

Assessment of the Air Quality and the Environmental Health Impact of the Petrochemical Plant in Ilaje Local Government Area of Ondo State, Nigeria

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ABSTRACT

Petrochemical facilities are recognised sources of ambient air pollutants, yet community-level evidence from rural Nigerian settings remains limited. This cross-sectional study assessed ambient air quality and respiratory symptoms among adult residents living near a petrochemical facility in Ilaje Local Government Area (LGA), Ondo State, Nigeria. Structured questionnaires were administered to 400 respondents selected by multistage and systematic random sampling. Fine and coarse particulate matter (PM_{2.5}, PM₁₀), volatile organic compounds (VOCs), sulphur oxides (SO_x), nitrogen oxides (NO_x) and carbon dioxide (CO₂) were monitored for seven days in each of the dry and rainy seasons (168 readings per season; 336 in total). Data were analysed using descriptive statistics, chi-square tests with Cramer's V, Mann-Whitney U, Kruskal-Wallis and Spearman correlation tests. All pollutants were significantly higher in the dry season ($p < .001$; $r = .47-.79$). PM_{2.5} exceeded the World Health Organization (WHO) 24-hour guideline of 15 µg/m³ in 98.8% of dry-season and 83.9% of rainy-season readings. Mucus production (59.8%) and breathlessness on hurrying (50.5%) were the most frequently reported symptoms, and 28.7% ($n = 115$) of respondents reported a confirmed respiratory diagnosis, of whom 54.8% described their illness as severe or very severe. Residents who were always exposed to factory emissions had the highest mean total symptom score (4.30), but the overall group difference was not significant ($H = 4.990$, $p = .173$), and no exposure variable was significantly associated with diagnosis (all $p > .05$). The findings suggest a possible relationship between petrochemical emissions and respiratory burden; longitudinal studies with clinical measurements are required to establish causality.

KEYWORDS

Petrochemical industry, Air quality, Particulate matter, Respiratory symptoms, Seasonal variation, Ilaje, Nigeria

I. INTRODUCTION

Ambient air pollution is a major environmental risk to human health, and the World Health Organization (WHO, 2021) has tightened its air quality guidelines to reflect evidence of harm at lower concentrations than previously recognised. The health burden is not evenly distributed: socio-demographic and geographic factors shape who is exposed and who is most affected.

Petroleum refining and petrochemical complexes are significant sources of air pollution, emitting volatile organic compounds (VOCs), particulate matter (PM), nitrogen oxides (NO_x), sulphur dioxide (SO₂) and carbon monoxide (CO), with substantial health risks for nearby populations. These emissions arise from process units, fuel combustion, flaring, fugitive leaks and the handling of feedstock and products. Gas flaring in particular releases carbon dioxide, methane and other pollutants and has attracted growing global attention (Stanley, 2018). Communities living close to such facilities may therefore be exposed to elevated concentrations of VOCs, SO₂, NO_x, fine and coarse PM and CO.

Ilaje is a coastal, oil-producing Local Government Area (LGA) in Ondo State, south-west Nigeria, where oil and gas activities coexist with fishing and farming livelihoods. Despite this setting, most Nigerian air-quality and health studies have concentrated on the Niger Delta, Lagos, Port Harcourt and Ibadan, and studies of petrochemical emissions in Ondo State are very limited. Cross-sectional studies in the region seldom combine objective pollutant measurements across seasons with a standardised assessment of respiratory symptoms, which limits the evidence available to guide local regulation.

This study therefore (i) assessed residents' perceptions of the contribution of the petrochemical facility to ambient air quality, (ii) determined the seasonal concentrations of PM_{2.5}, PM₁₀, VOCs, SO_x, NO_x and CO₂ relative to guideline values, and (iii) examined the relationship between air quality exposure and respiratory symptoms among adult residents of Ilaje LGA.

II. MATERIAL AND METHOD

A. Study Area

The study was conducted in Ilaje LGA, Ondo State, south-west Nigeria (6.2032°N, 4.7679°E). The LGA headquarters is Igbokoda, and the area lies along the Bight of Benin coast of the Atlantic Ocean. Ilaje covers about 1,357 km² and has an estimated population of 457,851 (National Population Commission). The terrain is low-lying and criss-crossed by rivers, creeks and lagoons, with rain forest and mangrove swamp vegetation. The local economy is driven by oil and gas, fishing, farming and timber exploitation, and several oil companies have operated onshore and offshore in the area.

B. Study Design and Population

A community-based cross-sectional design was adopted to collect exposure and health data from a defined population at a single point in time. The study population comprised adult residents aged 18 years and above who had lived in the community for at least one year before the study, a period chosen to ensure adequate exposure to ambient emissions. Petrochemical workers (occupational exposure) were excluded, as were individuals with a chronic respiratory condition diagnosed before they moved into the area. Data collection ran from November 2025 to May 2026 so that both the dry season (November) and the rainy season (May) were represented.

C. Sample Size and Sampling Technique

The sample size was based on Cochran's formula for cross-sectional studies, assuming a 95% confidence level, a 5% margin of error and an estimated prevalence of respiratory symptoms of 25% in industrial areas, with an allowance for non-response. A final sample of 400 respondents was recruited. A multistage sampling technique was used. First, residential areas were stratified into three zones according to their distance from the petrochemical facility. Households were then selected systematically in proportion to zone size, and one eligible adult per household was chosen by simple random selection.

D. Data Collection

Ambient air quality was measured with a portable, handheld real-time air quality monitor (Air quality monitoring) that records PM_{2.5}, PM₁₀, VOCs, SO_x, NO_x, CO₂, temperature and relative humidity. The instrument was calibrated according to the manufacturer's specifications before use. Measurements were taken outdoors at eye level within the study zones and recorded immediately on a data sheet. Monitoring was carried out over seven days in each of the dry and rainy seasons, yielding 168 readings per season (336 in total). Pollutant concentrations were compared with WHO guideline values.

Respiratory health and household exposure characteristics were assessed with an interviewer-administered questionnaire adapted from the American Thoracic Society Division of Lung Diseases respiratory questionnaire (ATS-DLD-78A), using Medical Research Council (MRC)-type symptom items, with additional household exposure items.

The questionnaire had six sections: socio demographic characteristics, respiratory symptoms, exposure history, lifestyle, medical and family history, and perceived air quality. The instruments were pre-tested on 10–12 respondents in Ese-Odo LGA, Ondo State, which has characteristics similar to the study area, and the questionnaire was revised to remove ambiguities. Environmental measurements and questionnaire administration were carried out simultaneously, and completed questionnaires were checked daily for missing information.

E. Data Analysis

Data were analysed with SPSS version 26. Frequencies, percentages, means and standard deviations summarised socio demographic, exposure and pollutant data. A Total Symptom Score (TSS) was derived for each respondent by summing the nine binary MRC symptom responses (range 0–9). Seasonal differences in pollutant concentrations were tested with the Mann–Whitney U test, with r as the effect size.

The Kruskal–Wallis test compared TSS and perceived air quality across exposure and proximity groups, followed by pairwise Mann–Whitney comparisons. Associations between exposure variables and a confirmed respiratory diagnosis (yes/no) were examined with chi-square tests, with Cramer's V as the effect size, and relationships among pollutants were assessed with Spearman's rank correlation. The level of significance was set at $p < .05$.

F. *Ethical Considerations*

Permission to conduct the study was obtained from the Chairman of Ilaje LGA. Participants were informed about the purpose of the study and their right to refuse or withdraw at any time. Anonymity and confidentiality were assured, and data were stored securely and used only for research purposes.

III. RESULTS

A. *Socio demographic Characteristics of Respondents*

A total of 400 adults took part (Table 1). The largest age group was 36–45 years (29.8%), followed by 26–35 years (26.2%) and 46–55 years (25.8%); only 6.8% were aged 56–65 years. Females made up 56.5% of respondents. Business or trading was the most common occupation (34.0%), and nearly half of the respondents were Christian (48.2%).

Table 1: Socio demographic Characteristics of Respondents (N = 400)

Variable	<i>n</i>	%
Age group (years)		
18–25	46	11.5
26–35	105	26.2
36–45	119	29.8
46–55	103	25.8
56–65	27	6.8
Sex		
Male	174	43.5
Female	226	56.5
Occupation		
Farmer	55	13.8
Business/trade	136	34.0
Civil servant	78	19.5
Self-employed	64	16.0
Student	67	16.8
Religion		
Christianity	193	48.2
Islam	100	25.0
Traditional religion	107	26.8

B. *Residents' Perception of Air Quality and Exposure History*

Most respondents rated the air quality in their community as excellent (35.0%) or good (29.2%), while 19.8% rated it fair, 12.8% poor and 3.2% very poor; in total, 35.8% rated it fair or worse. However, 61.8% (*n* = 247) said that air quality had worsened in recent years, and 53.3% (*n* = 213) always or often noticed smoke, odour or dust. Perceived air quality did not differ significantly across proximity groups (Kruskal–Wallis *H* = 0.912, *p* = .634).

Table 2 shows the exposure history of respondents. Four in ten (42.8%) lived within 100 m of the facility, and 41.5% had lived in the area for 5–10 years. Almost half (47.3%) reported being always or often exposed to factory smoke and dust, and 23.8% lived with a household member who smoked.

Table 2: Exposure History of Respondents (N = 400)

Variable	<i>n</i>	%
Distance from the facility		
< 100 m	171	42.8
100–200 m	147	36.8
> 500 m	82	20.5
Years lived in the area		
< 5	128	32.0
5–10	166	41.5
> 10	106	26.5
Exposure to factory smoke or dust		
Always	94	23.5
Often	95	23.8
Sometimes	115	28.7
Never	96	24.0
Smoker in household		
Yes	95	23.8
No	305	76.2

C. Concentrations of Air Pollutants

All pollutants and both meteorological variables differed significantly between seasons (Mann–Whitney U, $p < .001$), with large effect sizes ($r = .47-.79$; Table 3). Mean PM_{2.5} rose from 25.6 $\mu\text{g}/\text{m}^3$ in the rainy season to 59.9 $\mu\text{g}/\text{m}^3$ in the dry season, about four times the WHO 24-hour guideline of 15 $\mu\text{g}/\text{m}^3$. Mean PM₁₀ increased from 43.0 to 82.0 $\mu\text{g}/\text{m}^3$, against a guideline of 45 $\mu\text{g}/\text{m}^3$, and mean NO_x reached 39.5 $\mu\text{g}/\text{m}^3$ in the dry season against a reference value of 25 $\mu\text{g}/\text{m}^3$. Mean VOC and SO_x concentrations, although significantly higher in the dry season, remained below their reference values, as did CO₂.

Parameter	Guideline	Dry <i>M</i> (<i>SD</i>)	Dry max	Rainy <i>M</i> (<i>SD</i>)	Rainy max	<i>p</i>	<i>r</i>
PM _{2.5} ($\mu\text{g}/\text{m}^3$)	15	59.9 (17.6)	110.5	25.6 (10.1)	49.3	< .001	.79
PM ₁₀ ($\mu\text{g}/\text{m}^3$)	45	82.0 (24.8)	176.3	43.0 (14.6)	86.6	< .001	.73
VOCs (ppm)	1.0	0.84 (0.29)	1.62	0.50 (0.20)	1.05	< .001	.56
SO _x ($\mu\text{g}/\text{m}^3$)	20	15.3 (5.0)	27.0	9.8 (3.3)	18.3	< .001	.55
NO _x ($\mu\text{g}/\text{m}^3$)	25	39.5 (15.9)	76.6	25.6 (9.1)	56.4	< .001	.47
CO ₂ (ppm)	1000	553 (47)	678	451 (38)	568	< .001	.78

Temperature (°C)	—	32.1 (3.0)	40.0	28.0 (2.1)	33.3	< .001	—
Relative humidity (%)	—	59.8 (15.3)	96.8	79.7 (9.8)	100.0	< .001	—

Table 3: Seasonal Variation in Air Quality Parameters, Dry Versus Rainy Season

PM_{2.5} exceeded the guideline in 98.8% of dry-season readings and remained high in the rainy season (83.9%; Table 4). PM₁₀ exceeded its guideline in 95.2% of dry-season and 47.0% of rainy-season readings, and NO_x in 81.0% and 50.0%, respectively. VOC and SO_x exceedances occurred mainly in the dry season, and CO₂ never exceeded its reference value.

Table 4: Proportion of Readings Exceeding Guideline Values by Season

Pollutant	Threshold	Dry season, <i>n/N</i> (%)	Rainy season, <i>n/N</i> (%)
PM _{2.5}	> 15 µg/m ³	166/168 (98.8)	141/168 (83.9)
PM ₁₀	> 45 µg/m ³	160/168 (95.2)	79/168 (47.0)
NO _x	> 25 µg/m ³	136/168 (81.0)	84/168 (50.0)
VOCs	> 1.0 ppm	50/168 (29.8)	2/168 (1.2)
SO _x	> 20 µg/m ³	26/168 (15.5)	0/168 (0.0)
CO ₂	> 1000 ppm	0/168 (0.0)	0/168 (0.0)

Spearman's correlation showed significant positive associations among all measured pollutants ($p = .24-.57$, all $p < .001$; Table 5). The strongest association was between PM_{2.5} and PM₁₀ ($p = .57$), and PM_{2.5} correlated moderately with VOCs ($p = .46$) and SO_x ($p = .41$), which may indicate shared or related emission sources.

Table 5: Spearman Rank Correlations among Air Pollutants (Pooled Data, *N* = 336)

Pollutant pair	<i>p</i>	<i>p</i>	Interpretation
PM _{2.5} – PM ₁₀	.571	< .001	Moderate positive
PM _{2.5} – VOCs	.456	< .001	Moderate positive
PM ₁₀ – SO _x	.443	< .001	Moderate positive
PM ₁₀ – VOCs	.414	< .001	Moderate positive
PM _{2.5} – SO _x	.411	< .001	Moderate positive
PM _{2.5} – NO _x	.356	< .001	Moderate positive
PM ₁₀ – NO _x	.277	< .001	Weak to moderate positive
VOCs – NO _x	.273	< .001	Weak to moderate positive
SO _x – NO _x	.258	< .001	Weak to moderate positive
VOCs – SO _x	.237	< .001	Weak to moderate positive

D. Respiratory Symptoms, Diagnosis and Severity

Respiratory symptoms were common (Table 6). Mucus production was the most frequently reported symptom (59.8%), followed by breathlessness when hurrying or walking uphill

(50.5%), chest tightness on exposure to smoke, dust or cold air (47.0%) and usual cough (46.5%). The mean TSS across all respondents was about 4.0 of a possible 9 symptoms.

Table 6: Prevalence of Respiratory Symptoms among Respondents (N = 400)

Symptom	<i>n</i>	%
Mucus production (usually brings up mucus from chest)	239	59.8
Breathlessness when hurrying or walking uphill	202	50.5
Chest tightness on exposure to smoke, dust or cold air	188	47.0
Usual cough	186	46.5
Wheezing in the last 12 months (apart from colds)	173	43.2
Breathlessness at rest	169	42.2
Wheezing attack causing breathlessness	156	39.0
Mucus twice a day, 4 or more days a week	147	36.8
Morning cough	142	35.5

In all, 115 respondents (28.7%) reported a confirmed respiratory diagnosis: asthma ($n = 54$), chronic bronchitis ($n = 22$), tuberculosis ($n = 14$), allergies ($n = 10$) and chronic obstructive pulmonary disease ($n = 8$). Among those diagnosed, 16.5% ($n = 19$) described their illness as mild, 28.7% ($n = 33$) as acute, 32.2% ($n = 37$) as severe and 22.6% ($n = 26$) as very severe, so that 54.8% ($n = 63$) reported severe or very severe illness.

Mean TSS was highest among residents who were always exposed to factory smoke and dust (4.30) and lowest among those never exposed (3.84; Table 7). The overall difference across the four exposure groups was not significant (Kruskal–Wallis $H = 4.990$, $df = 3$, $p = .173$, $\eta^2 = .005$). A pairwise comparison of the always-exposed and never-exposed groups gave a small unadjusted difference ($U = 5270$, $p = .042$, $r = .148$). TSS did not differ significantly by distance from the factory ($H = 1.552$, $df = 2$, $p = .460$).

Table 7: Total Symptom Score by Exposure Frequency and Distance from the Factory

Group	<i>n</i>	<i>M (SD)</i>	<i>Mdn</i>
<i>Exposure frequency</i>			
Always	94	4.30 (1.53)	4.0
Often	95	3.92 (1.41)	4.0
Sometimes	115	3.97 (1.50)	4.0
Never	96	3.84 (1.45)	4.0
<i>Distance from the factory</i>			
< 100 m	171	3.93 (1.45)	—
100–200 m	147	4.16 (1.56)	—
> 500 m	82	3.89 (1.39)	—

None of the socio demographic or exposure variables was significantly associated with having a confirmed respiratory diagnosis at the .05 level (Table 8). Effect sizes were

negligible to small (Cramér's $V < .09$). Perceived worsening of air quality came closest to significance ($\chi^2 = 2.916$, $p = .088$, $V = .085$).

Table 8: Chi-Square Tests of Association between Respondent Characteristics and Respiratory Diagnosis

Variable	χ^2	df	p	Cramér's V
Distance from the factory	0.014	2	.993	.006
Exposure frequency	1.240	3	.743	.056
Years lived in the area	1.099	2	.577	.052
Smoking status	0.995	2	.608	.050
Air quality worsened	2.916	1	.088	.085
Sex	0.108	1	.742	.016
Family history	2.217	2	.330	.074
Age group	0.209	4	.995	.023

IV. DISCUSSIONS

A. Air Pollutant Concentrations

Fine and coarse particulate matter were the most pronounced concern in this study. Mean PM_{2.5} in the dry season was about four times the WHO (2021) 24-hour guideline, and the guideline was exceeded in 98.8% of dry-season readings and still in 83.9% of rainy-season readings, indicating persistent fine-particle pollution throughout the monitoring period. PM₁₀ and NO_x were also above their reference values on most dry-season readings. This pollutant profile is compatible with the emissions reported for petroleum refining and petrochemical complexes, which release particulate matter, NO_x, VOCs and SO₂ through process units, combustion, flaring and fugitive sources, and with the pollutants associated with gas flaring (Stanley, 2018).

The data do not, however, allow the pollution to be attributed to the facility alone. No source apportionment was undertaken, and vehicular traffic, domestic fuel combustion, open burning and seasonal dust cannot be excluded as contributors. The marked seasonal contrast, with all pollutants significantly higher in the dry season, may reflect reduced rainfall scavenging and poorer atmospheric dispersion, although these mechanisms were not measured here. The positive correlations among pollutants, strongest between PM_{2.5} and PM₁₀ and moderate between PM_{2.5}, VOCs and SO_x, suggest common or related sources, whereas the weaker correlations of NO_x with the other pollutants may point to additional or different sources.

B. Perception of Air Quality and Exposure

Although 64.2% of respondents rated their air quality as excellent or good, 61.8% considered that it had worsened, and more than half regularly noticed smoke, odour or dust. Perceived air quality, symptom burden and diagnosis did not vary with distance from the factory, which suggests that exposure may be spread across the community rather than

concentrated close to the facility. This interpretation should be treated with caution because pollutant concentrations were not reported separately for each proximity zone, and the zones may not have captured a true exposure gradient.

C. Respiratory Health

Respiratory symptoms were highly prevalent, with mucus production, breathlessness and chest tightness affecting roughly half of respondents, and more than half of those with a diagnosis reported severe or very severe illness. Such symptoms are consistent with the airway irritation and respiratory effects described for NO₂, SO₂ and CO exposure (Chen et al., 2007) and with the health outcomes linked to living near petrochemical complexes.

The evidence for an exposure–response relationship was, however, limited. Residents who were always exposed had the highest mean symptom score (4.30), a pattern in the expected direction, but the omnibus test was not significant, and the pairwise difference ($p = .042$, $r = .148$) was small and unadjusted for multiple comparisons. Likewise, no exposure or socio demographic variable was significantly associated with a confirmed diagnosis, and effect sizes were negligible. Dichotomising diagnosis may have discarded information on the degree of impairment that the symptom score retains, and a formal diagnosis may be under-reported where access to health services is limited. Other determinants of respiratory health, such as tobacco smoke (reported in 23.8% of households), indoor cooking fuels and socioeconomic circumstances, may also have diluted any association with petrochemical emissions.

The study has several strengths, including objective pollutant measurement in two seasons combined with a standardised symptom questionnaire in a setting where such data are scarce. Its limitations include the cross-sectional design, which precludes causal inference; reliance on self-reported symptoms without spirometer; a short monitoring window of seven days per season; the absence of personal exposure monitoring and source apportionment; and the possibility of residual confounding.

V. CONCLUSION

This study found elevated concentrations of PM_{2.5}, PM₁₀, NO_x, SO_x and VOCs in Ilaje LGA, particularly in the dry season, with PM_{2.5} exceeding the WHO 24-hour guideline in 98.8% of dry-season readings. Respiratory symptoms were highly prevalent among residents, with an average of about four of nine symptoms per respondent, and the always-exposed group reported the highest symptom burden. However, no exposure variable was significantly associated with a formal respiratory diagnosis, and effect sizes were negligible. The findings therefore point to a possible relationship between petrochemical emissions and respiratory health but do not establish it.

Continuous ambient air quality monitoring with publicly accessible data, effective emission controls at the facility, the replacement of gas flaring with gas recovery, systematic respiratory screening including spirometer for communities within 500 m of the facility, and community education on protective behaviours during the dry season are recommended. Future studies should use longitudinal designs with clinical measurements and personal exposure monitoring to quantify exposure–response relationships and confirm causal links.

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