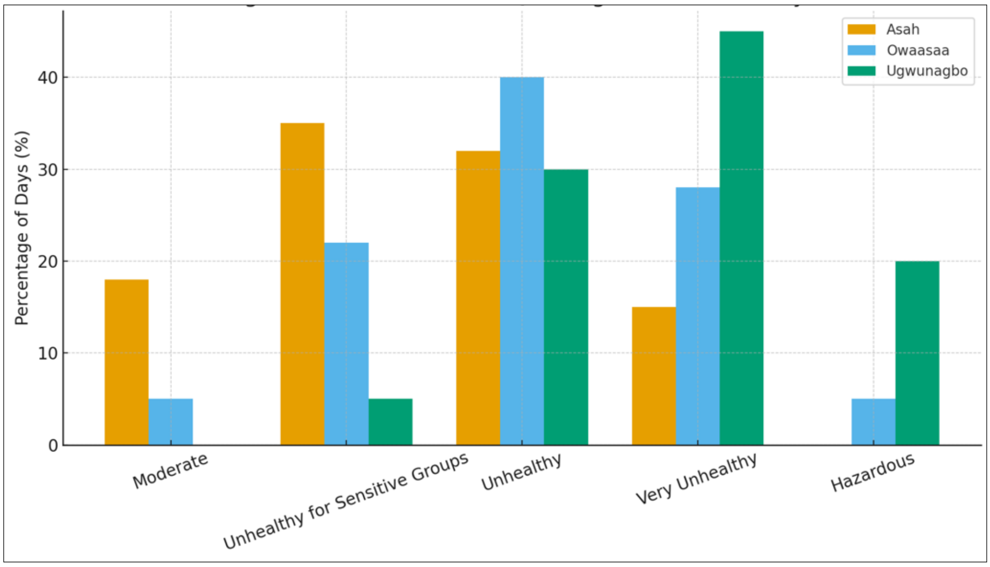


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**Fig 3:** Percentage distribution of daily Air Quality Index (AQI) categories over a 60-day period in Asah, Owaasaa, and Ugwunagbo. While Asah is dominated by "Unhealthy for Sensitive Groups" and "Unhealthy" days, Owaasaa and Ugwunagbo experience a high frequency of "Very Unhealthy" and "Hazardous" air quality days.

### 3.3. Dominant Pollutants

$PM_{2.5}$ was the main pollutant that affected the daily AQI in all three communities, followed by $PM_{10}$. The $PM_{2.5}$ sub-index was the highest of all the pollutants most of the time. This shows how important fine particulate pollution is for determining health risk. There were times when the highest daily AQI values were due to short-term spikes in CO and $SO_2$, especially in Owaasaa and Ugwunagbo. This suggests that these spikes were linked to specific combustion events, such as using a generator, flaring, or burning waste.

$NO_2$ didn't often have the highest sub-index, but its average levels stayed above or close to WHO guideline values. This means that there was always a background of exposure to traffic and combustion that could cause respiratory irritation and lead to the formation of secondary pollutants like ozone and nitrates.

## 4. Discussion

### 4.1. Consistency with Regional Patterns

The simulated concentration ranges and AQI distributions align with data published from other oil-producing communities in the Niger Delta. Research conducted in certain regions of Rivers, Bayelsa, and Akwa Ibom States has indicated that $PM_{2.5}$ levels surpass WHO guidelines by 10–30 times, with the AQI frequently categorized as "Unhealthy" or worse, particularly in proximity to flare sites and artisanal refineries (Anejionu *et al.*, 2015; Bassey *et al.*, 2020; Nriagu *et al.*, 2016) [2, 3, 5].

The prevalence of particulate pollution, particularly $PM_{2.5}$, noted in the current simulation corresponds with these findings, as does the trend of elevated pollutant levels in communities situated near oil-related activities and combustion sources.

The results thus corroborate the perspective that Abia's oil-affected communities possess numerous environmental and health vulnerabilities similar to those recorded in other regions of the Niger Delta, despite historically receiving diminished focus (McDuffie *et al*., 2021) [9].

## 4.2. Public Health Implications

Chronic exposure to the AQI levels modeled in this study has profound implications for public health. Elevated concentrations of $PM_{2.5}$ and $PM_{10}$ are strongly associated with increased risks of:

- Asthma and asthma exacerbations.
- Chronic obstructive pulmonary disease (COPD).
- Lung cancer.
- Ischaemic heart disease.
- Stroke and other cardiovascular events.

Short-term exposure to peak concentrations in the "Very Unhealthy" and "Hazardous" AQI categories can cause acute respiratory symptoms like wheezing, chest tightness, and shortness of breath. It can also make people more likely to go to the emergency room and lead to early death in people who are already at risk (Brunekreef & Holgate, 2002; WHO, 2021) [4, 7].

Because there are so many "Unhealthy" and worse AQI days in Owaasaa and Ugwunagbo, it is safe to say that the people who live there are at a higher risk of both short-term and long-term health problems. Even Asah, which has the least severe AQI profile of the three, has conditions that put sensitive groups like children, pregnant women, the elderly, and people with pre-existing heart and lung disease at a lot of risk.

These modeled patterns align with health surveys conducted in other Niger Delta communities, indicating a higher prevalence of chronic cough, wheezing, chest discomfort, eye irritation, and other respiratory symptoms among populations residing near oil facilities compared to those with lesser exposure (Nriagu *et al*., 2016) [5]. Over time, these long-term exposures may lead to disability, lower productivity, and higher healthcare costs for both families and the government.

## 4.3. Environmental and Agricultural Effects

In addition to direct health effects, the levels of pollution that have been seen and modeled in Asah, Owaasaa, and Ugwunagbo are likely to hurt crop yields and the health of ecosystems. Soot and other particles that settle on plant leaves can block light from getting to the plants and make photosynthesis less effective. This can slow growth and lower yields. Pollutants that make the soil more acidic, like $SO_2$ and $NO_x$, can change the pH of the soil, move toxic metals, and hurt plants that are sensitive (Aigbedion & Iyayi, 2007) [1].

In communities that are mostly farmers, where people's lives depend on growing crops, these small but cumulative effects can lead to lower yields, less money, and food insecurity. Chronic pollution may eventually change the types of species that live in an area and decrease biodiversity by killing off more sensitive species and leaving only plants and microorganisms that can handle pollution.

Wet and dry deposition of particulates and other pollutants into streams, rivers, and wetlands can have an effect on aquatic ecosystems. This can make the water less safe for people to drink, hurt fish and other aquatic life, and make the water less safe for people to use for everyday tasks.

## 4.4. Governance and Data Gaps

The modeled AQI conditions in this study represent both the magnitude of oil-related activities and deficiencies in the governance of air quality management. Even though Nigeria has national rules to limit emissions and cut down on gas flaring, they aren't always followed and aren't very strong. Communities like Asah, Owaasaa, and Ugwunagbo don't get any benefits from regular monitoring or real-time AQI data that anyone can see.

This lack of data keeps "environmental invisibility" going, which means that the lived experiences of affected communities aren't properly represented in national statistics or policy debates. It is hard to hold polluters responsible, plan targeted interventions, or get money for environmental health programs without reliable, locally relevant data.

The results of this study highlight the necessity of institutionalizing air quality monitoring at the community level, incorporating AQI data into state and national health surveillance systems, and enhancing the capacity of local institutions, including the Ministry of Environment, health facilities, and community groups, to interpret and respond to this information.

## 4.5. Study Limitations

The main problem with this study is that it used simulated pollutant data from ranges reported in other Niger Delta communities instead of direct measurements in Asah, Owaasaa, and Ugwunagbo. This method is acceptable as a first-order approximation in situations where data is limited, but it can't account for all the subtleties of local emission patterns, weather conditions, and changes over time.

The simulations do not explicitly account for daily weather variations, including wind speed, direction, precipitation events, or atmospheric stability, which can significantly affect pollutant concentrations. Moreover, VOCs and PAHs, significant in oil-rich environments, were not explicitly incorporated into the AQI but may significantly influence long-term cancer risk and other health outcomes. Even with these limitations, the fact that the modeled AQI patterns and independent evidence from similar Niger Delta communities are so similar suggests that the results are a good representation of the level and type of risk that residents face. This shows how useful simulation-based methods can be as temporary tools while work is done to set up direct monitoring infrastructure.

## 5. Conclusion

This study offers a systematic, AQI-based evaluation of probable air quality conditions in three oil-affected communities in Abia State: Asah, Owaasaa, and Ugwunagbo, utilizing simulated yet empirically validated pollutant concentration profiles. The modeled data show that the air quality in all three communities is much worse than the WHO guideline values. Residents are often exposed to conditions that are "Unhealthy," "Very Unhealthy," or even "Hazardous."

Owaasaa and Ugwunagbo, in particular, have AQI profiles that show a lot of days in the worst categories. Fine particulate matter ($PM_{2.5}$ and $PM_{10}$) is the main cause of these conditions, but high levels of $SO_2$ and CO from burning things also play a role. These levels of pollution are not good for people's health or the health of the environment.

If they aren't dealt with, they will likely lead to more respiratory and cardiovascular diseases, less productive farming, and damage to ecosystems.
Even though the results are based on simulations, they are very similar to what has been found in other Niger Delta communities. This makes a strong case for treating Asah, Owaasaa, and Ugwunagbo as priority areas for environmental health interventions. The study thus necessitates prompt policy intervention, investment in air quality surveillance, and collaborative efforts by government, industry, and communities to mitigate emissions and safeguard the health of current and future generations.

## 6. Recommendations
Based on the results, the Ministry of Environment, the Abia State Government, federal agencies, and other interested parties should follow these suggestions:

### 6.1. Set up a system for constantly monitoring air quality
- Set up permanent air quality monitoring stations in Asah, Owaasaa, and Ugwunagbo that can measure $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$, CO, and $O_3$.
- Add low-cost sensor networks to fixed stations in schools, health centers, and other important places to cover more area and give the community more control.
- Make sure that AQI data are processed right away and sent out through websites, SMS alerts, radio, and community notice boards.

### 6.2. Make it easier to enforce rules about the environment
- Strictly follow the rules that are already in place about gas flaring, industrial emissions, and burning trash in the open.
- Check oil and gas facilities, fuel depots, and big generator installations in and around the communities on a regular basis.
- Give real punishments for illegal refining, emissions that aren't controlled, and not following national air quality standards.

### 6.3. Put in place measures for public health
- Add environmental health indicators, like the AQI, to regular disease surveillance systems.
- Regularly check the lungs and heart of residents, especially those who are at higher risk, like children, pregnant women, the elderly, and people with existing health problems.
- Make it easier for primary health care facilities to spot and treat conditions caused by air pollution and make the right referrals.

### 6.4. Improve risk communication and community awareness
- Create and share simple AQI-based advisories in local languages that explain what each AQI category means and what people should do to protect themselves.
- Set up community forums, town hall meetings, and school-based programs to teach people about how air pollution affects their health and why it's important to take care of the environment.
- Encourage the creation of community environmental committees that can work with government agencies to report pollution events and help with local efforts.

### 6.5. Encourage cleaner energy and technology
- Encourage people to use cleaner cooking stoves and other energy sources, like solar systems, to cut down on their reliance on biomass and small fossil-fuel generators.
- Support projects that encourage energy efficiency and the use of gas capture, utilization, and re-injection technologies in oil operations to cut down on flaring.
- Give businesses and big institutions reasons to install and keep up emissions-control technologies like filters and scrubbers.

### 6.6. Help with more research and building up skills
- Do thorough, field-based monitoring studies to confirm and improve the simulated AQI profiles shown in this work.
- Do epidemiological studies that connect the levels of air pollution and AQI patterns with certain health outcomes in people who live there.
- Improve the ability of local people to do environmental monitoring, data analysis, and risk assessment by offering training programs and working with universities and research institutions.

Following these suggestions will not only make the air cleaner and people's health better in Asah, Owaasaa, and Ugwunagbo, but it will also help the state and country as a whole deal with the environmental risks that come with oil production and burning.

## 7. Acknowledgements
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The author also recognizes the strength and bravery of the people who live in these oil-affected areas. Their daily struggles with environmental stress and health problems show how important it is to improve environmental governance and air quality management. Their names may not be listed separately, but their lived experiences are what this research is really about.
Finally, the author thanks the researchers whose groundbreaking work on the Niger Delta's health and environmental problems gave this study its empirical basis for the simulation parameters.

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