

# Perception of air quality in a metropolis in Northeastern Brazil as a basis for risk communication

## Percepção da qualidade do ar numa metrópole do Nordeste do Brasil como suporte para comunicação em riscos

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**Abstract:** Air pollution has been investigated using various methods, particularly in developing countries, which still lack robust air quality monitoring systems. In these regions, perception surveys have been employed as an initial approach. This study aimed to analyze the perception of air pollution among the population of a Brazilian metropolis to support risk communication. The study assessed local perceptions, identifying possible correlations between socioeconomic profile and the beliefs of the respondents. A quantitative study was conducted based on a sample survey of 437 people in the city of Recife. The interviews were conducted in person, and the data were stored on the ArcGIS Survey123 platform, later being used for statistical analysis. Perception data were also compared with air quality monitoring data from nine low-cost stations. The majority of the population (57%) had never heard of or received information on the topic. This finding is correlated with educational attainment ( $p = 0.041$ ). Individuals who reported cardiovascular or respiratory health problems did not demonstrate greater knowledge on the subject. The main sources of pollution mentioned were transportation and dust; however, lower-income individuals cited the burning of biomass and waste as the primary sources. Perceptions of air pollution in the city vary according to income, education level, occupation, and the degree of information on the topic. In general, residents' beliefs align with the monitoring data observed during the period. This study purposed to provide information for decision-makers who do not yet have access to perception assessments and/or air pollution monitoring, thereby contributing to the development of risk communication policies and prevention alerts.

**Keywords:** urban environment; society; information; air pollution.

**Resumo:** A poluição atmosférica tem sido investigada por meio de diferentes métodos, especialmente em países em desenvolvimento, onde ainda não há sistemas robustos de monitoramento da qualidade do ar. Nessas regiões, pesquisas de percepção têm sido utilizadas como uma abordagem inicial. O objetivo deste estudo foi analisar a percepção da população de uma metrópole brasileira sobre a poluição atmosférica como suporte para comunicação de riscos. Buscou-se realizar um diagnóstico da percepção local, detectando possíveis correlações entre o perfil socioeconômico e as crenças dos entrevistados. Realizou-se uma pesquisa quantitativa baseada em um inquérito amostral com 437 pessoas na cidade do Recife. As entrevistas foram conduzidas de forma presencial, e os dados foram armazenados na plataforma Survey123 do ArcGIS, sendo posteriormente utilizados para análises estatísticas. Também foram comparados os dados de percepção com os dados de monitoramento da qualidade do ar de nove estações de baixo custo. A maioria da população (57%) nunca ouviu falar ou recebeu informações sobre o tema. Ademais, esse dado está correlacionado com o grau de escolaridade ( $p = 0,041$ ). Indivíduos que relataram problemas de saúde cardiovascular ou respiratória não demonstraram maior conhecimento sobre o assunto. As principais fontes de poluição mencionadas foram o

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tráfego de veículos e a poeira; porém, pessoas de menor renda citam a queima de biomassa e de resíduos como as fontes majoritárias. A percepção sobre a poluição atmosférica na cidade varia de acordo com renda, escolaridade, ocupação e grau de informação sobre o tema. De forma geral, as crenças dos habitantes estão de acordo com os dados do monitoramento observado no período. Este estudo buscou fornecer informações para os tomadores de decisão que ainda não dispõem de diagnósticos de percepção e/ou de monitoramento da poluição do ar, contribuindo assim para o desenvolvimento de políticas de comunicação de riscos e alertas de prevenção.

*Palavras-chaves:* ambiente urbano; sociedade; informação; poluição do ar.

## 1. Introduction

Air pollution is one of the fastest-growing topics in debates about the current environmental crisis (Manisalidis et al., 2020). It is a complex issue, as it spans various fields of knowledge (Garnett, 2017). Furthermore, because it is not visible or directly perceived, it often goes unnoticed by governments and society at large (Landrigan, 2017; Sharma, 2023). However, the adverse effects of pollutants dispersed in the atmosphere are known to have significant impacts on environmental quality and public health (Kinney, 2018; Moreira et al., 2024).

Globally, in developed countries, air pollution is monitored in a more structured manner, due to the technologies available and to strict environmental standards ((Krzyzanowski et al., 2014; Sicardi et al., 2021). However, in developing countries, such monitoring remains largely insufficient and, in some cases, is even nonexistent (Vormittag et al., 2021; World Health Organization [WHO], 2022), which contributes to the invisibility of the problem and to the limited capacity to communicate risks and alerts to the population (Cromar & Lazrak, 2023).

While governments and institutions have not established air quality monitoring networks in most developing countries, one way to bring visibility to the issue is to understand the public's perception (Bickerstaff, 2004; Cori et al., 2020; Song & Kwan, 2023). This would allow assessing whether communities experience and perceive air pollution and its impacts on daily life. Air pollution is perceived through sensory stimuli and interpreted by the brain, constituting highly subjective information that varies from person to person, influenced by various direct and indirect factors (Giri & Nagendra, 2024).

Although perception studies do not indicate objective air quality variables, they can provide insights into how different social actors view (or do not view) the problem and what associations can be established between this problem and the social, environmental, and cultural conditions of the places they live in (Bickerstaff, 2004; Day, 2007). The perception of air pollution has been extensively investigated in different contexts, and studies at various geographic scales (local, regional, and national) demonstrate an interaction between subjective perceptions of air quality and objective measurements of air pollutants.

Surveys on perceptions of air quality conducted in various countries indicate that communities often perceive air quality levels to be consistent with data from actual measurements of air pollutants (Pantavou et al., 2017; Peng et al., 2019). However, the opposite is also evident (Song & Kwan, 2023; Giri & Nagendra, 2024). In Brazil, there are few exploratory studies on the topic (Guimarães et al., 2019; Boso et al., 2024), and in the Northeast region, there is no research in this regard. Thus, it is essential to understand what the population thinks about the topic, including for planning actions, programs, and risk communication mechanisms aimed at different audiences, something advocated in the National Air Quality Policy (*Lei nº 14.850*, 2024)

This study thus aims to analyze the perception of the population of a Brazilian metropolis regarding air pollution as a basis for risk communication. We conducted an assessment of local perceptions and possible correlations with the socioeconomic profile and beliefs of the respondents. Additionally, we compared the perception data with air pollution monitoring data throughout 2024. The results may provide insights for local governments, contributing to the development of risk communication policies and prevention alerts, as well as to broadening the academic debate on the topic.

## 2. Theoretical Framework

Research on perceptions of air quality is essential to support risk communication and engage the public in preventive and mitigating actions. Studies indicate that a lack of knowledge about air pollution hinders informed decisions to reduce exposure (Meena et al., 2023). Individuals who monitor air quality tend to take protective measures, such as avoiding polluted areas or modifying outdoor routines (Veloz et al., 2020; Lynch & Mirabelli, 2021). However, understanding of the topic – such as interpreting data revealing the Air Quality Index (AQI) – is low, which limits the effectiveness of this information (Meena et al., 2023).

Risk perception is associated not only with actual environmental conditions but also with emotional, social, and economic factors (Bickerstaff, 2004; Wang et al., 2016; Cori et al., 2020). A lack of knowledge about actual sources of pollution is common, even among individuals with high levels of education (Maione et al., 2021). In the distribution of pollution, inequality is also reflected in individual perception, with low-income neighborhoods and those inhabited by racial minorities frequently associated with poorer air quality (King, 2015; Chakraborty et al., 2017; Chiarini et al., 2020).

Exposure to media coverage and content is also a factor that can amplify perceptions of air quality (Guimarães et al., 2019). Studies suggest that more urbanized communities, with greater access to media outlets, have a

higher perception of the effects of pollution, while in rural areas this perception is lower, regardless of actual pollution levels (Zeng & Yang, 2023).

Thus, the discrepancy between public perception and objective air quality monitoring data poses a challenge for policymakers, who must adapt their communication to make the information accessible and effective (Boso et al., 2024). Some studies confirm a significant correlation between actual and perceived pollution (Peng et al., 2019; Guimarães et al., 2019). However, there are also findings pointing to the opposite direction (Giri & Nagendra, 2024).

For example, in urban environments, there is a tendency to underestimate air pollution in residential areas compared to commercial zones (Song & Kwan, 2023). Likewise, the so-called “domestic halo effect” leads residents to perceive their neighborhoods as less polluted than their cities, even when data indicate high local pollution (Hofflinger et al., 2019).

There is no homogeneity in studies on environmental risk perception (Di Giulio et al., 2015), much less when it comes to risks associated with air pollution. Thus, the role of risk communication becomes even more relevant, as it seeks to convey information transparently and effectively, reaching a larger number of people (Covello & Sandman, 2001). In a globalized world, where traditional media compete for space with social media, evidence-based scientific communication should be the primary guideline in the process of communicating risks related to the impacts of air pollution (Ramírez et al., 2019).

Although risk communication alone does not solve the problem, it has the potential to mitigate it, reducing potential social and economic losses (Bradley et al., 2016; WHO, 2023). Furthermore, the communication process must involve the affected population, whether directly or indirectly. The participation of local stakeholders tends to yield better results in the areas of prevention and mitigation (Pfleger et al., 2023).

### **3. Method**

#### **3.1. Characterization of the Area**

This study was conducted in the city of Recife, located in the Northeast region of Brazil. The city is characterized by its coastal location, bordering the Atlantic Ocean, and serves as the core of a metropolitan area with a population of approximately 1.5 million inhabitants, making it the sixth-largest capital city in the country. From the perspective of urban land use, Recife exhibits significant population and building density, the result of an intense urbanization process that began in the 1970s. As a consequence of this process, various environmental problems – such as the presence of housing in high-risk areas, heavy traffic, and significant social inequality (Souza et al.,

2022) – add an extra layer of complexity to the city’s ability to implement environmental and intersectoral public policies.

From a geographical perspective, the urban site is characterized by its location on a fluvial-marine plain, surrounded by slopes and hills occupied by housing and small patches of vegetation. The local climate is hot and humid, with average temperatures ranging between 25°C and 27°C, and an annual rainfall of approximately 2,000 millimeters, with the rainy season concentrated between April and July (Agência Pernambucana de Águas e Clima de Pernambuco [APAC], 2024).

The choice of Recife as the subject of study is based on the city’s high vulnerability to the effects of global climate change (World Bank, 2011). Furthermore, the city has one of the worst urban mobility indices among the Brazilian state capitals (Moovit, 2024), a factor that significantly contributes to air pollution. Added to this is the absence, to date, of an air pollutant monitoring system in the city, which highlights the urgency of producing local information on this topic.

### 3.2. Data Collection and Analysis

This is a quantitative study conducted, between February and December 2024, with a questionnaire responded by 437 individuals over the age of 18 in various neighborhoods of the city. The questionnaire consisted of nineteen questions (see supplementary material), grouped into three sections:

1. Socioeconomic profile (gender, income, occupation, education level, health status);
2. Perception of pollution (air quality in the neighborhood, at home, sources of pollution);
3. Beliefs about the impacts of pollution (relationship with vegetation, relationship with social inequality, information on the topic).

The variables analyzed are listed in Table 1.

The sample was a convenience sample, but it is representative of the city’s population size. The sample size was calculated based on the municipality’s total population, with a 95% confidence level and a 5% margin of error, resulting in a minimum of 385 respondents. The questionnaires were administered using the *Survey123* tool, integrated with the ArcGIS *software* platform. This tool was chosen for the convenience of conducting interviews via smartphones. Additionally, the data were stored directly in the project database, which eliminated the need for data entry and/or export and reduced the risk of data loss.

The questionnaire was developed by the research team and pre-tested in a neighborhood of the city. Twenty questionnaires were administered during this initial stage on a single day. After analyzing the responses and discussing them with those responsible for the questionnaire design, minor

**Table 1** Variables used in the sample survey on perceptions of air pollution in Recife, Brazil.

Label	Variable	Responses
Gender	Gender	Dichotomous – male; female
Age	Age	Continuous – years of age
Educational	Education	Categorical – scale 1 – illiterate; 2 – Elementary School; 3 – High School; 4 – Higher Education; 5 – Postgraduate
Income	Income	Discrete – Number of minimum wages (1,2,3,4)
Marital status	Marital status	Marital Status 1 – single; 2 – married; 3 – divorced; 4 – widowed
Occupation	Occupation	Categorical: 1 – unemployed, 2 – self-employed, 3 – civil servant, 4 – private sector, 5 – retired, 6 – homemaker, 7 – student, 8 – other
Bolsa Família	Does the respondent have anyone in the household who receives Bolsa Família?	Dichotomous – yes and no
cardiacproblem	Does the respondent have any cardiovascular problems?	Dichotomous – yes and no
respiratoryproblem	Respondent has a respiratory problem	Dichotomous – yes and no
polu_afeta	Does air pollution affect health?	Categorical: yes, no, don't know
info_polu	Have you heard or been told about air pollution in the city?	Dichotomous – yes and no
neighborhood_air	Air quality in the neighborhood	Categorical: 1 – Very poor; 2 – Poor; 3 – Fair; 4 – Good; 5 – Excellent
air_home	Air quality at home	Rating: 1 – very poor; 2 – poor; 3 – fair; 4 – good; 5 – excellent
polui_res	Can household activities pollute the air in your home?	Categorical: yes, no, don't know
cooking	Can cooking pollute the air in your home?	Categorical: yes, no, don't know
pollution_source	Main source of air pollution where you live?	Subjective: Traffic, industry, bakeries, burning brush, burning trash, dust, other, don't know.
veget_ar	Does vegetation improve air quality? Yes, no, and don't know	Categorical: yes, no, don't know
neighborhoods_air	Is air quality better or worse in the city's poorer areas compared to the wealthier ones?	Categorical: Better, Worse, Don't know

adjustments were made to the final version of the instrument used to guide the fieldwork.

The selection of locations for conducting the interviews was based primarily on the proximity of the population to the areas of influence of the air quality monitoring stations installed as part of the project. Thus, the interviews were conducted in community centers (COMPAZ) and their surroundings, including urban parks, public squares, and public facilities, such as hospitals and schools, as well as the vicinity of the Federal University. This strategy allowed different social segments to participate, and covered residents of 67 of the city's 94 neighborhoods.

At the beginning of the interviews, the researchers presented the study and the Informed Consent Form (ICF) to the interviewees. After the par-

ticipants agreed, the interview began, with an average duration of eight minutes. Several fieldwork sessions were conducted to collect data in different areas of the city and at various times, for ensuring a diverse sample of respondents, both in terms of spatial and temporal specificities. The study was approved by the Research Ethics Committee through the Plataforma Brasil platform, under registration number 7,055,101.

The collected data were exported to an Excel spreadsheet and subjected to descriptive statistical analyses, as well as correlation and association tests between variables, using the chi-square and Cramer's V tests, given that most variables are categorical. The analyses were conducted using Excel, JuliusIA, and Stata 14 *software*.

For the statistical analysis, a significance level of 5% ( $p < 0.05$ ) was adopted, considered indicative of a statistically significant association between the variables. Cramer's V test was used to assess the strength of the association between categorical variables, interpreted based on the following criteria: values close to 0 indicate a weak association, between 0.1 and 0.3 indicate a moderate association, and above 0.3 indicate a strong association.

In addition, we used air quality monitoring data from nine stations located in different neighborhoods of the city (Mendes et al., 2024). The stations are low-cost IQAir sensors that monitor particulate matter ( $PM_{1\mu g/m^3}$ ;  $2.5\mu g/m^3$ , and  $10\mu g/m^3$ ), temperature, humidity, and pressure. For this study, we used only the daily average data for  $PM_{2.5\mu g/m^3}$ , as it is the most important variable from the perspective of risks associated with human health (WHO, 2021). Monitoring was conducted throughout 2024, and the results were compiled and presented using Excel *software*.

## 4. Results

Based on the data analyzed, the profile of respondents shows a female majority (55.8%), with an average age of 44, mostly single (49.8%), and having completed high school (38.9%). Most work in the private sector (22.2%), earn up to one minimum wage (45.9%), and do not receive Bolsa Família benefits (81%). Additionally, 30.4% report having some respiratory health issue, and 34.7% report cardiovascular health issues (Table 2).

When asked about the main factors causing air pollution in the city, respondents most frequently cited: transportation (73.5%); dust (49.2%); trash burning (38.6%); brush burning (21.2%); bakeries (16.9%); industries (15.9%); and, finally, 2.1% of the participants stated they did not know how to respond. For this question, respondents could choose up to two main sources of pollution.

Regarding occupation, the sample was well stratified, consisting of 22.2% private-sector workers; 16.5% self-employed individuals; 16.5% public

servants; 14.4% retirees and pensioners; 13.5% homemakers; 10.5% students; and 6.4% unemployed individuals.

Perceptions of air quality varied by occupation. The most frequent ratings assigned to air quality across all occupational groups were “fair” and “good”. Most respondents (71.5%) believed that air quality is worse in the city’s poorer neighborhoods compared to higher-income neighborhoods. In contrast, 15.5% believed the opposite, while 13% did not know how to answer.

Regarding knowledge about the topic of air pollution, the majority of respondents (56.75%) stated they had never heard of or received information about the problem, whether through official agencies or the media. In contrast, 43.25% stated they had already had some exposure to the topic.

Two questions that received high percentages of positive responses were: whether air pollution affects health (90.8%) and whether vegetation contributes to air quality (97%). In these responses, no significant variations were observed in relation to the socioeconomic profile and/or occupation of the respondents (Table 3).

Respondents’ perceptions of outdoor air quality, when compared to

**Table 2** Profile of respondents in the study on perceptions of air pollution in Recife, Brazil.

<b>Variable</b>	<b>%</b>	<b>Variable</b>	<b>%</b>
<b>Gender</b>		<b>Bolsa Família</b>	
Female	55.84	Yes	18.99
Male	44.16	No	81.01
<b>Marital Status</b>		<b>Occupation</b>	
Single	49.89	Self-employed	16.5
Married	39.59	Unemployed	6.4
Divorced	5.49	Homemaker	13.5
Widowed	5.03	Private-sector employee	22.2
<b>Education</b>		Student	10.5
Illiterate	2.52	Civil Servant	16.5
Elementary School	18.54	Pensioner/Retiree	14.4
High School	38.9	<b>Main source of pollution</b>	
Higher education	29.52	Transportation	73.5
Postgraduate	10.53	Dust	49.2
<b>Respiratory Problems</b>		Burning trash	38.6
Yes	30.43	Brush burning	21.2
No	69.57	Bakeries	16.9
<b>Cardiovascular problems</b>		Manufacturing	15.9
Yes	34.78	I don’t know	2.1
No	65.22		

**Table 3** Perception of air pollution in Recife (Brazil) and associated factors.

Variable	%	Variable	%
<b>Does Pollution Affect Health?</b>		<b>How do you assess the air quality in your home?</b>	
Yes	90.85	Very poor	5.26
No	9.15	Bad	7.09
<b>Have you been informed about pollution?</b>		Fair	30.66
Yes	43.25	Good	50.11
No	56.75	Great	6.86
<b>How would you rate the air quality in your neighborhood?</b>		<b>Do you contribute to pollution in your home?</b>	
Very poor	11.44	Yes	23.95
Bad	13.96	No	67.05
Fair	42.33	<b>Do you think cooking pollutes the air?</b>	
Good	28.83	Yes	42.11
Great	3.43	No	57.89
<b>Do you think the air is better or worse in the city's poorer neighborhoods?</b>		<b>Does vegetation contribute to air quality?</b>	
Worse	71.4	Yes	97.03
I don't know	15.56	No	2.97
Better	13.04		

indoor air quality, show significant variations. Most consider indoor air quality to be good (50.1%) or fair (30.6%), while only 7% and 5.2% rate it as poor or very poor, respectively. In turn, when the question refers to air quality in the neighborhood – that is, the air outside the residence – the responses were: fair (42.3%), good (28.8%), poor (13%), very poor (11.4%), and excellent (2.5%).

Regarding perceptions of individual practices that contribute to pollutant emissions inside the home, 67% of the respondents stated they did not engage in such activities, while 33% answered affirmatively. However, when asked whether cooking could contribute to worsening air quality, 58% answered negatively and 42% affirmed that it could.

When mentions of pollution sources were analyzed separately, a significant negative correlation was observed between income and the sources “brush burning” ( $r = -0.17539$ ;  $p = 0.000365$ ) and “garbage burning” ( $r = -0.18422$ ;  $p = 0.0001793$ ), suggesting that these practices are more associated with lower-income respondents. The “dust” source showed a weak positive correlation ( $r = 0.08774$ ), though not statistically significant ( $p = 0.0763$ ) (Table 4). The analysis shows that respondents with lower income (171 mentions) perceive trash and brush burning more frequently than those with higher income (38 mentions), suggesting a stronger association between these pollution sources and lower-income groups. In contrast, re-

**Table 4** Correlation between the main perceived sources of air pollution and income up to one minimum wage.

Variable	Correlation	P-value
Trash burning	•0.175392	0.0003653
Bush burning	•0.184223	0.0001793
Dust	0.008774	0.0763126

spondents with higher incomes cited traffic as the main source of air pollutant emissions.

The results of the statistical analyses demonstrated a strong correlation between the variables “neighborhood air quality” and “home air quality” (chi-square: 249.6376; p-value: 0.0; Cramer’s V: 0.3779), suggesting that the perception of neighborhood air quality is moderately associated with the perception of home air quality. However, between the variables “neighborhood air quality” and “actions that pollute the home”, there is a weak but significant association (chi-square: 14.1614; p-value: 0.0068; Cramer’s V: 0.18). Regarding the relationship between the variables “neighborhood air quality” and “cooking generates pollution”, the association is weak and not significant (chi-square: 8.127; p-value: 0.087; Cramer’s V: 0.1364) (Table 5).

A stronger correlation was observed between “actions that pollute the home” and “cooking generates pollution” (chi-square: 32.999; p-value: 0.000; Cramer’s V: 0.2748), indicating a moderate association between the perception of engaging in activities that may pollute the home indoor environment and cooking practices. A weak but significant association was also identified between “indoor air quality” and “actions that pollute the home” (chi-square: 13.6077; p-value: 0.0087; Cramer’s V: 0.1765). However, between “indoor air quality” and “cooking causes pollution”, the association was very weak and not significant (chi-square: 5.5607; p-value: 0.2344; Cramer’s V: 0.1128). Finally, a moderate and significant association was identified between “actions that pollute the home” and “cooking generates pollution” (chi-square: 32.999; p-value: 0.000; Cramer’s V: 0.2748).

The results also showed that there is no significant association between

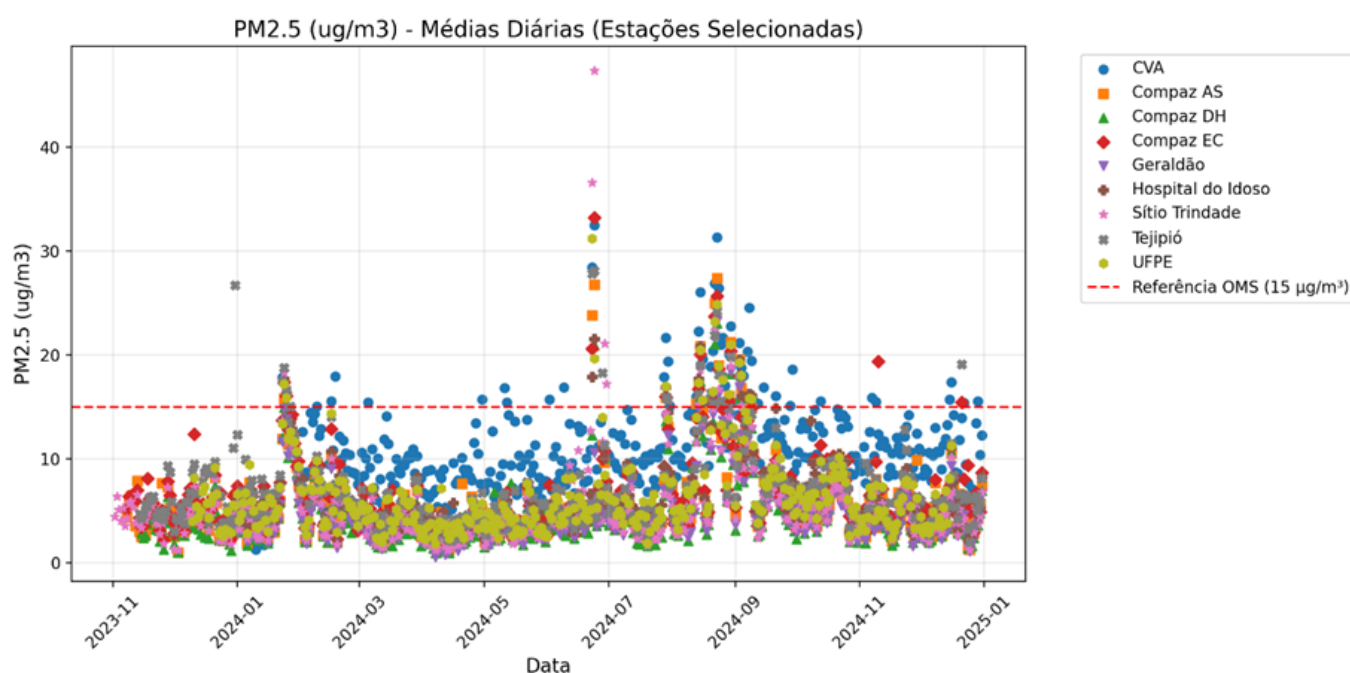
**Table 5** Analysis of the relationships between variables related to respondents’ perceptions of air pollution sources and consequences.

Variables	Chi-square	p-value	Cramer’s V
neighborhood_air vs pollution_consequences	14.1614	0.0068	0.1800
neighborhood_air vs cooking	8.1270	0.0870	0.1364
residential_air vs residential_pollution	13.6077	0.0087	0.1765
indoor_air vs cooking	5.5607	0.2344	0.1128
residential_pollution vs cooking	32.9990	0.0000	0.2748
neighborhood_air vs home_air	249.6376	0.0000	0.3779
info_pollution vs air_residence	5.162	0.2710	0.1090
info_polu vs polui_res	12,514	0.0000	0.1690
info_pollute vs cooking	4,562	0.0330	0.1020

having been informed about air pollution and the perception of air quality in the home (p-value = 0.271; Cramer's V = 0.109). However, there is a significant association between having been informed about pollution and engaging in activities that pollute the home (p-value < 0.001) and a weak to moderate association between the two variables (Cramer's V = 0.169), indicating that people who reported having received information about pollution tend to perceive that they engage in daily activities that may pollute the air in their homes (74.2% vs. 57.7%). For the variables "having already received information about pollution" and "cooking generates pollution", the results indicate a statistically significant, albeit weak, association (p-value = 0.033; Cramer's V = 0.102).

Regarding monitoring data throughout 2024, average PM 2.5 concentrations (in  $\mu\text{g}/\text{m}^3$ ) generally remained within the limits established by the World Health Organization (WHO, 2021). These standards were recently incorporated into the Brazilian legislation through Law No. 14,850/2024, which established the National Air Quality Policy (*Lei nº 14.850, 2024*). However, throughout the time series, significant periods were observed in which exposure to PM 2.5  $\mu\text{g}/\text{m}^3$  reached values exceeding the WHO-recommended limit of 15  $\mu\text{g}/\text{m}^3$  over 24 hours. Such changes in trend are related to local events, such as the June festivities, characterized by the burning of bonfires in urban areas, but also to global-scale events associated with atmospheric dynamics, such as the transport of aerosols originating from the African continent, which caused a change in the recorded values between July and September. Overall, when summing the recorded values from the nine stations over the course of a year, it was observed that on 52 days, the WHO reference limit for PM 2.5  $\mu\text{g}/\text{m}^3$  was exceeded in at least one of the stations (Figure 1).

Figure 1 Distribution of PM 2.5 values in the city of Recife, PE.



## 5. Discussion

The adverse effects of air pollution are recognized as significant risk factors for human health, particularly in the exacerbation of cardiovascular and respiratory diseases (Landrigan, 2017). This study allowed observing that 31% of respondents had respiratory problems, a percentage close to the national average of 30% (Associação Brasileira de Alergia e Imunologia [ASBAI], 2024). In turn, the prevalence of cardiovascular problems in the sample (34%) was significantly higher than that reported for Brazil (7%) (Oliveira et al., 2023), although the Ministry of Health reports that 28% of the Brazilian population has hypertension (Ministério da Saúde, 2024). Nevertheless, no significant correlation was found between the respondents' health status and their knowledge of the effects of air pollution. This result differs from studies indicating that people with respiratory diseases, such as asthma, pay greater attention to air quality data and alerts as they seek to protect themselves from health impacts (Pantavou et al., 2017; Veloz et al., 2020). These findings reinforce the need for more effective government risk communication strategies, whether through broad campaigns or those targeted at vulnerable populations (Boso et al., 2024).

Complementarily, most respondents acknowledge that air pollution affects health, but less than half stated they had ever received information or heard about the topic. These data indicate limitations in the dissemination of information and the existence of air quality warning systems in the studied context, corroborating research pointing to a low level of public knowledge on the subject (Meena et al., 2023). Effective data dissemination can bridge this gap between the public, policymakers, and scientists, increasing social participation and acceptance of mitigation measures (Boso et al., 2024; Giri & Nagendra, 2024).

There is also a tendency for communities to associate air pollution with distant problems, evidenced by the perception of polluted air on larger geographic scales (Guimarães et al., 2019; Hofflinger et al., 2019). In this study, respondents assessed air quality more negatively at the neighborhood level than at the level of their own residence. This behavior can be explained by affective psychological factors linked to the home environment (Bickerstaff, 2004), in contrast to collective areas, such as neighborhoods. Furthermore, participants showed reluctance to admit that their domestic actions might contribute to air pollution, indicating that collective responsibilities are more readily acknowledged and shared than individual impacts (Placani, 2025).

When asked about actions performed at home that might influence air pollution, the majority responded negatively. However, when specifically asked about cooking, there was an increase in the percentage of those who acknowledged the contribution to indoor pollution, although still less than half of the respondents. This highlights a lack of awareness regarding the daily effects of domestic activities, such as cooking, smoking, or burning

incense, which raise indoor pollutant levels (Wang et al., 2016; Morawska et al., 2017).

Regarding local sources of pollution, traffic continues to be identified as the main factor, consistent with studies in various contexts (Wang et al., 2016; Maione et al., 2021). However, other factors, such as dust from unpaved streets, biomass burning, and solid waste were also frequently mentioned, reflecting the reality of the city studied (Pantavou et al., 2017). Respondents with lower income and education levels placed greater emphasis on biomass and waste burning as the main sources, surpassing traffic, which reveals a concrete perception of the environmental problems faced by vulnerable populations (King, 2015; Chakraborty et al., 2017).

Several studies indicate that lower-income populations are the most affected by air pollution (King, 2015; Rentschler & Leonova, 2023). In our study, most participants perceived higher levels of pollution in economically vulnerable neighborhoods compared to higher-income areas. In Recife, monitoring data from stations located in the western part of the city – generally inhabited by lower-income populations – recorded slightly higher concentrations of particulate matter than in the eastern, more central, and coastal areas (King, 2015; Chiarini et al., 2020). This difference is consistent with local perceptions, although it may be linked to specific conditions in the immediate surroundings of the stations and may not be generalizable to the entire city.

Practices such as the burning of biomass and waste, associated with poor urban infrastructure and the presence of airborne dust, may explain the negative perception of poorer areas, whereas in affluent regions, vehicle pollution is the primary perceived source (Maione et al., 2021). There is also a tendency to confuse different types of pollution (air, water, soil, visual) due to local structural conditions (Santos & Souza, 2015).

The monitoring data presented (Figure 1) highlight the challenge of continuously monitoring air quality and communicating risks when particulate matter levels exceed WHO recommendations (WHO, 2021). Such communication must be immediate or predictive, allowing the population to take protective measures. However, in Brazil, air quality alerts are generally limited to extreme events, such as wildfires in the Northern Region (Moura et al., 2024). In Recife, air quality is generally considered good, which does not justify the absence of alerts regarding episodes of deteriorating air quality and consequent health risks.

When comparing monitoring data and public perception, a general consistency is observed between the measurements and the population's subjective assessment (Peng et al., 2019; Guimarães et al., 2019). Approximately 57% of the respondents rate the air quality in their neighborhood as excellent or good, which aligns with the results from the monitoring stations.

Given these data, the importance of reliable information for environmental risk management through effective communication tools is high-

lighted (Hofflinger et al., 2019). Perception surveys are valuable for highlighting the heterogeneous knowledge of the population, influenced by social, economic, and cultural differences (Peng et al., 2019; Boso et al., 2024). Therefore, we reiterate the need for both formal and informal educational strategies (Wang et al., 2016) that enable greater ownership of risks by society and public authorities, fostering the development of collective protection tactics and mitigation of problems (Veloz et al., 2020; Lynch & Mirabelli, 2021).

Another barrier to be overcome is the normalization of pollution. In cities as Recife, various environmental problems are perceived as normal, even though they negatively impact well-being and health. It is thus essential to intensify risk communication to “denaturalize” air pollution through sensitive strategies for disseminating and interpreting data in the local context (Ramírez et al., 2019), highlighting the harm this issue causes to society (Bradley et al., 2016; WHO, 2023).

## 6. Conclusions

The results of this study demonstrated that perceptions of air quality are directly related to the population’s educational level, regardless of the presence of health problems. We observed that most residents had never heard of or been informed about this topic prior to the survey, which is concerning given the importance of air quality for people’s lives. Furthermore, we found that the main sources of pollution perceived by respondents were transportation and dust, while industries were mentioned less frequently. It should be noted, however, that this perception varied according to the respondents’ income and place of residence.

We also found that respondents are more cautious when making statements about air pollution inside their homes compared to the outdoor environment. Similarly, most are unaware that simple activities, such as cooking and smoking, can potentially pollute both the indoor and outdoor environments. This reflects the need to develop communication and ongoing education initiatives regarding the causes and effects of air pollution on health and on the environment.

There is a prevailing perception that less affluent areas of the city tend to be more polluted than more affluent areas. This perception is reinforced as residents of these areas identify sources of pollution, such as the burning of biomass and solid waste, as quite frequent, unlike residents of more developed neighborhoods, who do not perceive these pollution factors as present. This demonstrates the cross-cutting nature of the issue, which must be addressed in conjunction with solid waste management policies and environmental education to raise awareness of the negative impacts of these activities.

One of the main limitations of this study concerns the geographic

scope of the sample, which is restricted to a single city. Although it is the sixth-largest metropolis in the country, this limitation prevents the generalization of the results to other regions with distinct socioeconomic contexts. Furthermore, although the sample was random and well-stratified across different segments of the population, this approach does not completely eliminate the possibility of bias in the results.

Another point of concern relates to the income variable. In surveys of this nature, it is common for some respondents to be reluctant to report their actual income, whether out of fear regarding the use of the information or discomfort in addressing the topic, even when anonymity is guaranteed.

Despite these limitations, we believe the study offers a relevant contribution, especially as it is the first assessment of the topic in the analyzed region. The originality of the data and the diversity of the profiles included give the study significant exploratory value, serving as a foundation for broader future research. Furthermore, the study can serve as a basis for similar investigations in different urban contexts across Brazil.

We suggest that air quality monitoring be viewed as a priority in the context of the metropolis studied, given the population's perception of the issue. We also encourage new investigations that explore perceptions of air quality among different population segments (workers with higher exposure, those engaging in outdoor physical activities, children, the elderly, etc.). Furthermore, there is a need for comparative studies between public perception and physical monitoring data, which can help guide communication and education campaign strategies for specific vulnerable groups and for society as a whole.

To this end, we recommend the widespread use of low-cost sensors to complement measurements taken by reference stations. This strategy will enable the creation of a broader database capable of informing policies for monitoring and preventing environmental risks, as well as supporting decision-makers in communicating with the public. Additionally, we propose that the topic of air pollution be incorporated into the school environment, using real-world data as a teaching resource. This data can be explored in an interdisciplinary manner, promoting a broader and more contextualized understanding of the problem among students.

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