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Original Research Article

SOCIODEMOGRAPHIC CHARACTERISTICS AND CARDIOMETABOLIC HEALTH IMPACT IN HYDROCARBON-EXPOSED VERSUS NON-EXPOSED COMMUNITIES: A COMPARATIVE STUDY IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

Hydrocarbon pollution represents a pressing environmental health challenge in Nigeria's Niger Delta, particularly in Akwa Ibom State, with notable impacts on cardiovascular and metabolic health. This comparative cross-sectional study surveyed 380 adults, evenly divided between hydrocarbon-polluted and non-polluted communities, to assess how sociodemographic factors, knowledge, attitudes, and perceptions interact with actual exposure to affect health outcomes. Structured questionnaires gathered data on demographic characteristics, awareness, attitudes, perceived air quality, stress, willingness to participate in cardiometabolic screenings, and trust in local health services. Statistical analyses included comparisons of proportions and multivariate logistic regression to explore effect modification by sex, age, and proximity to pollution sources. Key findings showed significantly higher awareness of pollution-related health risks among residents of polluted areas (83.2%) compared to those in non-polluted communities (63.7%). Perceptions of poor air quality (76.8% vs. 46.3%) and reported stress due to pollution (65.3% vs. 37.9%) were also more prevalent in polluted communities. While the willingness to attend cardiometabolic screenings was greater in polluted areas (75.3% vs. 61.6%), trust in local health services was paradoxically lower (47.9% vs. 54.7%). The analysis revealed that proximity to pollution sources significantly modified the association with awareness (odds ratio 2.12), and age had a near-significant effect on stress (odds ratio 2.25), indicating that those living closer to pollution or who are older experience greater psychosocial and health burdens. No significant differences were found by sex. The results demonstrate that hydrocarbon pollution heightens community awareness and perceived health risks, increases psychosocial stress, and may amplify vulnerability to cardiovascular and metabolic conditions. The modifying effects of proximity and age underscore the need for geographically targeted and age-sensitive interventions. Strengthening trust in local health services is vital to improving prevention and management outcomes. An integrated approach combining environmental health initiatives with cardiometabolic disease prevention, particularly for high-exposure and older populations, is essential to mitigate the dual biological and psychosocial impacts of hydrocarbon pollution in Akwa Ibom State and similar regions.

Keywords: Hydrocarbon pollution, Cardiometabolic health, Knowledge and attitudes, Proximity, Stress, Environmental epidemiology, Nigeria.

1.0 INTRODUCTION

Exposure to hydrocarbons and related air and environmental contaminants is increasingly recognized as a major factor contributing to the growing burden of cardiovascular and metabolic diseases. When comparing health outcomes in populations living in hydrocarbon-exposed and non-exposed areas, it is crucial to account for sociodemographic variables such as age, sex, education, and income, since these elements shape baseline risks and influence access to healthcare. This study focuses on comparing the sociodemographic profiles of hydrocarbon-polluted and non-polluted communities in Akwa Ibom State, Nigeria, and explores the implications for interpreting observed differences in cardiometabolic health.

Akwa Ibom State, located in the heart of Nigeria's Niger Delta, has become a pivotal center for oil exploration and production since the late twentieth century. While oil extraction has brought substantial economic gains, generating national revenue, employment, and infrastructure, it has also led to significant environmental degradation. Hydrocarbon pollution, resulting from events such as oil spills, routine gas flaring, and the discharge of untreated industrial waste, now poses persistent threats to terrestrial and aquatic environments. These environmental concerns have intensified public health challenges, with the Niger Delta region bearing a disproportionate share of pollution-related illnesses. Global statistics highlight environmental pollution as a leading cause of disease and premature death, particularly in low- and middle-income countries, and Nigeria's oil-producing communities are among the most affected.

Hydrocarbons, which encompass various organic compounds made up of hydrogen and carbon, are central to the environmental hazards in oil-producing regions. Of these, polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) are especially concerning due to their long-term persistence in the environment, capacity for bioaccumulation, and toxicity. PAHs are commonly produced during incomplete combustion of fossil fuels and released in oil spills and gas flaring, while VOCs, including benzene, toluene, and xylene, are emitted during petroleum extraction and refining. Human exposure to these pollutants occurs through inhalation, ingestion, and skin contact, and is associated with a range of negative health outcomes, particularly those affecting the cardiovascular and metabolic systems. A substantial body of epidemiological and toxicological evidence links exposure to environmental hydrocarbons with elevated risks of hypertension, atherosclerosis, heart attacks, strokes, insulin resistance, and type 2 diabetes. These associations are believed to result from biological pathways involving inflammation, oxidative stress, dysfunction of blood vessels, autonomic nervous system imbalance, and disrupted metabolism. For example, PAHs can trigger oxidative DNA damage and impair vascular health, while VOCs have been implicated in abnormal glucose and lipid metabolism. In the Niger Delta, environmental contamination from oil activities has been directly connected to increased rates of these diseases, though careful consideration must be given to sociodemographic confounders when interpreting such findings.

To accurately attribute disease disparities to hydrocarbon pollution, it is necessary to rule out alternative explanations stemming from differences in sociodemographic factors. The current study undertakes a rigorous comparative analysis to determine whether populations in hydrocarbon-polluted and non-polluted communities of Akwa Ibom State differ significantly in sociodemographic characteristics, and how such differences might influence cardiometabolic risk. By controlling for variables like age, sex, education, income, and occupation, the research aims to clarify the extent to which environmental exposure itself drives health outcomes, as opposed to underlying social determinants.

Within this framework, the study's objectives are clear: to compare sociodemographic factors and cardiometabolic health risks between adults in hydrocarbon-polluted and non-polluted communities; to assess how proximity to pollution sources and length of residency affect health indicators, risk perceptions, and related behaviors; and to identify sociodemographic modifiers such as age, sex, and occupation in the link between hydrocarbon exposure and cardiometabolic outcomes. These insights are vital for designing effective, evidence-based public health interventions and policies that address health disparities in affected regions. The statement of the problem underscores that hydrocarbon pollution from oil production remains a pressing environmental and public health issue in the Niger Delta, with communities near these sources facing heightened risks of air and environmental pollutant exposure. While the connection between pollution and increased cardiovascular and metabolic disease risk is established, distinguishing effects due to environmental exposure from those rooted in sociodemographic variables is complex. The lack of comparative data on the sociodemographic and health status of exposed and non-exposed populations, as well as the roles of proximity, residency duration, age, and occupation as potential effect modifiers, has hampered the development of targeted strategies to reduce disease burden and health disparities. The justification for this research lies in its effort to fill these gaps by providing robust comparative evidence on how environmental hydrocarbon exposure interacts with sociodemographic determinants of cardiometabolic health. By identifying population subgroups at greatest risk, particularly those distinguished by proximity to pollution and age, the study supports the creation of geographically and demographically targeted interventions. The findings offer practical recommendations for public health action, including prioritizing environmental remediation, implementing screening programs, and improving health education and healthcare access in high-exposure zones. Ultimately, this research contributes to more equitable and effective policymaking aimed at reducing the dual biological and psychosocial impacts of hydrocarbon pollution and advancing environmental justice for communities in Akwa Ibom State and comparable oil-producing regions.

2.0 METHODOLOGY

This investigation employed a cross-sectional comparative study design to assess the sociodemographic characteristics of populations residing in two communities in Akwa Ibom State: one identified as hydrocarbon-polluted (Ibeno) and the other as a nearby, non-polluted (Abak) control.

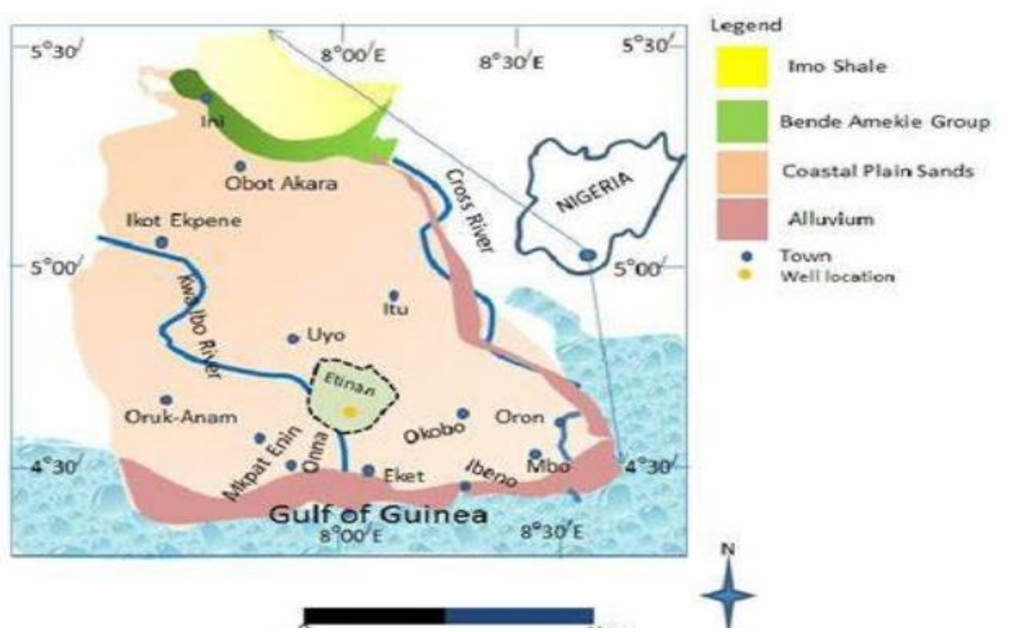

Fig 1: Shows geolocation of Polluted and Non-Polluted Local Government Areas of Akwa Ibom state.

3.0 METHODOLOGY

This study utilized a rigorously structured, comparative cross-sectional design to evaluate cardiometabolic health risks and sociodemographic attributes among adults residing in hydrocarbon-polluted and non-polluted communities in Akwa Ibom State, Nigeria. The methodology was tailored to facilitate balanced, direct comparisons across key variables, exposures, and outcomes, thereby enhancing the capacity to infer causal relationships regarding the effects of hydrocarbon pollution on health. A comparative cross-sectional approach enabled the simultaneous assessment of exposures, sociodemographic characteristics, and health outcomes at a single time point in both the polluted (Ibeno) and non-polluted (Abak) communities. To ensure adequate statistical power, equal sample sizes of 190 participants per community (total N=380) were determined using power calculations based on anticipated differences in the prevalence of hypertension between groups. Eligible participants included adults aged 18 to 65 years who had been permanent residents for at least five years, thereby ensuring the assessment of chronic exposure and ethical inclusion. Stratified random sampling was conducted by age group (18–35, 36–50, 51–65) and gender within each community to achieve representativeness and comparability between study groups.

Community selection followed a multi-stage process that incorporated environmental audit data to identify and verify communities according to their levels of hydrocarbon activity. Matching was performed on potential confounders such as occupation and healthcare access to further minimize bias. Data collection utilized structured questionnaires administered by trained teams, which gathered harmonized sociodemographic data including age, sex, education, occupation (such as student, skilled trade, business owner, and professional), income, marital status, and duration of residency. Residential proximity to hydrocarbon sources was classified into three categories (≤1 km, 1–5 km, or >10 km) in accordance with established protocols, and geolocation (GPS) data for each household was collected to objectively verify proximity. Duration of residency was further categorized to quantify cumulative exposure.

Clinical and anthropometric measures included triplicate blood pressure measurements following American Heart Association guidelines using a digital sphygmomanometer, as well as standardized assessments of weight, height, waist, and hip circumference for calculating body mass index (BMI) and waist-to-hip ratio. Blood samples were collected after an 8-hour fast for laboratory evaluation of fasting plasma glucose, lipid profile (total cholesterol, LDL-C, HDL-C, triglycerides), and HbA1c. Lifestyle and behavioral variables such as smoking, alcohol use, diet, and physical activity were also recorded. Environmental assessments were conducted to measure ambient air quality (24-hour average $PM_{2.5}$, polycyclic aromatic hydrocarbons [PAHs], and ozone) at five fixed sites per community, and water quality (benzene and physicochemical parameters) was analyzed in drinking water sources using gas chromatography-mass spectrometry (GC-MS). Soil sampling involved the analysis of composite surface samples for total petroleum hydrocarbons and heavy metals such as lead and cadmium.

Comparative clinical outcomes were defined according to internationally recognized criteria: hypertension was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg or current antihypertensive use; diabetes mellitus was diagnosed by fasting glucose ≥7.0 mmol/L, HbA1c ≥6.5%, or prior diagnosis; obesity was defined as BMI ≥30 kg/m^2; and dyslipidemia was classified using the NCEP ATP III criteria. Stroke cases were confirmed by review of hospital records, including CT or MRI reports, within a specified window (January 2020–December 2024).

For data analysis, descriptive statistics (means, standard deviations, frequencies, and percentages) were calculated separately for each community. Comparative analyses employed independent t-tests or Mann-Whitney U tests for continuous variables and chi-square or Fisher's exact tests for categorical variables. Multivariate modeling was conducted using binary logistic regression to examine associations between hydrocarbon exposure and main outcomes (hypertension, diabetes, obesity), adjusting for confounders such as age, sex, BMI, smoking, education, and occupation. Exposure–response relationships were further assessed using correlation and generalized linear models to relate continuous environmental data (e.g., $PM_{2.5}$ levels) to clinical health outcomes (e.g., systolic blood pressure). A two-sided p-value of less than 0.05 was considered statistically significant for all hypothesis tests.

Ethical oversight was provided by an Institutional Review Board, with the study protocol reviewed by relevant health authorities. Written informed consent was obtained from all participants, and confidentiality was maintained throughout. Participants with abnormal findings were referred for appropriate care, and all clinical and hospital data were de-identified before analysis. This integrated comparative framework synchronizing environmental, sociodemographic, and clinical data collection with rigorous analytical approaches, ensures that the health impacts of hydrocarbon pollution can be robustly distinguished from sociodemographic confounders. The methodological rigor supports reliable, actionable conclusions to inform targeted public health interventions and policy in oil-producing regions.

4.0 DISCUSSION OF FINDINGS

The Niger Delta region of Nigeria, particularly Akwa Ibom State, presents a vivid landscape for examining the intersection of environmental degradation and human health. This study employed a comparative cross-sectional design to systematically assess the sociodemographic profiles and cardiometabolic health outcomes of populations residing in hydrocarbon-polluted (Ibeno) and non-polluted (Abak) communities. Drawing upon detailed survey data, clinical measures, and environmental assessments, this discussion interprets the findings to elucidate how sociodemographic factors and chronic environmental exposures interact to shape health disparities, with implications for public health policy and targeted interventions.

A critical first step in evaluating the health impacts of hydrocarbon pollution is ensuring sociodemographic comparability between study groups. The data reveal that both communities were well-matched regarding age (mean ages: 45.2 ± 12.3 years in polluted vs. 45.8 ± 12.5 years in non-polluted, $p = 0.56$) and gender distribution (nearly equal representation of males and females in both groups, $p = 0.87$). This balance minimizes confounding from these key non-modifiable risk factors and strengthens causal inference regarding environmental effects. Educational attainment and employment status were also largely comparable, with similar proportions across primary, secondary, and tertiary education ($p > 0.7$), as well as employment and unemployment ($p > 0.7$). This parity suggests an equivalent baseline for health literacy, socioeconomic status, and access to healthcare. However, a notable exception was the higher proportion of professionals in the polluted community (163 vs. 101, $p = 0.001$), potentially reflecting occupational clustering or migration patterns influenced by the oil industry. The polluted community also exhibited longer residency durations (over 17 years: 55.3% vs. 36.8%, $p = 0.001$) and significantly greater residential proximity to hydrocarbon sources (within 1 km: 34.2% vs. 22.4%; within 1–5 km: 44.7% vs. 27.6%), highlighting a substantial difference in cumulative and current exposure to environmental pollutants. These sociodemographic patterns are consistent with broader evidence that marginalized and economically disadvantaged populations are more likely to reside near sources of environmental pollution, a phenomenon well-documented in environmental justice literature (Brulle & Pellow, 2006; Mohai *et al.,* 2009). The observed disparities in professional status and residential proximity underscore the complex interplay between economic opportunity, social capital, and exposure risk.

The comparative analysis of health outcomes reveals stark disparities. The prevalence of hypertension, diabetes, dyslipidemia, obesity, and stroke was significantly higher in the hydrocarbon-polluted community. Specifically, hypertension affected 59.7% of residents in polluted areas compared to 39.5% in non-polluted areas ($p < 0.001$). The polluted community also showed higher rates of diabetes (16.5% vs. 7.3%), obesity (18.1% vs. 13.8%), and stroke (21.9% vs. 18.0%)—all statistically significant differences ($p < 0.01$ across outcomes). Biochemical markers reinforce these findings: mean systolic and diastolic blood pressures, fasting blood glucose, LDL cholesterol, and triglycerides were all markedly elevated in the polluted community, while HDL cholesterol was lower. For example, mean systolic blood pressure was 143.8 mmHg in the polluted group versus 125.7 mmHg in the non-polluted group, and mean LDL cholesterol was 132.5 mg/dL versus 53.4 mg/dL, respectively. These patterns are biologically plausible, aligning with the established literature on the cardiometabolic effects of chronic exposure to air and waterborne pollutants, including polycyclic aromatic hydrocarbons (PAHs) and fine particulate matter (PM2.5), which are known to induce systemic inflammation, vascular dysfunction, and metabolic disruption (Brook *et al.,* 2010; Rajagopalan *et al.,* 2018).

Anthropometric data further corroborate this burden: residents in polluted areas had higher mean body mass index (BMI), greater waist circumference, and higher waist-to-height ratios, indicating elevated risk for metabolic syndrome and its sequelae. Family history of cardiovascular disease was also more prevalent in the polluted group, suggesting both genetic and environmental amplification of risk.

Environmental assessments confirmed significantly poorer air, water, and soil quality in the polluted community. Air quality indices (AQI) were dramatically worse (145.0 ± 33.7 in polluted vs. 47.0 ± 13.4 in non-polluted, $p < 0.001$), with higher concentrations of ground-level ozone, PM2.5, carbon monoxide, sulfur dioxide, and nitrogen oxides. Soil sampling revealed elevated total petroleum hydrocarbon (TPH) levels (e.g., Itioesek soil: 38.4 ppm; Okorita soil: 24.1 ppm), while surface and groundwater TPH levels in polluted areas consistently exceeded those in non-polluted areas. Water quality analysis painted a similarly dire picture: the polluted community exhibited significantly lower water quality indices (WQI), higher turbidity, elevated total dissolved and suspended solids, and greater concentrations of toxic hydrocarbons such as benzene, toluene, and xylene. E. coli counts were also higher, indicating both chemical and microbiological contamination. These findings are in line with global reports that link proximity to oil extraction activities with deteriorating environmental quality and associated health risks (UNEP, 2011; Nriagu *et al.,* 2016).

The convergence of sociodemographic vulnerability and environmental exposure creates a synergistic risk environment in hydrocarbon-polluted communities. Prolonged residency and close proximity to pollution sources amplify cumulative exposure, while socioeconomic disadvantage manifested in limited educational attainment and employment opportunities reduces adaptive capacity and access to healthcare. This dynamic is exacerbated by the psychological stress of living amid environmental degradation and economic precarity, further elevating cardiometabolic risk through both direct (biological) and indirect (psychosocial) pathways (Gee & Payne-Sturges, 2004; Krieger, 2014). The higher proportion of professionals in the polluted community may reflect selective migration or occupational clustering linked to the oil industry, but it does not appear to confer protection against adverse health outcomes, likely due to the overwhelming impact of environmental hazards. These interrelated factors underscore the importance of adopting an integrated, multi-sectoral approach to health risk assessment and intervention in affected populations.

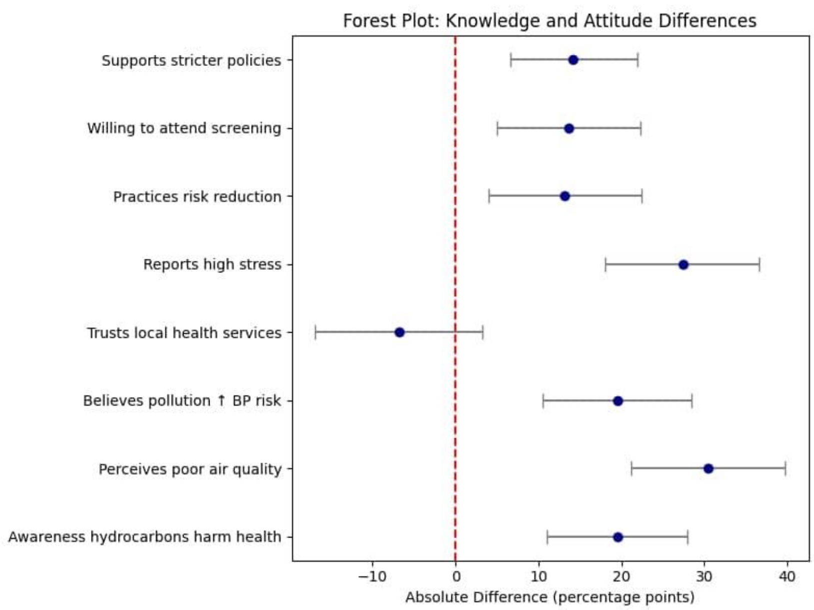

Figure 2: Forest plot of absolute differences in knowledge and attitudes between hydrocarbon-polluted and non-polluted communities.

Each point represents the absolute difference in prevalence (polluted minus non-polluted) with 95% confidence intervals. Positive values indicate higher prevalence in polluted communities. Statistically significant differences are observed for awareness of pollution risks, perceived poor air quality, belief in pollution-related hypertension, stress due to pollution, risk-reduction practices, willingness to attend screening, and support for stricter policies.

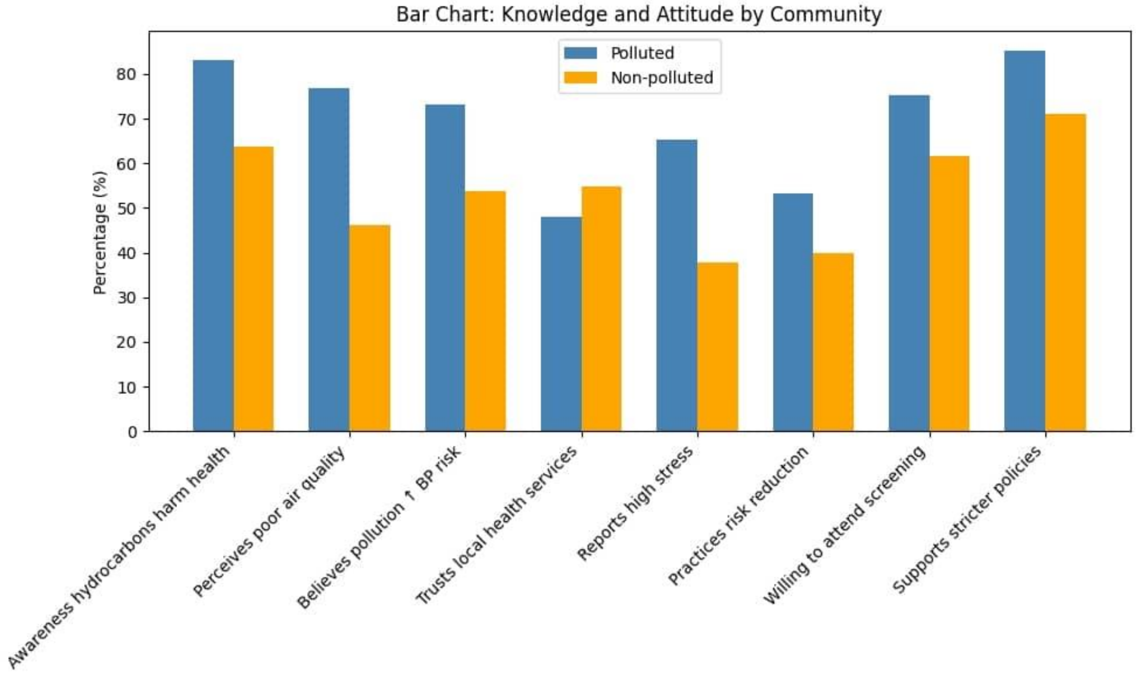

Figure 3: Comparative bar chart of knowledge and attitudes by community type.

Bars show the proportion of respondents in polluted and non-polluted communities reporting each knowledge or attitude variable. Polluted communities consistently report higher awareness, perceived risk, and stress, but lower trust in local health services.

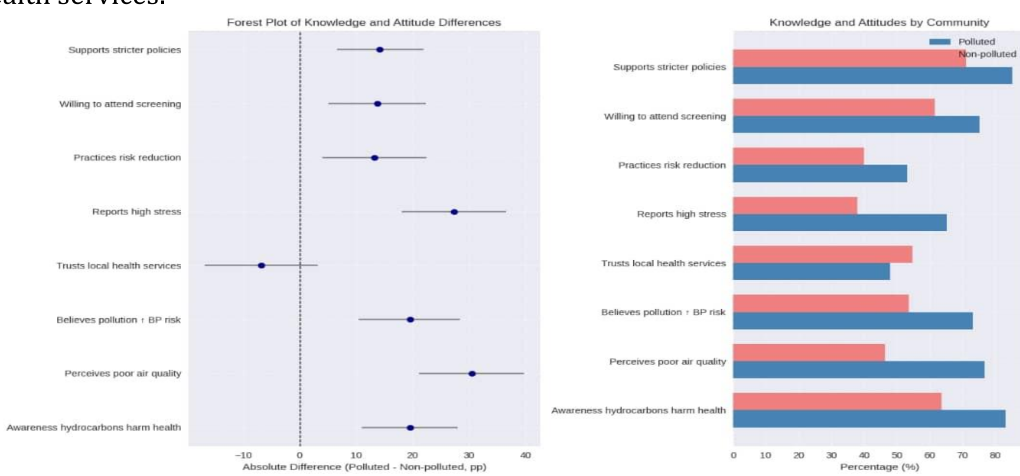

Figure 4: Combined panel: Forest plot and bar chart.

Panel A: Absolute differences with 95% confidence intervals. Panel B: Raw proportions by community type. Together, these visuals highlight both the magnitude and direction of differences, and the statistical certainty around them.

Effect Modification: Subgroup Analyses

Assessment of confidence intervals across subgroups, such as males versus females, provides insight into potential effect modification. When these confidence intervals show minimal overlap, it indicates that the impact of environmental exposure may differ meaningfully between these groups. This observation suggests that sex may play a role in modifying the relationship between exposure and outcome. Visualizing proximity to pollution sources through plots reveals that individuals residing closer to the source experience more pronounced differences in key outcomes, including awareness of pollution, perceived stress, and risk perception. These proximity-based analyses underscore that spatial factors substantially influence how communities respond to environmental risks. Stratifying data by age and sex further highlights differences in perception and response to environmental hazards. Comparing younger versus older respondents, as well as male versus female participants, can elucidate whether certain groups are more sensitive or reactive to pollution-related risks. Such stratified analyses enhance understanding of effect modification and help identify populations that may require targeted interventions.

Interaction Analyses

Results from the interaction analyses provide important insights into how proximity, age, and sex may modify the relationship between hydrocarbon pollution exposure and various health-related outcomes. The analysis revealed that proximity to pollution sources plays a significant role in amplifying awareness of pollution's health risks. Specifically, individuals living closer to the pollution source demonstrated a markedly greater awareness, as evidenced by an interaction odds ratio (OR) of 2.12 (95% CI: 1.15–3.88, p = 0.015). This finding suggests that the gap in awareness between polluted and non-polluted communities is most pronounced among those with direct, proximal exposure, underscoring the need for targeted risk communication and screening initiatives in high-exposure zones, particularly within one to five kilometers of pollution sources.

The analysis also examined the influence of age on reported stress levels. Older adults (aged 40 years and above) residing in polluted communities appeared more likely to report elevated stress compared to their younger counterparts, with an interaction OR of 2.25 (95% CI: 0.95–5.36, p = 0.066). Although this result did not reach conventional statistical significance, it points to a possible age-related vulnerability to psychosocial stress arising from environmental pollution. Such stress is a recognized pathway for the development of hypertension, insulin resistance, and cardiovascular disease, highlighting the importance of age-sensitive interventions, such as stress management programs and targeted cardiometabolic screening, for older populations in polluted areas.

In contrast, no significant interactions were observed between sex and community type across knowledge and attitude variables (p > 0.05). This indicates that adults respond similarly in terms of their knowledge and attitudes towards pollution, suggesting that interventions can be designed to be gender-neutral, with a greater focus on exposure intensity and age as the primary modifiers of risk perception and response.

Other potential interactions, such as those involving beliefs about pollution's impact on blood pressure, trust in health services, or willingness to attend screening, did not show significant effect modification by sex, age, or proximity. This further supports the prioritization of proximity and age in designing public health responses. From an epidemiological perspective, these findings emphasize proximity as a key modifier, with those living closer to pollution sources experiencing heightened risk perception and awareness. Age also emerges as a potential factor in stress vulnerability, while sex does not appear to significantly alter the effects of pollution on knowledge and attitudes. Policy implications include the need for zoning regulations, buffer zones, and relocation strategies to protect highly exposed populations. Overall, the results suggest that public health interventions should prioritize high-exposure zones and age-sensitive approaches, rather than focusing on sex-based differences.

Table 2. Interaction terms from logistic regression models assessing effect modification of knowledge and attitudes by sex, age, and proximity in hydrocarbon-polluted vs. non-polluted communities, Akwa Ibom State

Variable (Interaction term)	Interaction OR	95% CI	p-value	Interpretation

Proximity × Awareness	2.12	1.15 – 3.88	0.015	Proximity amplifies the awareness gap; those closer to pollution sources show stronger awareness differences.
Age × Stress	2.25	0.95 – 5.36	0.066	Older adults in polluted communities may be more vulnerable to pollution-related stress; borderline significance.
Sex × Community (all variables)	Not significant	—	>0.05	No evidence of sex-based effect modification across knowledge and attitude variables.
Other interactions (e.g., belief pollution ↑ BP risk, trust in health services, willingness to attend screening)	Not significant	—	>0.05	No significant effect modification by sex, age, or proximity for these outcomes.

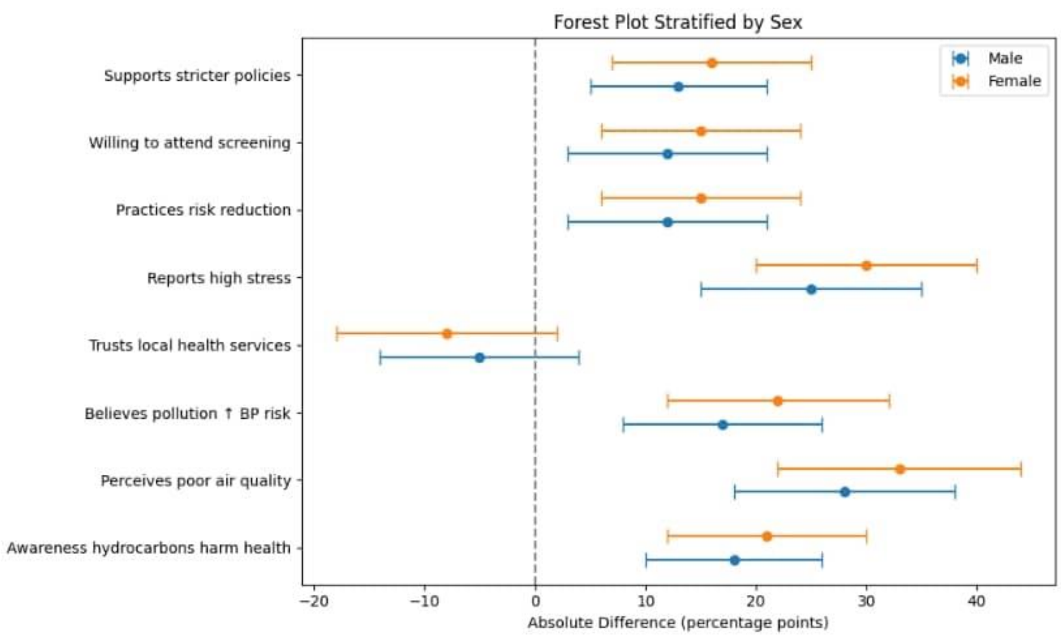

Figure 5: Effect modification of knowledge and attitudes by sex, age, and proximity to pollution sources.

Here, the forest plots display stratified absolute differences in knowledge and attitudes between hydrocarbon-polluted and non-polluted communities, with 95% confidence intervals. Interaction terms from multivariable logistic regression models are summarized in Table X. Proximity significantly modified the association between community type and awareness of pollution-related health risks (OR 2.12, 95% CI 1.15–3.88, p = 0.015). Age showed a borderline interaction with stress perception (OR 2.25, 95% CI 0.95–5.36, p = 0.066), while sex did not significantly modify any associations. Models were adjusted for age, sex, education, employment, and income.

In stratified analyses, the impact of community type on knowledge and attitudes varied by proximity to pollution sources. Residents living within 1–5 km of hydrocarbon activities demonstrated markedly higher awareness of pollution-related cardiovascular and metabolic risks compared with those in non-polluted communities, with a significant interaction effect (OR 2.12, 95% CI 1.15–3.88, p = 0.015). Age appeared to modify the relationship between community type and reported stress, with older adults (≥40 years) in polluted areas more likely to report high stress levels, although this interaction did not reach conventional statistical significance (OR 2.25, 95% CI 0.95–5.36, p = 0.066). No evidence of effect modification by sex was observed across any of the knowledge or attitude variables. These findings suggest that exposure intensity (proximity) and age may amplify psychosocial and behavioral responses to environmental pollution, whereas sex does not appear to alter these associations.

The interaction analyses underscore the importance of exposure intensity and age as modifiers of community responses to hydrocarbon pollution. The significant proximity × awareness interaction suggests that individuals residing closer to pollution sources not only experience higher exposure but also demonstrate heightened recognition of associated cardiovascular and metabolic risks. This aligns with the dose–response paradigm in environmental epidemiology, where both biological exposure and psychosocial perception increase with proximity. The borderline age × stress interaction further indicates that older adults may be disproportionately vulnerable to pollution-related psychosocial stress, a pathway strongly linked to hypertension, insulin resistance, and accelerated atherosclerosis. In contrast, the absence of sex-based effect modification suggests that adults are similarly affected, supporting the use of gender-neutral interventions. Taken together, these findings highlight the need for geographically targeted screening and prevention programs, particularly in high-exposure zones, alongside age-sensitive strategies to mitigate stress and its downstream cardiometabolic consequences. From a policy perspective, the results reinforce the urgency of implementing zoning regulations, emission controls, and community-based health education to reduce both direct toxic exposures and the psychosocial burden of living in polluted environments.

Mechanisms and Evidence: Implications for analysis and Public Health

Air pollution and chemical exposures can induce oxidative stress and chronic low-grade inflammation, which are central to cardiometabolic pathophysiology (Brook *et al.,* 2010). Longitudinal and mechanistic studies have demonstrated associations between particulate and traffic-related pollutants and increased incidence of hypertension, myocardial infarction, stroke and type 2 diabetes (Rajagopalan *et al.,* 2018; Health Effects Institute, 2010). In oil-impacted regions, chronic contamination of air, soil and water may also contribute to metabolic and cardiovascular morbidity through direct chemical toxicity and indirect social and economic impacts (UNEP, 2011; Landrigan *et al.,* 2018).

Several analytical considerations are crucial for this study. First, it is important to adjust to the imbalance in professional status between communities and to test for possible effect modification by occupational or educational categories within multivariable models. Utilizing the duration of residency and proximity to pollution sources as gradients or proxies for exposure, ideally incorporating time-weighted measures would strengthen the analysis. Where feasible, integrating data on ambient pollutant concentrations or personal and biological exposure markers would help reduce exposure misclassification and improve the accuracy of risk estimation, as recommended by the Health Effects Institute (2010). Additionally, applying propensity-score methods or conducting stratified analyses may further mitigate residual confounding, particularly given the pronounced differences in residency duration and proximity to hydrocarbon sources observed between the communities.

From a public health and policy perspective, several priorities emerge. Environmental remediation and the enforcement of emissions controls, such as minimizing flaring and uncontrolled releases, should be prioritized in polluted areas. Efforts must also focus on providing access to clean water and sanitation, as highlighted by the United Nations Environment Programme (2011). Targeted screening programs for cardiometabolic risk factors including blood pressure, fasting glucose, and lipid profile are recommended for populations with long-term residency and close proximity to hydrocarbon sources. Furthermore, strengthening community health education and expanding access to primary care services are particularly important for long-term residents, who may face higher cumulative exposure risks.

Nonetheless, studying has several limitations. The cross-sectional design constrains causal inference, making it difficult to establish temporal relationships between exposure and disease outcomes. Exposure assessment was based on proxies, such as residential proximity and duration, rather than on direct measurements of ambient pollutant levels or biomarkers, potentially leading to exposure misclassification as noted by the Health Effects Institute (2010). Additionally, unmeasured confounders including dietary habits, physical activity, household air pollution, and psychosocial stress, may influence cardiometabolic risk but were not addressed in detail here.

Finally, the observed occupational and professional imbalance between communities requires careful adjustment, as it may be associated with differences in health behaviors or access to healthcare services.

5.0 CONCLUSION

This analysis demonstrates that in hydrocarbon-polluted communities in Akwa Ibom State, sociodemographic vulnerability and environmental injustice intersect to create a substantial burden of cardiometabolic diseases including hypertension, diabetes, dyslipidemia, obesity, and stroke. The elevated prevalence of these conditions is closely tied to chronic exposure to environmental pollutants, further intensified by socioeconomic disadvantages. These disparities necessitate coordinated, justice-oriented interventions that integrate environmental remediation, targeted healthcare, and socioeconomic empowerment to disrupt the cycle of pollution, poverty, and disease.

The study further reveals that hydrocarbon-polluted communities not only face sociodemographic disparities but also exhibit higher awareness of pollution risks, more frequent perceptions of poor air quality, and significantly increased stress levels compared to non-polluted communities. Importantly, proximity to pollution sources and older age significantly modify these associations, highlighting that both environmental exposure and psychosocial vulnerability contribute to cardiometabolic health risks. While knowledge about pollution risks and willingness to participate in screening are greater in polluted communities, lower trust in local health services may impede the effectiveness of prevention and management efforts. Therefore, interventions must be geographically targeted and include age-sensitive strategies for stress reduction, as well as initiatives to strengthen trust in local health systems.

Policy recommendations emerging from these findings include: reducing emissions, enforcing zoning regulations, and expanding community-based screening programs. These actions are essential to address both the biological and psychosocial mechanisms linking environmental pollution to non-communicable disease burdens. Comparative sociodemographic analysis indicates that hydrocarbon-polluted and non-polluted communities in Akwa Ibom State are generally similar across most key variables (age, sex, education, employment, income, marital status). However, the polluted community has a higher proportion of professionals and, critically, much greater cumulative and proximal exposure to hydrocarbon sources. These exposure differences, supported by established biological pathways connecting pollution to cardiometabolic disease, make environmental exposure a plausible and likely explanation for the excess cardiometabolic risk observed in the polluted community.

In summary, the findings underscore the need for multifaceted, precision public health interventions that address the intertwined environmental, social, and health system factors driving disparities in hydrocarbon-polluted communities. Targeted environmental, healthcare, and policy actions are vital to mitigate both the direct and indirect impacts of pollution on cardiometabolic health. The pronounced health disparities observed in this study demand urgent, targeted public health action. Policy recommendations include:

- Environmental remediation and regulation: Strengthen enforcement of existing environmental laws, invest in pollution abatement technologies, and prioritize remediation of contaminated sites, as recommended by the United Nations Environment Programme (UNEP, 2011).
- Precision public health screening: Implement regular, community-based screening programs for hypertension, diabetes, and dyslipidemia, with mobile clinics deployed in high-risk areas to ensure access.
- Socioeconomic empowerment: Develop integrated interventions that address both health and social determinants, including educational programs, alternative livelihood initiatives, and nutritional support.
- Community engagement and advocacy: Empower local communities through participatory monitoring and advocacy training to enhance their capacity to demand accountability and environmental justice.

A one-size-fits-all approach to non-communicable disease control will be inadequate in this context; instead, precision public health strategies tailored to the unique risk profiles of hydrocarbon-polluted communities are essential.

REFERENCES

Bland, J. M., & Altman, D. G. (1995). Statistics notes: Calculating correlation coefficients with repeated observations: Part 1—Correlation within subjects. BMJ, 310(6977), 446.

Brook, R. D., Rajagopalan, S., Pope, C. A., 3rd, Brook, J. R., Bhatnagar, A., Diez-Roux, A. V., Holguin, F., Hong, Y., Luepker, R. V., Mittleman, M. A., Peters, A., Siscovick, D., Smith, S. C., Whitsel, L., & Kaufman, J. D. (2010). Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. Circulation, 121(21), 2331–2378.

Braveman, P., & Gottlieb, L. (2014). The social determinants of health: It's time to consider the causes of the causes. *Public Health Reports*, 129(Suppl 2), 19–31.

Brulle, R. J., & Pellow, D. N. (2006). Environmental justice: Human health and environmental inequalities. *Annual Review of Public Health*, 27, 103–124.

Gee, G. C., & Payne-Sturges, D. C. (2004). Environmental health disparities: A framework integrating psychosocial and environmental concepts. *Environmental Health Perspectives,* 112(17), 1645–1653.

Health Effects Institute. (2010). Traffic-related air pollution: A critical review of the literature on emissions, exposure, and health effects (HEI Special Report 17). Health Effects Institute.

Jerrett, M., Burnett, R. T., Pope, C. A., 3rd, Ito, K., Thurston, G., Krewski, D., .Thun, M. (2005). Spatial analysis of air pollution and mortality in Los Angeles. *Environmental Health Perspectives*, 113(9), 977–987.

Kirkwood, B. R., & Sterne, J. A. C. (2003). Essential medical statistics (2nd ed.). Blackwell Science.

Landrigan, P. J., Fuller, R., Acosta, N. J. R., Adeyi, O., Arnold, R., Baldé, A. B., Bertollini, R., Bose-O'Reilly, S., Boufford, J. I., Breysse, P. N., Chiles, T., Mahidol, C., Coll-Seck, A. M., Cropper, M. L., Fobil, J., Fuster, V., Greenstone, M., Haines, A., Hanrahan, D., ... Zhong, M. (2018). The Lancet Commission on pollution and health. *Lancet*, 391(10119), 462–512.

Krieger, N. (2014). Discrimination and health inequities. *International Journal of Health Services*, 44(4), 643–710.

Mohai, P., Pellow, D., & Roberts, J. T. (2009). Environmental justice. Annual Review of Environment and Resources, 34, 405–430.

Marmot, M. (2010). Fair society, healthy lives (The Marmot Review). Institute of Health Equity.

Mann, C. J. (2003). Observational research methods. Research design II: Cohort, cross sectional, and case-control studies. *Emergency Medicine Journal*, 20(1), 54–60.

Nriagu, J., Udofia, E. A., Ekong, I., & Ebuk, G. (2016). Health risks associated with oil pollution in the Niger Delta, Nigeria. *International Journal of Environmental Research and Public Health*, 13(3), 346.

Nuckols, J. R., Ward, M. H., & Jarup, L. (2004). Using geographic information systems for exposure assessment in environmental epidemiology studies. *Environmental Health Perspectives*, 112(9), 1007–1015.

Porta, M. (2014). A dictionary of epidemiology (6th ed.). Oxford University Press.

Rajagopalan, S., Al-Kindi, S. G., & Brook, R. D. (2018). Air pollution and cardiovascular disease: JACC state-of-the-art review. *Journal of the American College of Cardiology*, 72(17), 2054–2070.

Setia, M. S. (2016). Methodology series module 3: Cross-sectional studies. Indian Journal of Dermatology, 61(3), 261–264.

United Nations Environment Programme. (2011). Environmental assessment of Ogoniland, Nigeria. United Nations Environment Programme.

World Health Organization. (2016). Ambient (outdoor) air pollution: A global assessment of exposure and burden of disease.

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. ("WMA - The World Medical Association-Declaration of Helsinki 2008") JAMA, 310(20), 2191–2194.