"Our bodies are not strong anymore": a focus group study on health risk perceptions of ambient air pollution near a petrochemical industry

Ogochukwu Okoye,[1,2] Elaine Carnegie,[2] Mora Luca[3]

[1]Department of Medicine, College of Health Sciences, Delta State University Abraka, Nigeria; [2]School of Health and Social Care, Edinburgh Napier University, Scotland, United Kingdom; [3]The Business School, Edinburgh Napier University, Scotland, United Kingdom

Abstract

Background. Ambient air pollution has persisted in less-endowed communities, resulting in exposure to unhealthy pollutants. Epidemiological studies on air pollution have been mainly quantitative, with a dearth of information on community health risk perception, a key component of risk management.

Objectives. The aim of this focus group study was to highlight the health risk perception of ambient air pollution among people residing near a petrochemical industry and to determine their perceptions of the existing control measures and ideas for more effective control.

Methods. Participants were purposefully selected based on age, sex, long-term residence near a petroleum refinery, and occupation. Three 90-minute face-to-face focus groups and one individual interview were conducted. The moderator guided discussions using a pre-formed topic guide. Discussions were audio-recorded, transcribed manually, and coded using NVivo software. The data analysis was conducted using reflexive thematic analysis.

Results. Six themes were generated: negative perception of the environment; the refinery is to blame; air pollution is seen or smelled; air pollution is associated with health and non-health risks; poor response to air pollution- everyone is to blame and the government is primarily responsible for healthy air quality. The participants were not aware of the extent of air pollution's health risks. Suggestions for air pollution control included regulating gas flaring, environmental health education, and incentives for community members.

Conclusion. Participants perceived that their ambient air was unhealthy. However, concerns about the health risks were shaped by contextual factors. The key barriers to effective mitigation were poor environmental health literacy and political factors.

Correspondence: Ogochukwu Chinedum Okoye, Department of Internal Medicine, Delta State University Teaching Hospital, Oghara, PMB 07, Nigeria.
Tel.: +234.8023443621
E-mail: ogonwosu2002@yahoo.com

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Introduction

The World Health Organization (WHO) estimates that seven million deaths occurring annually from noncommunicable diseases (NCDs) are attributable to the effects of air pollution, with 91% of these premature deaths occurring in low- and middle-income countries (LMICs).[1] Despite existing policies and interventions aimed at mitigating the adverse effects of air pollution on environmental health, it has persisted, especially in less-served and vulnerable communities, resulting in chronic exposure to unhealthy pollutants with significant health risks.[2-4]

Epidemiological evidence on the negative health effects of air pollution is still emerging. However, several toxicological studies have demonstrated the toxicity of specific air pollutants, providing biological plausibility for air pollution-related diseases.[5,6] Air pollutants of environmental health significance include particulate matter (PM) carbon monoxide, ground-level ozone, nitric oxide, sulfur oxide, and lead.[7] These air pollutants result from traffic fumes, industries, coal and oil combustion, and crustal sources (road dust). Similar to other environmental exposures, the health effects of air pollutants are influenced by multiple factors, including the physical and chemical properties of the pollutant, the duration and time point of exposure, and environmental, social, and economic factors.[8,9] These contextual factors influencing the relationship between exposure and disease are best understood by exploring the lived experiences of the inhabitants of exposed communities.

Existing epidemiological studies on air pollution have been mainly quantitative, focusing on exposure and effect measurement.[7,10] Although such epidemiological evidence aimed at establishing causation is relevant for informing policies and planning interventions, exploring the experience of inhabitants

may provide critical information needed for more inclusive environmental health risk management. Qualitative studies are best suited for health risk perception assessment, which is a key component of environmental health risk management.[11] Qualitative studies are needed to explore the deeper and nuanced meanings of individuals' perceptions of air pollution-related health risks to possibly uncover factors that contribute to the underestimation, overestimation, or ignorance of the problem. The public perceives air pollution and its health risks differently from the scientific community. Noel and colleagues' review of qualitative research about public health risk perceptions about ambient air pollution revealed that such studies are still scarce.[11] Only 4 out of the 20 included studies were from LMICs. The majority reported being unaware of specific air pollutants, and the level of concern about air pollution was not commensurate with the degree of the problem due to other pressing needs. The authors recommended more qualitative and mixed-methods studies geared towards informing future practices, policies, and interventions that will foster sustainable planetary health. The aim of this study was therefore to illuminate the health risk perception of ambient air pollution among persons residing near a petrochemical industry and to understand their perception of existing control measures and ideas for more effective control. The health-risk perception of inhabitants of a single exposed and vulnerable community may be transferable to other communities in similar contexts across the globe.

Materials and Methods

This focus group study is the first phase of an ongoing exploratory mixed-method study (qual®QUAN survey variant) investigating the impacts of long-term exposure to ambient air pollution in communities situated near petrochemical industries, which has not been previously analyzed or published. Findings from this qualitative study will be used to modify a survey questionnaire meant for collecting quantitative data to determine any association between air pollution and chronic kidney disease risk.

The lead researcher (OO) is a female clinician-academic practicing in a developing country who is undertaking a research degree program at a university in the UK with an interest in kidney disease epidemiology. Being cognizant of the issues of positionality and power, the lead researcher, who is also the moderator of all group discussions, presented herself as a postgraduate student who was curious to learn from the participants about a mutually concerning environmental issue. The Ethical Review Committee of the Hospital Management Board serving the community (CHW/ECC VOL 1/226) and the University granted approval for the study. Additionally, we obtained the assent of the local government chairman and community head. To ensure safety, protection, privacy, and anonymity, all identifiers are excluded from this report.

Patient and public engagement

This study does not involve patient or public engagement.

Setting

The study took place in a small semiurban community in a developing country situated near a petrochemical refinery and natural gas plant with the capacity to process large amounts of crude oil daily. Although the oil refinery was temporarily shut down for renovations, the natural gas company is still functional. In addition, the community hosts petroleum depots with diesel trucks transporting products to and from the depot. The people are predominantly engaged in small-scale farming, trading, and transportation.

Community entry and participant selection

The community leader granted access to their community and collaborated with the researchers throughout the study. Based on the recommended maximum of 6-8 persons per focus group and a total of three-four focus groups for simple research topics,[12] the research team distributed 30 invitation cards to purposefully selected members of the community to attend three focus groups. 24 out of 30 people responded; 23 participated in the focus groups, while one individual (a community executive) was interviewed. Participants were selected based on age, sex, long-term residence in the community, level of education, occupation (outdoor *vs* indoor), members of community executive or groups, indigenes, and non-indigenes; this was to ensure our sample was representative of the community and that participants were capable of expressing themselves.

Data collection

Data collection spanned from September 2021 to January 2022. Three 90-minute face-to-face focus groups and one 45-minute individual interview were conducted while observing COVID-19 safety precautions. The individual interview was to ensure the inclusion of at least one community executive since it was difficult to have a group session because of their busy schedule and unavailability. The moderator was responsible for conducting all interviews and was aided by two trained assistants who helped with the logistics of preparing the venues and took notes during the sessions. Informed consent was obtained from all participants before the discussion, although they had prior information about the study and had time to consider their decision to participate. The first two focus groups were held in a rented hall located a short distance from the community to reassure participants of safety and privacy, while the third focus group and interview with a community executive were held in the community hall.

The format of each focus group was as follows: first, a brief survey was completed by each participant to collect basic demographic information and their general perception of their environment. Thereafter, the focus group discussion started with introductions and icebreaker; next, the topic discussion was initiated based on the predefined topic guide, and participants were allowed to talk freely. Midway through the session, the moderator gave a brief PowerPoint presentation aimed at informing the group about air pollution and its potential health impacts. Following the presentation, the session concluded with further discussions as outlined in the topic guide. The topic guide (*Supplementary File 1*) was researcher-structured based on existing literature and comprised questions to ascertain participants' perceptions of their environment generally, the perceived sources of air pollution, the perceived health impacts, their opinions about air pollution control measures, the barriers to control, and any suggestions for more effective control. The guide was pilot tested by initially interviewing a member of the community to check the clarity and comprehension of the questions; this member was not included in the focus group.

All discussions were audio-recorded and encrypted on a dictaphone, while two assistants and the moderator took notes to capture nonverbal expressions from participants. At the end of each session, the moderator summarized the highlights of the discussions for the participants and obtained their approval. Additionally, the moderator would reflect, discuss with her assistants, and record general observations about the focus group.

Data analysis

Data were analyzed using reflexive thematic analysis;[13] our approach is underpinned by the critical realist ontological position and contextualist epistemology.[13] One author manually transcribed

the audio-recorded discussion while two authors read through it, searching out errors and familiarizing themselves with the data. The moderator reviewed the final transcripts with the participants for corrections and comments, although not all were present for the exercise, they had approved an earlier summary of the focus group discussions. Next, the transcription was imported into NVIVO 20 release 1.5 for line-by-line open coding of the transcripts and inductively generating the initial themes. These preliminary codes and themes were further reviewed and developed by two authors to capture both semantic and latent meanings.

Results

Participant profile and demographics

Twenty-four individuals agreed to participate: 23 in 3 focus groups (A: n=3, B: n=6, C: n=14) and one individual interview (D). 3 volunteers did not show up during the first focus group due to other competing assignments. The ages ranged from 29 to 72 years, with females in the majority (16 out of 24). The majority (20 out of 24) were from one tribe; 19 of the participants were married, and 18 had at least a primary level of education. Table 1 shows the participants' profiles.

Themes and sub-themes

The themes, sub-themes, and selected quotes are presented in Figure 1 and *Supplementary File 2*. 6 themes were formed from the data, as follows: i) negative perception of the environment; ii) the refinery is to blame; iii) air pollution is seen or smelt; iv) air pollution is associated with health and non-health risks; v) poor response to air pollution: everyone is to blame; vi) the government is primarily responsible for healthy air quality.

Negative perception of the environment

Perception of air quality

Before the group discussion, 21 out of 24 participants selected the terms "fair", "poor", or "very poor" when asked about their opinion of the ambient air; only three of the participants reported that their air environment was 'good' (n=1) or 'very good' (n=2). However, during the focus group, the participants described their ambient air using the following terms: polluted, not good, bad, not perfect, not ideal to live in, amongst others. One of the male participants describes it as follows:

"*To me the environment is not good. It is not too safe for our human health. There's a lot of pollution mostly this flare and tankers. They are risky to people…. to lives and properties*"- B1

When presented with the WHO classification for air quality, the majority perceived their environment as "unhealthy"; a few people described the environment as "hazardous", while one person chose "unhealthy for sensitive groups". None of the participants described their air environment as "good". When asked about the most worrisome pollution in their environment, one participant responded as follows:

"*Well, mere looking at it... the air is most worrisome. Because this is what we breathe in*" - D1

One of the participants thought that the ambient air pollution had decreased compared to when the refinery was in full operation.

"*The environment is bad, but lately because the refinery has not been working, the level of pollution has reduced. But when it was working, when you wake up in the morning, you see this soot on vehicles everywhere. That's to tell you the amount of pollution*" - B2

Water pollution

All participants were concerned that rainwater was no longer useful to them since it was blackened by soot that settled on their roofs (*Supplementary File 2*: subtheme: contamination of water bodies). The all-women group spoke passionately about the oil contamination of their rivers, which they attributed to the presence of the oil refinery and oil spills. They were particularly concerned about fish scarcity as a result of contaminated rivers, which threatened their main source of livelihood (fishing).

Air pollution is seen or smelt

The participants identified air pollution mainly through their visual and olfactory senses. Black discoloration of rainwater, clothing, household furniture, and floors caused by soot were some of the evidence of air pollution. Other visual evidence of air pollution included soot on cars and in their nostrils. One participant (A2) recounted how, during the COVID-19 pandemic, she had to change her face mask frequently because it was often stained black. Some participants described perceiving a strong odor, which was sometimes associated with difficulty breathing at night. Others mentioned a pepperish sensation in their eyes, nostrils, chest, and skin as signs of air pollution. One participant described how he would wash more frequently because of the soot on his skin. Apart from carbon black or soot, no other specific air pollutant was mentioned or described by the participants.

The refinery is to blame

The perceived sources of air pollution included the petrochemical refinery and natural gas plant, illegal oil bunkering, vehicle emissions from tankers commuting to and from the oil depot, outdoor smoking and cooking, and poor environmental hygiene (*Supplementary File 2*). The participants perceived the oil and gas refinery as the main source of outdoor air pollution. While a few claimed the refinery was no longer functional and only emitted the carbon black that was stored, others strongly claimed that the refinery was operational, especially at night. Below are some quotes from the interview with one participant representing the community executives.

"*Moderator: In your opinion, do you think there is a heavy burden of trailers on your roads?*

D1: Yes, there is, but the carbon from the refinery is worse. Because whenever they pump it out, that's when you know that we have a problem

Moderator: Are they still pumping it out until now? I thought the refinery was shut down.

D1: They work only at night. 'There is a company inside the refinery burning chemicals inside. It is not closed. Operations are still ongoing inside producing chemicals and gases. The odours, the smoke is a major worry"

An elderly female who resides close to the refinery corroborated this claim that the refinery was functional. Two young male participants (A1 and B5) hinted at the contributory role of illegal oil bunkering (artisanal refineries) in the community, while two young ladies (A2 and A3) lamented about dust and smoke from petroleum tankers driven to and from the oil depot in the community. In addition, they complained about tanker drivers and young community boys smoking tobacco openly. Another male participant corroborated their complaints about tankers, but interestingly, none of the

males complained about outdoor smoking.

Several participants felt that odors from dirty drainages contributed to air pollution. None of the women from the all-women focus group raised the issue of poor environmental hygiene, smoking, or diesel tankers; could this be an attempt to project the refinery as the only cause while deliberately de-emphasizing other sources of air pollution? Or were these women truly unaware of other sources of air pollution in their community?

After the moderator made the short presentation on air pollution, interestingly, one of the female participants showed surprise at the information that cooking could contribute to air pollution.

"*Cooking? I am surprised that it can lead to pollution. I know that sometimes when cooking, it makes us cough, and we have to move away from the smoke. I thought that was just a normal thing, never knew it contributes to air pollution*" - C3.

Air pollution is associated with health and non-health risks

Health risks associated with air pollution

According to the participants, the prevailing diseases in the community included malaria, fevers, cough, catarrh, heart failure, kidney disease, liver disease, hypertension, and diarrhea in children. The symptoms/diseases ascribed to air pollution were mainly respiratory, including cough, catarrh, difficulty breathing, and chest pain. Other symptoms were eye irritation and skin irritation (*Supplementary File 2*). Two participants volunteered that anemia, heart, liver, and kidney failure were prevalent and may be due to air pollution exposure. An elderly woman had this to say when asked about prevailing illnesses in the community and then asked to specify which she attributed to air pollution.

"*They have cough. At times, when they test some have kidney, some liver. Most of them. Even as I am talking to you now, my husband…. I lost my husband last year. Kidney too….the whole leg got swollen and before you know it the person is dead*" - C1

While these two participants associate air pollution with major organ failures, we admit that there may be other contributory risk factors. For instance, we observed that regular intake of alcohol was a common social habit among community members (male and

Table 1. Participants' socio-demographic characteristics.

Participant characteristics	Focus group A N=3	Focus group B N=6	Focus group C N=14	Interview D N=1	Total N=24
Gender					
Male	1	6	0	1	8
Female	2	0	14	0	16
Age group (yr)					
18-39	3	3	1	1	8
40-59	0	3	5	0	8
60-79	0	0	8	0	8
Tribe					
Tribe 1	1	4	14	1	20
Tribe 2	0	1	0	0	1
Tribe 3	2	0	0	0	2
Tribe 4	0	1	0	0	1
Marital Status					
Married	3	4	11	1	19
Single	0	2	1	0	3
Widow	0	0	2	0	2
Widower	0	0	0	0	0
Children?					
Yes	3	5	13	1	22
No	0	1	1	0	2
Educational attainment					
Primary	0	0	6	0	6
Secondary	0	1	1	1	3
Tertiary	3	5	1	0	9
None	0	0	6	0	6
Occupation					
*Employed	0	2	0	0	2
**Self-employed	3	4	13	1	21
Unemployed	0	0	1	0	1
Perception of air environment					
Very good	1	1	0	0	2
Good	1	0	0	0	1
Fair	0	2	0	0	2
Poor	1	3	3	1	8
Very Poor	0	0	11	0	11
Previous research participation					
Yes	0	2	0	0	2
No	3	4	14	1	22

*Civil servant, health worker; **trading, business, artisan, farming, fishing.

female), and this may also contribute to the burden of liver disease. In addition, the majority of the participants opined that persistent exposure to air pollution was associated with chronic fatigue, reduced life span, and premature death in their community. Two aggrieved women said the following:

"(upset) *I no see my body carry! I no see my body carry!!* (meaning 'My body is not strong anymore'). *Chest pain, body aches. I cannot go out to hustle as I should*" - C3

"*I have been here for 35 years so I know what is really happening. Like most of my age group, some have not lived long up to. Because of this* (pollution)*, they lost their lives*" - C1

Some participants believed that "good genes" and "God's Grace" were protective of environmental health risks. Although the participants did not mention any psychological or emotional symptoms, we observed expressions of annoyance, frustration, and apathy, particularly among the female participants, which could result in significant stress and distress. The males, on the other hand, expressed fewer emotions, although their complaints were similar. After the participants were educated about the potential health risks associated with air pollution, the moderator would notice quietness in the room and expressions of surprise among the participants. Specifically, they were surprised at the extent of the potential health risks associated with air pollution.

"*If you did not say so, I would not have known that air pollution can contribute to causing cancer. But I believe you, because you wouldn't say it if it is not in the books*"- C2

"*I never thought air pollution can be responsible for kidney problems. We talk about not drinking enough water, stones, but not air pollution…. No*"- B2

Non-health impacts of air pollution

Some participants complained about other impacts of air pollution, including soot causing physical damage to properties such as clothing, zinc roofing sheets, and wares in their stores, and homes covered in soot and requiring repeated cleaning. Some participants mentioned the economic impacts of poor air quality, including businesses relocating from their community and the high cost of accessing health care. One participant (A3) reported that outdoor relaxation was no longer enjoyable due to odor and irritative symptoms. Next, the participants were asked to share their perceptions about stakeholders' responses to air pollution, barriers to effective responses, and suggestions for effective air pollution control (*Supplementary File 2*). Two themes were generated, as detailed below.

Poor response to air pollution: everyone is to blame

The participants perceived that the response to their environmental challenges was generally poor and that the community was being ignored by the government. Although all participants were unanimous in their negative perception of the existing government response, some participants strongly believed that their leaders worsened the situation, while others were silent about the contributory role of their leaders. The only community executive interviewed appeared shocked at the revelation. The sub-themes generated included unsatisfactory responses by stakeholders, distrust and lack of confidence in community leaders and government, a lack of environmental health information, and poor health literacy.

Unsatisfactory response by stakeholders

The majority of the participants reported that there were no visible efforts by the government or industry management to address the issue of air pollution and its effects on their community. The problems highlighted included an unresponsive government, poor enforcement of protection laws, a lack of incentives for community members, and unaffordable health care. (*Supplementary File 2*: subtheme-unsatisfactory stakeholder response).

One participant (A1) repeatedly suggested that the focus group should have been held within the community to involve the community executives, whom he claimed should be privy to more information. We sensed this was a subtle way of referring us to those perceived as "custodians of information" and distancing himself from deeper revelations; he was reassured that his suggestion would be addressed in subsequent sessions. Conversely, two participants in the same group session who spoke more freely expressed their dissatisfactions and frustrations with the government, but more so with the community leaders. The location of that particular session outside the community must have provided some safety and allowed them to express their views without fear; in

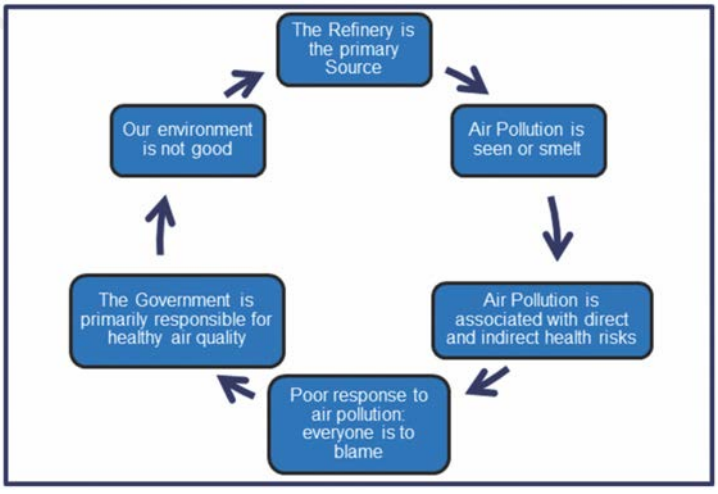

Figure 1. Health risk perception of ambient air pollution near petrochemical plants: six themes

addition, the participants did not know one another.

Concerning community response, recurring codes included "protests for solution", "helplessness and apathy due to fear of oppression", and "perseverance due to community attachment". Some people also responded by relocating away from the community. Some of the participants cited instances where groups organized peaceful protests directed at refinery management but received disappointing responses (*Supplementary File 2*). An elderly woman describes the experience of an all-women group protest.

"*Over time, we have noticed that our health is not optimal. Particularly women. We have tried to go to the refinery to peacefully explain what we are going through. They oppressed us! it was a serious matter. We were beaten and driven away*" - C1

Distrust and lack of confidence in community leaders and government

Some of the participants expressed distrust in their community leaders, whom they referred to using the term "community" or "community boys". Some codes generated here included: feeling oppressed and voiceless; leaders as saboteurs of community efforts; corruption and selfishness; leadership that is not inclusive and unaccountable leadership. Some participants claimed that their leaders received incentives from the refinery management but did not extend this to the community members, others claimed that their leaders were not concerned about their welfare (*Supplementary File 2*).

Interestingly, a member of the community executive who was individually interviewed had this to say when asked to comment on the views of some of the participants about community leadership:

"(Appearing surprised and upset) *Instantly I disagree. Nobody will see something bad happening and want to engage in it. As a leader, we are for the people and for all. So that is something to look into. Because every human being will always talk, some will be true and some will be lies*" – D1

Lack of environmental health information and poor health literacy

The participants were not aware of the extent of health risks that may be associated with air pollution, as mentioned earlier; however, they expressed concerns after receiving information about the subject. In addition, some participants misinterpreted symptoms and the etiology of certain ailments (*Supplementary File 2*). The majority of participants were not aware of where to obtain environmental health information or where their concerns could be addressed. A few mentioned that an office existed on the premises of the Local Government Council, although they had never accessed it. One participant (A2) mentioned that social media may be the source of such information.

Government is primarily responsible for healthy air quality

The participants perceived that effective air pollution control in their community was primarily the government's task but would

Table 2. Multilevel strategies for air pollution control in communities near petrochemical plants in disadvantaged communities.

Levels	Recommendations
Level 1: government/systems	• Enforce environmental protection laws and policies. • Provide accessible health care including health surveillance. • Address unemployment and economic impact of environmental pollution. • Job creation • Cater for the vulnerable (elderly, children). • Monitoring and evaluation in partnership with community members. • Demand accountability from community leaders
Level 2: industries	• Adhere to remediation policies to control gas flaring and carbon emissions. • Partner with government to provide preventive health services. • Partner with government and community to alleviate hardship in exposed communities • Demand accountability from community leaders • Show tolerance and discourage oppression of community members
Level 3: community leaders	• Transparent, accountable and accessible leadership • Inclusiveness in all community development projects • Leaders should be advocates of the community • Encourage regular community meetings • Partner with other stakeholders to alleviate community hardship • Co-produce health information with researchers for wide dissemination.
Level 4: individual members	• Behavioral changes • Use of protective masks and clothing • Improve environmental hygiene • Replace wood or coal with safer cooking fuels • Improved health-seeking behavior • Refrain from artisanal oil-refining • Explore opportunities to gain health information • Volunteer in research to be educated and empowered. • Channel grievances peacefully through leadership and avoid forms of aggression.
Level 5: research community	• More inclusive participatory research to co-produce evidence with community members • Ensure accurate information is disseminated to all relevant stakeholders • Educate and empower the public and advocate for health-protective policies and interventions. • Follow-up visits to communities.

also involve all stakeholders, including refinery management (which also reports to the government), community leaders, community members, and the research community. Their suggestions include providing incentives for community members, stopping gas flaring (alternative disposal of gas), regulating tanker drivers and illegal refineries, banning outdoor smoking and cooking with fossil fuel, providing public health education and empowerment in partnership with the community, disseminating research findings to all stakeholders, improving environmental hygiene, and wearing protective face masks. These suggestions are summarized in the multilevel strategy for air pollution control presented in Table 2.

The majority of the participants suggested that public education may improve the environmental situation in their community.

"*To add to it, most of them are not aware, they don't know the effect of what they are doing. If they were aware, they will not just pocket whatever the industries give to them because they are endangering their live*"- B2

"*Maybe the research will help. Maybe people will be hearing about this* (air pollution and disease) *for the first time. They don't even know what is air pollution. Awareness is needed*"- A2

Interestingly, none of the participants suggested the relocation of the refinery due to perceived benefits.

"*There is no person on the earth, who has a company in their land and will want it to go. Because one day it will be useful. So, we are not praying for companies to come and go but rather stay and reap all the benefits*" - D1

This parting plea by the 70-year-old woman-group leader succinctly captures the expectations of the women:

"*I have something else to say. You see in those days when we did not have this air pollution in our community. We remember that this crude will enter into our waters, and I know that it costs a lot to clean it up. Companies will come in too. I am almost 70 years now, I still recall that government then brings aids in the form of money, health care to support the community. We want to speak as women and urge you to ensure your findings reach the government and let them help us like they used to in the past... We are suffering, we cannot afford medications, and our staple food (fish) is no longer accessible. We hope the government will come to our aid*"- C1

Concerning the dissemination of research findings, the participants suggested reaching the community leaders, the petrochemical companies, the local and State governments, the Legislators, and the national and international communities. Finally, we summarized our findings using the Pressure, State, Impact and Response (PSIR) framework (Figure 2),[14] and presented a conceptual framework describing the determinants of air pollution health risk perception in the study community (Figure 3).

Discussion

This qualitative study was aimed at understanding the health risk perception of air pollution in a vulnerable community. Residents of the community perceived that their ambient air was polluted mainly by the activities of petrochemical industries but were not aware of the extent of its potential health implications. They expressed strong concerns about aesthetic damages from carbon black and crude oil contaminating their rivers, resulting in a shortage of fish, a major source of livelihood for women. The majority denied any meaningful government or community response, and some blamed their community leaders for sabotaging government efforts. Key suggestions for air pollution control included stopping gas flaring (alternative disposal of gas), regulating tanker drivers and illegal artisanal refineries, providing environmental health education, disseminating research findings to all stakeholders, providing access to affordable health care, and providing incentives for community members.

Qualitative studies on air pollution-related health risks in exposed communities are scarce; however, some existing studies have also found that community members were often aware of air pollution and the sources in their communities but were not as concerned about the potential health effects.[11,15] In the systematic review by Noel *et al*., the authors found that the public's perception of air quality was based on personal experience and not objective scientific measurements as obtained among academics.[11] In addition, the public identified air pollution using mainly olfactory (odor) and visual senses and emphasized sources of air pollution rather than referring to specific air pollutants; this was also the case in our study.

Interestingly, although the refinery in the community had been reportedly closed since 2019, there were diverging opinions regarding its contributory role. It is unclear which of the accounts is true and the reasons behind the diverging views among residents of the same community. According to Braun and Clarke, language

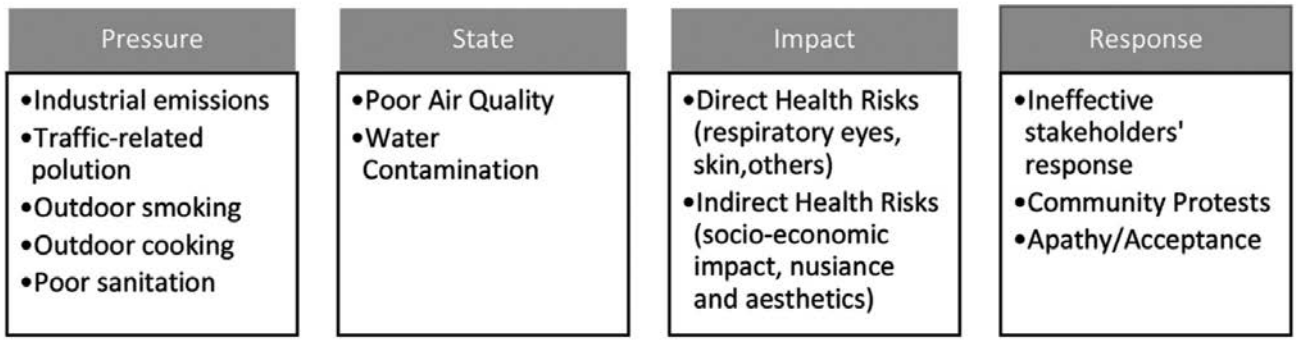

Figure 2. Participants' perception of air pollution summarized using the pressure, state, impact and response model.

is considered "a tool for communicating experience in a relatively straightforward way". However, individuals may forget or hide details, reinterpret past experiences as current, deliberately misinform to either exaggerate or minimize a problem or struggle to find the appropriate words.[13] Furthermore, although language reflects people's thoughts, feelings, and beliefs, it can be influenced by environmental, socio-cultural, and economic contexts. Some factors that may underlie the participants' diverging opinions regarding the functionality of the refinery include spatial proximity to the refinery, such that persons residing closer to the refinery may be privileged to observe activities at a closer range, time spent outdoors *vs* indoors, and poor access to information. In addition, emissions from the functional gas company and other illegal refineries in the community may be wrongly perceived as originating from the closed government refinery. Although the perception of the source of air pollution varies slightly among the participants, they were mostly in agreement concerning the status of the ambient air; this is concerning and requires attention.

Researchers have previously described a situation where individuals maintain the sensation of poor local air quality even when it is improved (the stigma effect) and, conversely, a situation where individuals consistently perceive their environment as less polluted compared to other areas despite the poor air quality (the neighborhood halo effect). Improved environmental transparency and effective risk communication can have a moderating effect on this discordance between public perception of air pollution and actual air pollution,[16] but it requires the commitment of public health professionals working in partnership with the government and other relevant agencies.

The participants in this study unanimously perceived that petrochemical refining (illegal or legal) was the primary source of air pollution in their community. However, the associated health risks were not well appreciated. Some authors have found that respondents often referred to nonspecific general health effects such as feeling unwell when asked to describe the health effects of air pollution but acute symptoms such as respiratory symptoms and irritative symptoms were more easily associated with more tangible exposures.[11] Similarly, the participants in this study easily associated air pollution with the recurrent respiratory and irritating symptoms they experienced. Other potential health effects were hardly mentioned, possibly due to the long latency period and subclinical nature of most chronic diseases and poor environmental health literacy. This study created an opportunity to inform the participants who were urged to inform their family and friends; however, more efforts are needed to provide accessible environmental health education beyond the index community, as this may encourage positive behavioral changes and empower individuals towards sustainable environmental health.

Public perception of a health problem is often influenced by existing environmental, cultural, and socioeconomic factors.[11,16,17] Although the participants were aware of some health impacts associated with air pollution, they often emphasized other pressing challenges, and this has been previously described by Noel *et al*. as "the crowding-out effect".[11] For instance, we observed that the women in the community were more concerned about the oil contamination of their rivers and fish shortages, which directly affected their means of livelihood. Similarly, traders were more concerned about the aesthetic damages caused to their wares by carbon black, but the older and retired age group were more concerned about poor general health and reliance on medications they could hardly afford. Consequently, some participants demanded the provision of regular incentives such as monetary aid and free treatment when asked about their suggestions for effective air pollution control. One can deduce that poverty is a key barrier to health risk perception and needs to be addressed to improve the acceptance of public health interventions in poor communities.

The review of qualitative studies earlier described revealed that "awareness" about an environmental risk does not necessarily translate to "concern" and that some factors alleviated public concern, including crowding-out effects, feelings of uncontrollability or powerlessness, compensation of perceived benefits for living in a polluted environment, perceived fairness (everybody perceived as equally exposed), long latency of health effects, habituation, and acceptance.[11] Our findings mirror these factors to a great extent, but in addition, we identified the perception that younger people are immune and protected from the health risks associated with air pollution, the notion of genetic protection and religious beliefs. These factors need to be considered when developing and implementing environmental health interventions.

Finally, pursuing our goal to co-produce an inclusive strategy for effective air pollution control in communities near petrochemical industries, our focus group participants suggested measures

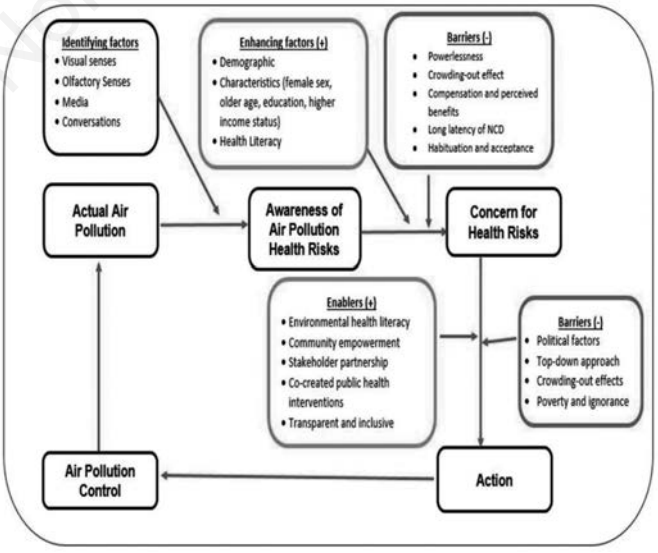

Figure 3. Determinants of air pollution health risk perception.

that they perceived might be effective. This segment of our work is lacking in most other qualitative studies on air pollution,[18] and may provide the crucial ingredient required for meaningful progress in the control of air pollution in a similar context. Although none of the participants desired the relocation of the refinery due to its perceived benefits to the community, they reiterated the need for the government to enforce regulations concerning gas flaring and compel industries to seek alternative means of gas disposal. Following the information they received during the focus group, participants unanimously urged health professionals and the research community to partner with other stakeholders in providing environmental health education to the community and its leaders, as they perceived that improved health literacy would empower the community to join the advocacy for change.

Limitations

The study was based on reports from some members of a small community and may not be applicable in other scenarios. Only three people participated in the first focus group, although 10 people had been invited, so at best it can be regarded as a mini-focus group. This initial low turnout may have been due to the controversial nature of the topic and issues of confidentiality and trust; however, subsequent sessions were well attended. Despite these limitations, our findings are credible and transferable to populations in a similar context.

Conclusions

We report that people living near a petrochemical industry in a developing country perceive their ambient air quality as unhealthy and associated with negative impacts. However, concerns about the health risks are shaped by the participants' demographic and socioeconomic attributes and other existing environmental problems. Current efforts to mitigate the effects of air pollution are perceived as inadequate or nonexistent, and the barriers to effective control are mainly poor environmental health literacy and political factors. More inclusive and collaborative approaches are needed to improve environmental and public health.

The research community and health professionals should disseminate reliable information about environmental and disease relationships to empower the public and possibly influence government policies toward achieving a healthy planet. Qualitative and public engagement research should be encouraged in health research and synergized with quantitative research to inform robust and effective interventions.

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Online supplementary material:
Supplementary File 1. Topic guide.
Supplementary File 2. The themes, sub-themes, and selected quotes.