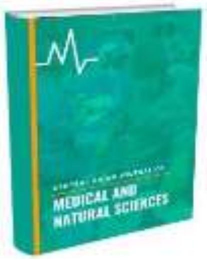

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Article

Health Risk Assessment of Air Quality of Egbema, Rivers State

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Abstract: Air pollution has become a major environmental and public health concern worldwide due to its significant impacts on human health and environmental sustainability. This study assessed the ambient air quality of Egbema in Ogba/Egbema/Ndoni Local Government Area of Rivers State, Nigeria, and evaluated the associated non-carcinogenic health risks to residents. Ambient air quality monitoring was conducted at selected sampling stations during the wet season (December 2024–March 2025) and dry season (June–September 2025). A digital anemometer was used for measurements of some of the meteorological parameters such as temperature, relative humidity, wind speed, atmospheric pressure and wind direction; particulate matter(PM_2. We used portable air monitoring instruments to determine the concentrations of particulate matter of different sizes ($PM_{2.5}$ and PM_{10}) and gaseous pollutants including carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ammonia (NH_3), methane (CH_4), ozone (O_3), and volatile organic compounds (VOCs). In order to evaluate air quality status, air quality index (AQI) was calculated while hazard quotient (HQ) model was used for selected pollutants to carry out the non-carcinogenic health risk assessment. Meteorological parameters presented seasonal differences: the relative humidity was higher in the wet season whereas the temperature and wind speed were higher in the dry season (media ± standard deviation). PM_2 concentrations were 0.008–0.010 ppm of particulate matter. dry season: 0.012–0.018 ppm and 0.015–0.020 ppm for PM_5 and PM_{10} respectively) compared to the wet season (PM_5: 0.014–0.018 ppm; PM_{10}: 0.013–0.017 ppm). Higher concentrations were recorded for the dry season, however, these levels were still within the permissible limits (WHO and NESREA). Based on Air Quality Index analysis, PM_{10} values were classified as "good" in both seasons, whereas CO and NO_2 were classified as poor for the range (station to station) and some classified as very poor at certain locations. Health risk assessment for non-carcinogenic pollutants indicated that the values of hazard quotient (HQ) were higher than one related to $PM_{2.5}$, PM_{10} and NO_2, which suggests that many adults who are subjected to these pollutants over the long term are at risk of adverse health effects. Consequently, the authors conclude that even though most of the pollutants concentrations were below international guideline for air quality limits, the values of hazard quotients indicate long-term health risks due to non-carcinogenic effects of ambient air pollutants at Egbema (Niger Delta). Thus, consistent air quality management, stringent environmental regulation, and pollution control laws are recommended to protect public health and ensure sustainable environmental management in the region.

Keywords: Air pollution, air quality index, health risk assessment, particulate matter, Niger Delta, Egbema.

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1. Introduction

Air is a vital component of the environment, essential for sustaining human, animal, and plant life. However, rapid urbanization, industrialization, population growth, and increased energy consumption have contributed significantly to the deterioration of ambient air quality in many urban and industrial regions worldwide. Air pollution has emerged as a major environmental and public health concern due to its association with respiratory, cardiovascular, and other systemic diseases [1].

Air quality health risk assessment is an important method for assessing the potential effects of pollutants on human health. It serves as an informative measure of the probability of adverse health effects including respiratory infections, asthma, chronic obstructive pulmonary disease (COPD), and cardiovascular events [2], by quantifying exposure, and potentially hazard [3]. Background: Despite the observed dominance of industrial activities with high air particular matters, trapped inside deep valleys and residence on high anthropogenic emission locations, real-time data on ambient air quality and the related health threat in Nigeria, and more especially the Niger Delta area, exist in a terribly constrained way.

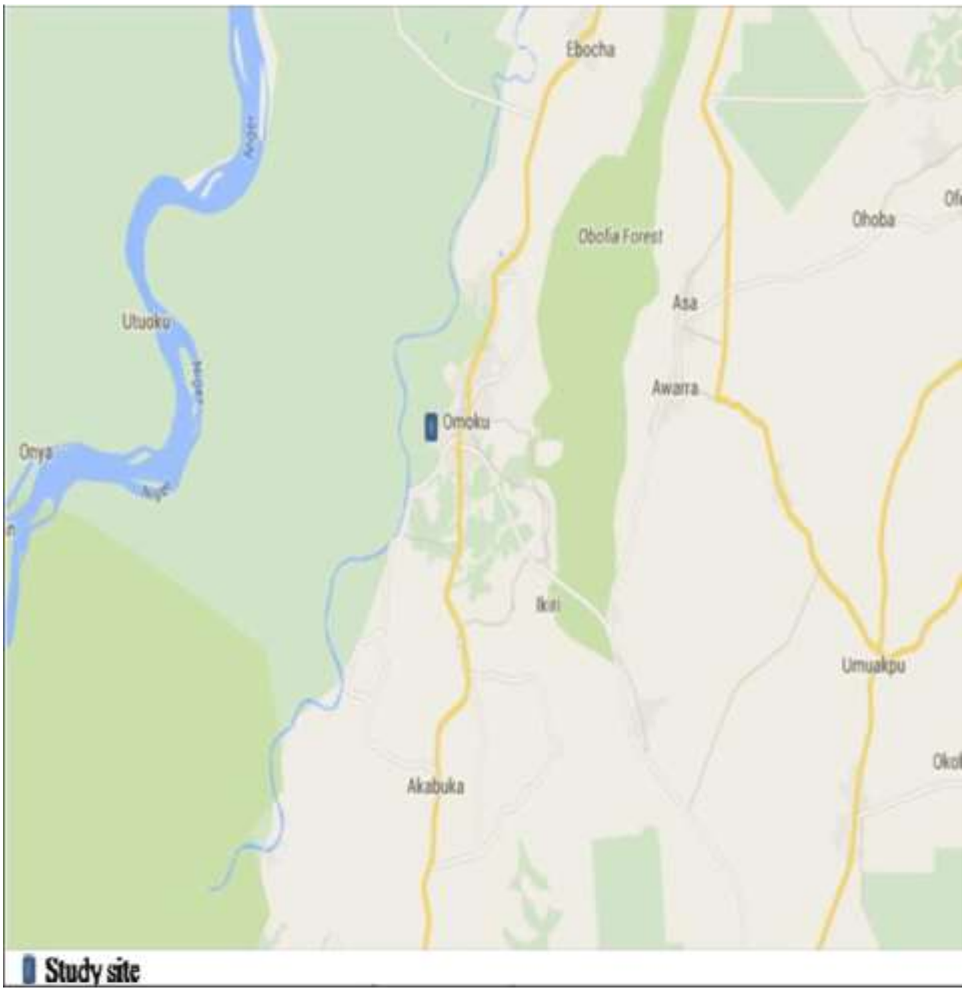
Egbema is a semi-constituent of the Ogba/Egbema/Ndoni Local Government Area of Rivers State, Nigeria, and upland community with a history and extensive experience of industrial, oil and gas exploration. Multiple upstream oil production fields are sited upstream of the area, including those operated by AGIP, Total Energies, and Shell/NPDC, all owned by multinational companies. Along with vehicular emissions, gas flaring, and other anthropogenic sources, these activities serve to release pollutants like particulate matter (PM_2.) Send particulate matter (PM, PM_5 and PM_{10}), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), ammonia (NH_3), methane (CH_4), and volatile organic compounds (VOCs) into the atmosphere. Such pollutants can affect the health of residents, especially through long-term inhalation exposure [3].

AbstractObjectiveThis study aimed to register the ambient air quality of Egbema while simultaneously evaluating the local non-carcinogenic health risk it poses to the residents. It tackles seasonal variations, quantification of hazardous air pollutants using air quality monitoring stations and the hazard quotients to identify pollutants of concern. The results are intended to provide scientific support to environmental management, policy-making, and public health protection of the community.

2. Materials and Methods

Study Area

Egbema, located in Ogba/Egbema/Ndoni Local Government Area of Rivers State, lies in South-South Nigeria within the Rivers West Senatorial District, it has an estimated population of 258,700. It shares boundaries with Imo, Delta, Bayelsa, Anambra States, and the Ahoada West, Ahoada East, and Emohua LGAs of Rivers State. The area is predominantly Igbo-speaking, with Ogba as the dominant tribe (12 legislative wards), and Egbema and Ndoni peoples having 2 and 3 wards respectively, also present in neighboring states. Egbema is mainly upland and hosts significant upstream oil and gas activities, with around 12 operational fields managed by AGIP, Total Energies, and Shell/NPDC, alongside several untapped reserves. Part of the Ogba/Egbema/Ndoni/Ahoada West federal constituency, Egbema (4°49’27’’N, 7°2’1’’E) serves as a commercial and industrial hub, supporting boat building, fishing, mining, light crude oil production, and vehicular activities.



Map of Study Area

Sample Collection and Measurement

Ambient air quality was assessed using handheld monitoring equipment across selected stations during both wet (December 2024–March 2025) and dry (June–September 2025) seasons. Meteorological parameters—including wind speed, wind direction, temperature, relative humidity, and atmospheric pressure—were recorded using a multi-parameter digital anemometer (Model 45170) in open areas to avoid shading effects.

Particulate matter ($PM_{2.5}$, PM_{10}, and TSPM) was measured using a Mini Volume portable air sampler (Sharp DN7C3CA006, Osaka, Japan) equipped with a vacuum system and pre-weighed filters, allowing the collection and gravimetric analysis of airborne particles. Total suspended particulates were additionally monitored using a Met One Aerosol Mass Monitor (GT-321), which provides real-time laser-based measurements.

Gaseous pollutants were measured with Industrial Scientific Corporation ITX Multigas monitors and the Multirae Plus (PGM-50) for volatile organic compounds (VOCs). Carbon monoxide (CO), nitrogen dioxide (NO_2), ammonia (NH_3), and methane (CH_4) were detected electrochemically, while sulfur dioxide (SO_2) and VOCs were monitored using photo-ionization and electrochemical sensors. Ozone (O_3) concentrations were determined using ultraviolet photometry, which measures UV light absorption by ozone in ambient air relative to an ozone-free reference.

All measurements were conducted at approximately two meters above ground level in the prevailing wind direction to ensure representative sampling.

Air quality index (AQI)

The ambient air pollutants are classified into categories ranging from very good to very poor. From (0 – 15) AQI rating is A which is very good, (16 – 31) AQI is B which is good, (32 – 49) AQI is C which is moderate, (50 – 99) AQI is D which is poor and (100 and above) AQI is E

Table 3.1 shows the AQI for criteria pollutants. This is the rating set by USEPA for determining ambient air quality.

AQI pollutant = $x = \frac{\text{Conc.of Pollutant}}{\text{Standard limit}} x\ 100$……………………………………………..(1)

Table 1. Air quality index for criteria pollutants

AQI Category	AQI rating	PM_{10} µg/m^3	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)
Very good (0 -15)	A	0 – 15	0 -2	0 – 0.02	0 – 0.002
Good (16 -31)	B	15 – 75	2.1 – 4.0	0.02 – 0.03	0.02 – 0.03
Moderate (32 – 49)	C	76 – 100	4.1 – 6.0	0.03 – 0.04	0.03 – 0.04
Poor (50 – 99)	D	101 – 150	6.1 – 9.0	0.04 – 0.06	0.03 – 0.04
Very Poor(100 or over)	E	>150	>9.0	>0.06	>0.06

Source: USEPA 2000

Health risk assessment

Non-carcinogenic risk assessment

The target non-carcinogenic risk value was set at 1, indicating lack of negative health effect on humans when risk values were <1. Non-carcinogenic risk was calculated for NO_2, PM_{10}, and $PM_{2.5}$ because the reference values of those contaminants, i.e., the reference dose (RfD) for NO_2 and PM_{10} and the reference concentration (RfC) for $PM_{2.5}$, were available in the toxicological databases [2]. However, for all the measured contaminants, the mean daily values of intake through the inhalation exposure pathway were estimated. To obtain the daily intake of pollutants through the inhalation exposure pathway, exposure concentration (EC) was calculated according to Equations (3.2) (OERR, 2009)

EC = (C x ET x EF x ED)/AT……………………………………………………………(2)

Where:

EC - exposure concentration

C -contaminant concentration in air

ET -exposure time

EF -exposure frequency

ED -exposure duration

AT - averaging time

Table 2. Exposure parameters used for the risk estimation in this study

Parameters	Adult	Child
ET Exposure time per person (h/day)	24	24
ED Exposure duration (year)	30	6
EF Exposure frequency (days/year)	188	188
AT Averaging time (hours)	135360	27072

(USEPA, 2011)

HQ = EC/RFC……………………………………………………………………………..(3)

Where:

HQ -hazard quotient

EC, exposure concentration

RfC, reference concentration.

The following RfC values were used for calculations: NO_2: 1.1 x 10^{-2} (mg/kg-day) [2], PM10: 1.1 x 10^{-2} (mg/kg-day) [2]. $PM_{2.5}$: 5.00 x 10^{-3} (mg/m^3) (De Oliveira et al. 2012).

3. Results and Discussion

Table 3. Meteorological data of Egbema

PARAMETER	WET SEASON AQ1	AQ2	AQ3	DRY SEASON AQ1	AQ2	AQ3
Relative Humidity (%)	81.00	80.08	750.00	70.20	69.08	71.00
Wind Speed (m/s)	2.90	2.40	2.40	3.80	3.00	3.60
Temp (oC)	31.30	32.80	33.10	36.30	38.00	36.20
Pressure (hPa)	1014	1015	1019	1010	1011	1015
Altitude (m)	15.00	15.00	15.00	15.00	15.00	15.00
Noise (decibel)	72.00	71.00	73.00	78.00	75.00	72.00
Wind Direction	N.W.	N.W.	N.W.	N.W.	N.W.	N.W.

Table 4. Particulate matter in ambient air of Egbema during wet season

Parameters (PPM)	AQ1	AQ2	AQ3	AQ4 (CONTROL)	WHO	NESREA
PM2.5	0.009±0.002	0.010±0.003	0.008±0.001	0.003±0.001	0.025	0.075
PM10	0.013±0.001	0.014±0.001	0.017±0.002	0.002±0.001	0.05	0.15

Table 5. Particulate matter in ambient air of Egbema during dry season

Parameters (PPM)	AQ1	AQ2	AQ3	AQ4 (CONTROL)	WHO	NESREA
PM2.5	0.012±0.002	0.015±0.003	0.018±0.001	0.003±0.001	0.025	0.075
PM10	0.015±0.001	0.018±0.001	0.020±0.002	0.002±0.001	0.05	0.15

Table 6. Results of pollutants in air of Egbema during wet season

Parameters (PPM)	AQ1	AQ2	AQ3	AQ4	WHO	NESREA
CO	1.300±0.001	1.500±.0.002	1.500±0.002	1.000±0.002	10	11
CO2	673±0.100	686±0.889	661±0.636	636±0.222	-	-
NO2	0.039±0.002	0.030±0.001	0.029±0.001	0.020±0.001	0.15	0.01
SO2	BDL	BDL	BDL	BDL	0.02	0.06
CH4	BDL	BDL	BDL	BDL	-	-
NH3	6.760±0.600	6.550±0.700	6.590±0.511	5.290±0.300	-	-
O3	3.020±0.300	0.011±0.001	1.080±0.300	0.211±0.001	0.06	0.07
VOC	58±0.030	61±0.030	63±0.011	63±0.021	-	-

Table 7. Results of pollutants in air of Egbema during dry season

Parameters (PPM)	AQ1	AQ2	AQ3	AQ4	WHO	NESREA
CO	2.500±0.001	2.500±.0.002	1.700±0.002	0.500±0.001	10	11
CO2	693±0.600	706±0.719	681±0.600	636±0.999	-	-
NO2	0.062±0.002	0.049±0.001	0.057±0.001	0.025±0.001	0.15	0.01
SO2	BDL	BDL	BDL	BDL	0.02	0.06
CH4	BDL	BDL	BDL	BDL	-	-
NH3	7.960±0.710	7.850±0.660	7.110±0.111	5.370±0.400	-	-
O3	3.800±0.300	0.002±0.000	0.800±0.300	0.003±0.000	0.06	0.07

Parameters (PPM)	AQ1	AQ2	AQ3	AQ4	WHO	NESREA
VOC	65±0.120	64±0.130	66±0.010	62±0.440	-	-

Table 9. Interpretation of the estimated air quality index (I) of pollutants in atmospheric air of Egbema study locations

Parameter	Wet Season	Dry Season
PM10	30	34
CO	14.3	22.2
NO2	19.3	37.3
SO2	-	-

Parameter	Wet Season (Class)	Dry Season (Class)
PM10	B	B
CO	D	E
NO2	E	E
SO2	-	-

Table 10. Non-carcinogenic health risk assessment of pollutants in air of Egbema for Adults

Parameter	Wet Season	Dry Season
PM2.5	1.8	3.6
PM10	1.3	1.5
NO2	2.6	5.1

Discussion

There is distinct seasonal variation between the wet and dry seasons in the weakly measured meteorological parameters in Egbema (Table 1). In the wet season relative humidity ranged from 80 to 81%, while in the dry season it was 69 to 71%. This trend is in accordance with seasonal behaviour of Niger Delta climatic region, where moisture surplus during rainy season is a function of excess of rainfall over evapotranspiration [4][5]. High relative humidity can influence the formation and transformation of atmospheric pollutants by enhancing the condensation of particulate matter and facilitating secondary aerosol formation [6].

Wind speed values ranged from 2.4–2.9 m/s during the wet season and increased to 3.0–3.8 m/s during the dry season. Higher wind speeds during the dry season may enhance dispersion of air pollutants but can also contribute to resuspension of dust particles, particularly in areas with significant human activities. Similar seasonal patterns of wind speed variation have been reported in other studies conducted in the Niger Delta and other tropical regions [7][8].

Temperature also showed seasonal differences, with wet season temperatures ranging from 31.3–33.1 °C and dry season temperatures ranging from 36.2–38.0 °C. Elevated temperatures during the dry season are typical of tropical climates and can increase photochemical reactions in the atmosphere, leading to the formation of secondary pollutants such as ozone (O_3) [9]. Previous studies in the Niger Delta have reported similar temperature ranges, indicating the strong influence of regional climate on atmospheric conditions [10][11].

Noise levels during the study period ranged from 71–73 dB during the wet season and increased to 72–78 dB during the dry season. These values exceeded the permissible limits for environmental noise of 55–65 dB for residential areas, thus indicating high intensity of anthropogenic activities (road traffic, industry and generators) in the study area [12]. Similar elevated environmental noise levels have been documented in urban and semi-urban areas of Nigeria [13].

Particulate matter ($PM_{2.5}$ and PM_{10}) concentrations measured in Egbema during both seasons were below the limits recommended by the World Health Organization and the National Environmental Standards and Regulations Enforcement Agency [14][15]. During the wet season, $PM_{2.5}$ concentrations ranged from 0.008–0.010 ppm while PM_{10} ranged from 0.013–0.017 ppm (Table 2). These relatively low concentrations may be attributed to rainfall scavenging, which removes particulate matter from the atmosphere through wet deposition processes [16].

However, particulate matter concentrations increased during the dry season, with $PM_{2.5}$ ranging from 0.012–0.018 ppm and PM_{10} ranging from 0.015–0.020 ppm (Table 3). The higher dry-season values may be due to increased dust resuspension, biomass burning, and reduced atmospheric washout during periods with little rainfall [17]. Similar seasonal increases in particulate matter concentrations have been reported in several Nigerian cities including Port Harcourt, Warri, and Lagos [18][19][20].

Although the measured values were within regulatory limits, long-term exposure to particulate matter even at moderate levels has been associated with respiratory and cardiovascular diseases [21][22]. Studies have shown that $PM_{2.5}$ is particularly dangerous because it can penetrate deep into the lungs and enter the bloodstream [23].

Seasonal trends were observed for gaseous pollutants (Tables 4 and 5) with the exception for CO concentrations. For carbon monoxide (CO), the concentrations ranged from between 1.3–1.5 ppm in the wet season and increased across the dry season to between 1.7–2.5 ppm. Although these values were much lower than WHO guideline value of 10 ppm, anthropogenic activities like vehicular emissions, use of generators, and gas flaring in oil producing communities of the Niger Delta obviously impacted these values.

CO_2 concentrations varied between 661–686 ppm in the wet season and 681–706 ppm in the dry season. Concentrations are modestly above typical global background values (~420 ppm, Figure 3) due to emissions from combustion, industrial activities, and less uptake by vegetation in some instances (IPCC, 2021).

Nitrogen dioxide (NO_2) concentrations ranged from 0.029–0.039 ppm in the wet season and increased to 0.049–0.062 ppm in the dry season. While these values were below the WHO guideline limit of 0.15 ppm, they exceeded the NESREA standard of 0.01 ppm. Elevated NO_2 levels are commonly associated with fossil fuel combustion, industrial activities, and traffic emissions (WHO, 2021). Similar findings have been reported in studies conducted in Port Harcourt and other oil-producing regions of Nigeria where combustion-related emissions are prevalent .

Sulphur dioxide (SO_2) and methane (CH_4) were below detectable limits (BDL) in both seasons. The absence of detectable SO_2 may indicate relatively low sulfur content in fuel sources or efficient atmospheric dispersion. However, other studies in the Niger Delta have reported measurable SO_2 concentrations linked to gas flaring and petroleum refining activities .

Ammonia (NH_3) concentrations ranged from 6.55–6.76 ppm during the wet season and increased to 7.11–7.96 ppm during the dry season. At these relatively high levels they could be related to agricultural practices, waste breakdown, and industrial emissions. During POSTAMMO you will evaluate and reduce the reactivity of ammonia with acidic gases in order to form secondary particulate matter in the form of ammonium nitrate and ammonium sulfate.

Between sampling points, Ozone (O_3) concentrations appeared to vary widely and were notably elevated during the dry season. This pattern might be related to increased photochemical reactions; thereby, dry conditions favoring high temperature and solar radiation. Over similar seasonal ozone patterns have been reported among tropical urban areas.

The concentrations of volatile organic compounds (VOCs) were 58–63 ppm during the wet season and slightly higher during the dry season (64–66 ppm). Volatile organic compounds (VOCs) may be emitted from petroleum operations, fuel combustion, and industrial processes, all prevalent in an oil producing community like Egbema.

As seen from Table 6, the Air Quality Index (AQI) values of CO, PM_{10} and NO_2 have been calculated; the values of PM_{10} are in the "good" category for both of the seasons, however the values of CO and NO_2 fall under moderate to unhealthy category depending on the season (USEPA, 2018). As shown by AQI interpretation (Table 7), in both cases, the NO_2 values are in the “very poor” class, which can indicate a risk of ecotoxicological and environmental health level problems.

These findings were in agreement with some earlier studies in the Niger Delta, which had variously reported that air quality was moderately to poorly affected by oil exploration activities. Residing in oil-producing communities has been associated with increased incidence of respiratory illnesses because of high levels of airborne pollutants.

Hazard quotient (HQ) values for particulate matter and nitrogen dioxide (Table 8) were over 1 for adult participants in both seasons. HQ greater than 1 shows that there is a potential risk for non-carcinogenic health effects caused by long-term exposure to these pollutants.

PM_2. HQ values were 1.8 during the wet season and 3.6 during the dry season, suggesting that the health risk was higher in the dry season than in the wet season $_5$. Likewise, NO_2 presented HQ values of 2.6 (wet season) and 5.1 (dry season). Conclusion: These results indicate that long-term exposure to ambient air pollutants in the study area may exert potential health risk on respiratory or cardiovascular.

Research from developing nations has also shown comparable health risks associated with long-term exposures to particulate matter and nitrogen dioxide (no), the studies mentioned. But in Nigeria, pollution-related air exposure has been linked to a higher incidence of asthma, bronchitis and other respiratory illnesses.

Overall, the results indicate that although some pollutant concentrations remain within regulatory limits, the cumulative exposure and seasonal increases in pollutant levels may pose significant health risks to residents of Egbema. Continuous monitoring and implementation of effective air quality management strategies are therefore essential to protect public health in the region.

4. Conclusion

This study assessed the ambient air quality and associated health risks in Egbema, Rivers State, by evaluating meteorological parameters, particulate matter concentrations, gaseous pollutants, air quality index (AQI), and non-carcinogenic health risks. The results revealed noticeable seasonal variations in both meteorological conditions and pollutant concentrations. The findings of this study indicate that although some pollutant concentrations are within international regulatory limits, the cumulative exposure and elevated hazard quotient values suggest potential health risks for residents of Egbema. Continuous environmental monitoring, effective pollution control measures, and public health interventions are therefore essential to protect the wellbeing of communities in the area.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

a. Regular monitoring of ambient air quality should be carried out in Egbema and surrounding communities.
b. There is a need for stricter enforcement of environmental regulations regarding industrial emissions, gas flaring, and vehicular pollution in the Niger Delta region.
c. Oil and gas companies operating in the region should adopt cleaner technologies and strategies aimed at reducing gas flaring and industrial emissions.

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