

How Do People Understand Urban Air Pollution? Exploring Citizens' Perception on Air Quality, Its Causes and Impacts in Colombian Cities

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Abstract

Similarly to other Latin American countries, urban air quality is a major concern in Colombia. The purpose of the present study was to explore citizens' perception on local air pollution, its causes and impacts. A questionnaire was individually applied to a sample of 994 participants. Relationships between demographic features and the perception on air quality were analyzed using a logistic regression, its odds ratio (OR), and a Chi-square test. Eighty percent of the respondents perceive their local air quality as either bad or fair, 65% recognize particulate matter as the main local air pollutant, and 90% recognize negative impacts on people's health as the main consequence of air pollution. In contrast to other studies where age and economic status are variables highly related with public perception on the level of atmospheric pollution, in this study only the size of the cities has a statistically significant relationship with the perception on local air quality regarding the level of pollution ($OR \geq 1$, confidence intervals > 1 and p -values < 0.05). While area sources such as mining and infrastructure construction are identified as the main sources of pollutant emissions in small towns (less than 50,000 inhabitants), in big cities, road traffic is identified as the main source contributor to atmospheric pollution. Opposite to data from official reports, and regardless of the size of the city, households are perceived as the place with greatest contribution to personal air pollution exposure. Results show that citizens are aware of the state of air quality and its health impact is a major concern. Such findings suggest people's opinions can be used as provisional indicators in cities without data, as well as to monitor the results of local air quality management. As a com-

plementary process, or at the same level of importance given to technical-based policy, citizen participation can contribute to a collective construction of urban air pollution control strategies.

Keywords

Public Perception, Citizen Participation, Air Quality, Air Pollution, Colombia

1. Introduction

In Colombia, as in other Latin American countries, urban air pollution is a major concern [1] [2] [3] [4]. According to the monitoring made by national environmental authorities, particulate matter (PM) levels are well above national standards [5] [6]. Moreover, there is strong local evidence showing an association between low air quality conditions with higher rates of respiratory diseases [7] [8] [9] [10]. In many Colombian urban areas, public health authorities indicate that respiratory illness is the leading cause of morbidity and mortality among children under five years of age and represent one of the top causes of mortality across the entire population [11] [12] [13]. This condition has aroused the interest of the academia and scientific community to support the identification and characterization of the air pollution problem in different Colombian cities [14]. Such studies have supported the technical formulation of public policy strategies aiming at improving air quality.

Despite these efforts, much is yet to be done towards an improved understanding of the air pollution problem at a local level. While most of the research in Colombia has been focusing on the physical and chemical characterization of the problem, relatively no attention has been given to the socio-cultural aspects that underlie it. For instance, cities have neglected how different actors perceive air pollution problems and what is their level of concern, both individually and collectively.

Different reasons support the incorporation of social factors, in addition to economic and technical analysis, in the design and implementation of air quality policies. A comprehensive air quality management process requires information that reveals implicit socio-cultural aspects and the incorporation of a social value dimension [15]-[20]. Several case studies in policy making, demonstrate how public perception is crucial for environmental policies success. Delving into the social aspects can encourage public participation in air pollution control programs, especially if public is involved since early stages in decision-making processes [21]. Public consultation can be also useful to empower people in requesting the compliance to air quality standards [16]. And results of perception studies have an additional value, as they could be useful to enrich the analysis of scientific data or technical information.

In Colombia, there are few researches linking socio-cultural variables to air pollution. Daniels *et al.* [22] studied the perception on the impact of air pollu-

tion on outdoors worker's health in the metropolitan area of Medellín. Other authors have analyzed the perception on environmental noise caused by vehicular traffic [23] [24] and the perception on air pollution problems coming from solid waste disposal [25]. The designing of Bogotá's Air Quality Management Plan included a participation process where several communities within the city were asked about their perception on air pollution, its causes and solutions [26]. Ariza *et al.* [27] also studied citizens' perception on the impact of air quality on health and quality of life in four localities in Bogotá. These previous works have had a limited geographical scope and there is no registry of a previous nationwide air quality perception study. Within this context, this research aims to explore citizens' perception on local air pollution, its causes and consequences in different municipalities in Colombia.

2. Methods

2.1. Participants and Sample

Participants were third-year students from Environmental Engineering and Sanitation Technology undergraduate programs on distance-learning-methodology. Students under this learning methodology do not attend classes in a central campus, but follow the academic curriculum from different locations. This allows to have a sample with participants living in diverse cities in Colombia.

The objective population was 1775 people, which corresponds to the total enrolled students in the mentioned academic programs during the time-period of study (October 2014 to November 2015). The statistically representative size of the sample was calculated to be of 667, considering an error of 3%, a confidence level of 95% ($\alpha = 0.05$) and a distribution of responses of 50%. However, the final sample was made up of 994 participants, geographically distributed as shown in **Figure 1**.

2.2. Questionnaire and Survey Method

The questionnaire designed for the study included 15 questions, grouped in three sections: demographic characteristics, recognition of local environmental issues and understanding of the local air pollution condition (see **Table 1**). Questions were closed-answer except for some requesting additional description. The questionnaire was applied individually using an online platform.

As suggested by other authors [28] [29] [30] [31] [32], we used an online application for the survey because: a) participants were familiar with this practice; b) the possibility to have people from different geographical regions; c) the budget available for this research; d) its flexibility in data gathering and transcription; and e) lower bias—not having an interviewer. The questionnaire was pre-tested with a group of students of the target population in order to ensure face validity and comprehension of the survey.

2.3. Statistical Analysis

Questionnaire responses tabulation and graphical summaries were completed

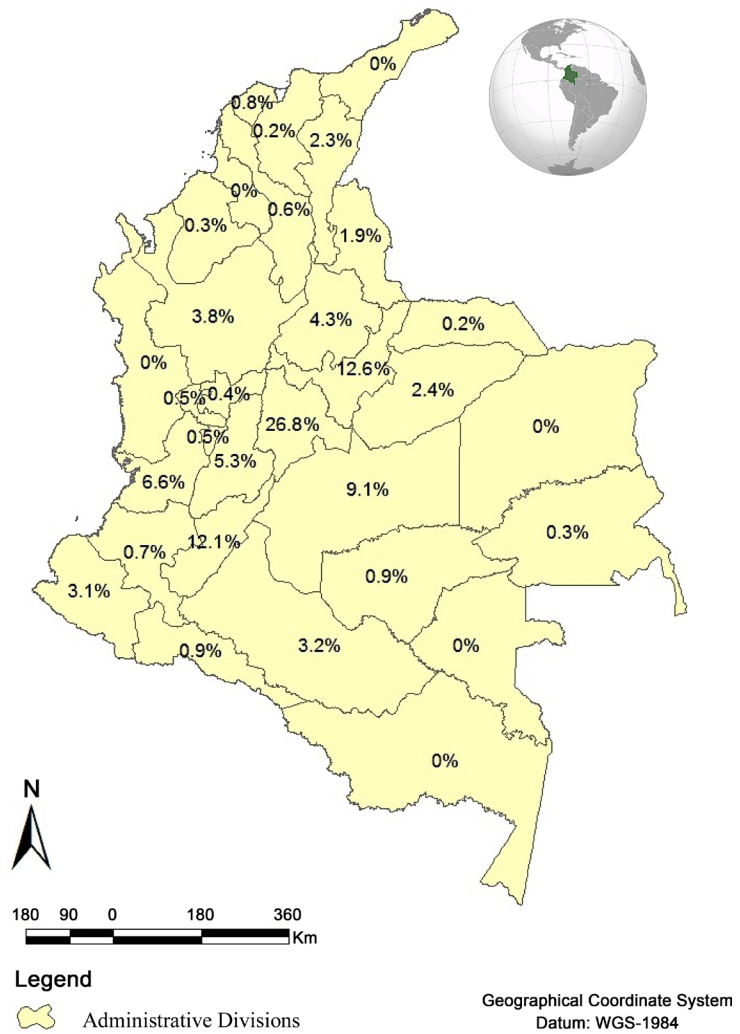


Figure 1. Map of Colombia with its administrative division (states) and the geographical distribution of the participants (% of the total sample).

Table 1. Questionnaire structure.

Section	Question Subject
<i>Demographic characteristics</i>	Name and surname
	Gender
	Age
	State
	City
<i>Local environmental issues</i>	Socioeconomic conditions
	Identification of environmental problems
	Ranking of environmental problems
<i>Local air pollution</i>	<i>Perception on</i>
	Air quality condition
	Emission sources
	Air pollutants
	Magnitude of the impacts
	Impacts description
	Health related impacts perceived
Characteristics of the affected population	

with Microsoft Excel 2016, while statistical analyses were carried out using SPSS v.22 and R v.3.3.1 packages. To examine relationship between demographic characteristics and the perception on air quality a logistic regression was used. The odds ratio (OR) analysis consider that values of OR different than 1, with confidence intervals that do not include that value, express significant levels of association. The Chi-square test was used to assess the level of dependency between the demographic traits having the largest influence on air quality perception (according to the previously estimated OR) and other variables that could be potentially predictors of the local air pollution problem understanding (e.g., pollution sources). A *p*-value less than 5% was the criterion used to consider the test result as statistically significant.

3. Results

3.1. Sample Characterization

Table 2 shows the demographic characterization of the sample. Most respondents are women between 18 and 40 years of age. More than 95% of the participants live in households classified in socio economic strata 1, 2 or 3, with strata 2 being the one with highest percentage (44.9%) (urban areas in Colombia and its dwellers are classified in six socio-economical strata, with stratum 1 being the lowest and stratum 6 the highest). As shown in **Figure 1**, we have a sample from different administrative regions in Colombia with the number of participants at each department representing a percentage of the total that varies from 0.2 to 26.8. Participants were categorized in five classes according to the size of their city or town (see **Table 2**).

3.2. Relevance of Air Pollution as a Local Environmental Concern

When asking participants about the three-main local environmental issues in their cities or towns of residence, water pollution was included in this list 77.8% of the times, air pollution (together with offensive odors and noise) 74%, inadequate solid waste management 65.3%, and deforestation 35.7%. Other environmental issues mentioned in a lesser extent were soil degradation (29.2%), loss of plant and animal species (11.5%), agrochemicals food contamination (7.8%) and illegal wildlife trade (2.5%). However, when deciding the leading environmental problem in the city, about 40% of the participants selected air pollution among the others (see **Figure 2**). This proportion was higher in large cities, with about 60% of the responses. In small towns, other environmental issues such as solid waste management, soil degradation, and water pollution are perceived as more relevant (see **Figure 3**).

3.3. Perception on Local Air Quality

Among the 994 responders, 80% perceive their city air quality as either bad or fair (see **Figure 4**). **Table 3** lists the crude odds ratios (OR), confidence intervals (CI) and *p*-values resulting from the multivariate regression analysis. For these specific analysis, age and socioeconomic strata variables were grouped in three

Table 2. Sample characteristics.

Feature	<i>f</i>	%
Gender		
Female	600	60.4
Male	394	39.6
Age		
<18	21	2.1
18 - 30	721	72.5
31 - 40	206	20.7
>40	46	4.6
Socioeconomic status*		
1	224	22.5
2	446	44.9
3	279	28.1
4	27	2.7
5	14	1.4
n/a	4	0.4
City size (population)		
<50,000	287	28.9
50,000 - 100,000	95	9.6
100,000 - 250,000	219	22.0
250,000 - 500,000	123	12.4
>500,000	270	27.2

*In Colombia, urban areas and its dwellers are classified in six socio-economical strata, with stratum 1 being the lowest and stratum 6 the highest.

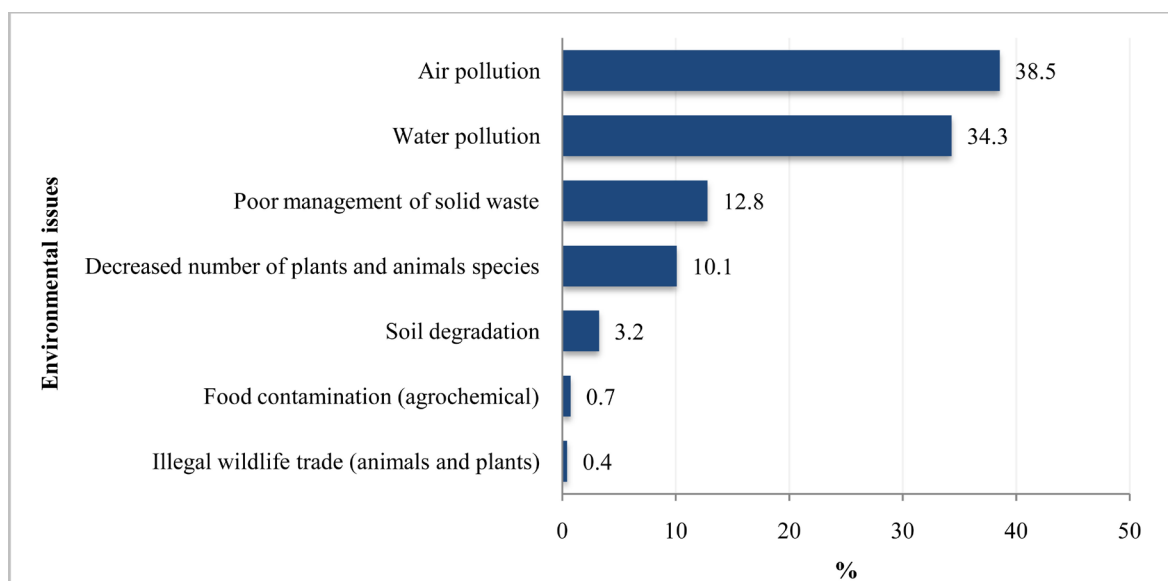


Figure 2. Leading local environmental problem in the city/town of residence (whole sample).

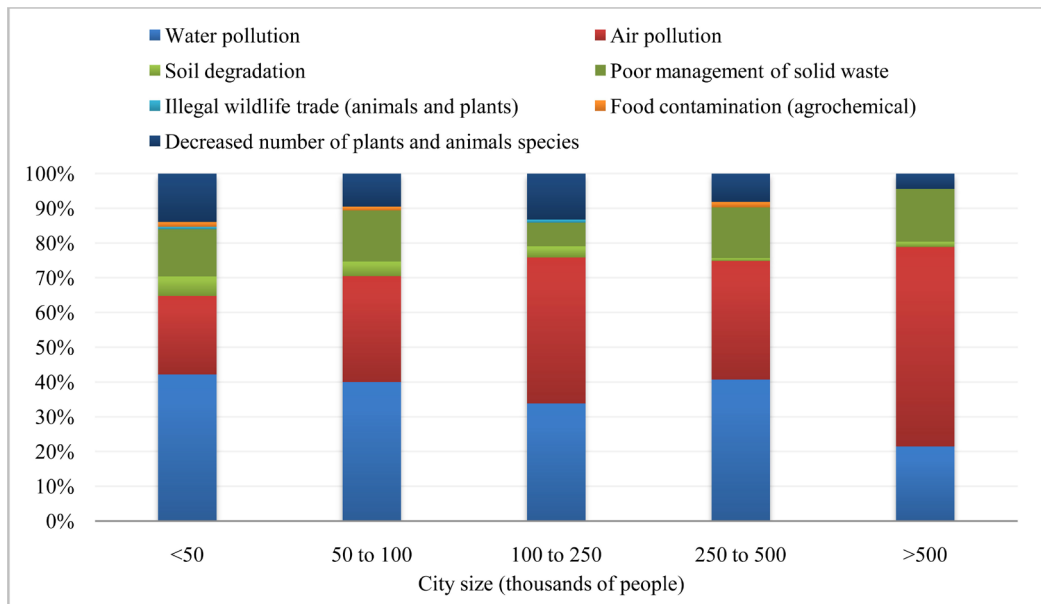


Figure 3. Leading local environmental problem in the city/town of residence classed by city size.

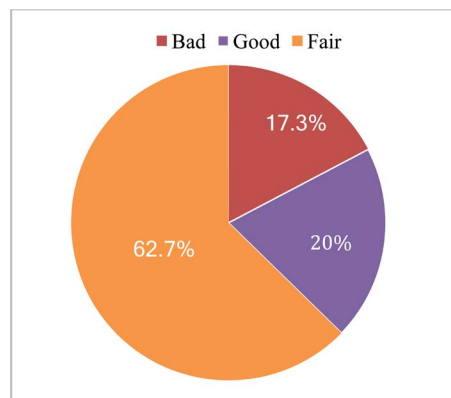


Figure 4. Perception on local air quality.

Table 3. Odds ratio for the demographic characteristics and perception on local air quality.

	Crude Odds Ratio (OR)		
	OR	95% CI	p-value
Gender			
Male to Female	0.896	(0.693, 1.158)	0.404
Age			
18 < Age ≤ 30 to Age < 18	0.797	(0.329, 1.939)	0.616
30 < Age ≤ 40 to Age < 18	0.656	(1.266, 1.646)	0.369
40 < Age to Age < 18	0.916	(0.318, 2.648)	0.872
Socioeconomic strata			
3 - 6 to 1 - 2	0.677	(0.367, 1.256)	0.214
City population (in thousands)			
50 < Size ≤ 100 to Size < 50	1.641	(1.032, 2.624)	0.037
100 < Size ≤ 250 to Size < 50	2.879	(1.982, 4.202)	<0.001
250 < Size ≤ 500 to Size < 50	2.308	(1.494, 3.585)	<0.001
500 < Size to Size < 50	7.553	(5.222, 11.001)	<0.001

and two categories respectively. Participants with more than 55 years of age were included in the >40 class and respondents from socioeconomic strata 3, 4, 5 and 6 were grouped to make this class equivalent in terms of size of the sample. With $OR \geq 1$, confidence intervals >1 and p -values < 0.05, we found an association between the size of the participant's city of residence and the perception of high local air pollution. This means a person living in a larger city is likely to have a negative perception on its air quality condition. Other variables such as gender, age and socioeconomic strata showed not statistical significance.

3.4. Perception on Air Pollution Sources and Impacts

Figures 5-9 show the participant's perception on other aspects that define the level of understanding of the air pollution problem at a local level. Those aspects included type of pollutant (gases or particles-PM), emission sources, health impacts and places associated with higher levels of air pollution exposure.

According to the Chi-square test level of significance, variables such as "type of contaminant" and "pollution sources" are dependent on the variable "size of the city" ($p = 0.02$ y $p < 0.001$, respectively). Figure 5 shows that for all city classes, participants consider particulate matter (PM) as the main local air pollutant. In the cities with greater population this opinion becomes stronger. When asking participants about the primary source of air pollution in their location, 37% of those living in smaller cities (less than 50,000 inhabitants) and considering PM as the main air pollutant, mentioned local area sources as the most important ones (mining, infrastructure construction and use of artisan furnaces in production processes located in the same area). On the other hand, 72% of those living in largest cities (more than 500,000 inhabitants) identified road traffic as the main source of PM (see Figure 6).

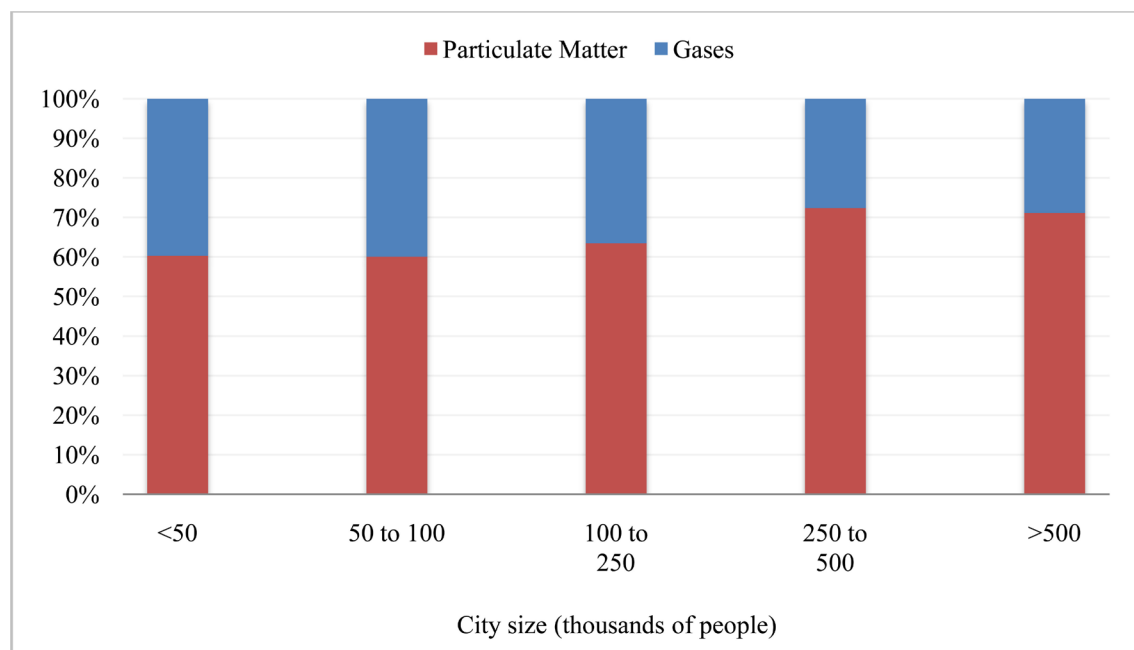


Figure 5. Perception on the main pollutant ($X^2 = 11.43$, $p = 0.02$).

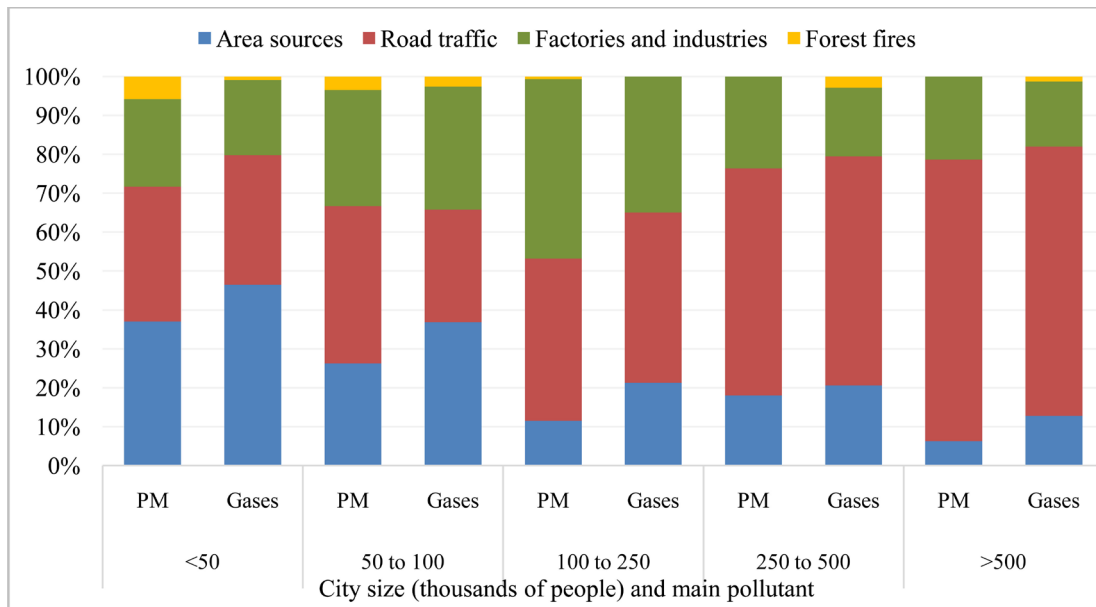


Figure 6. Perception on the main pollutant grouped by city size and primary source.

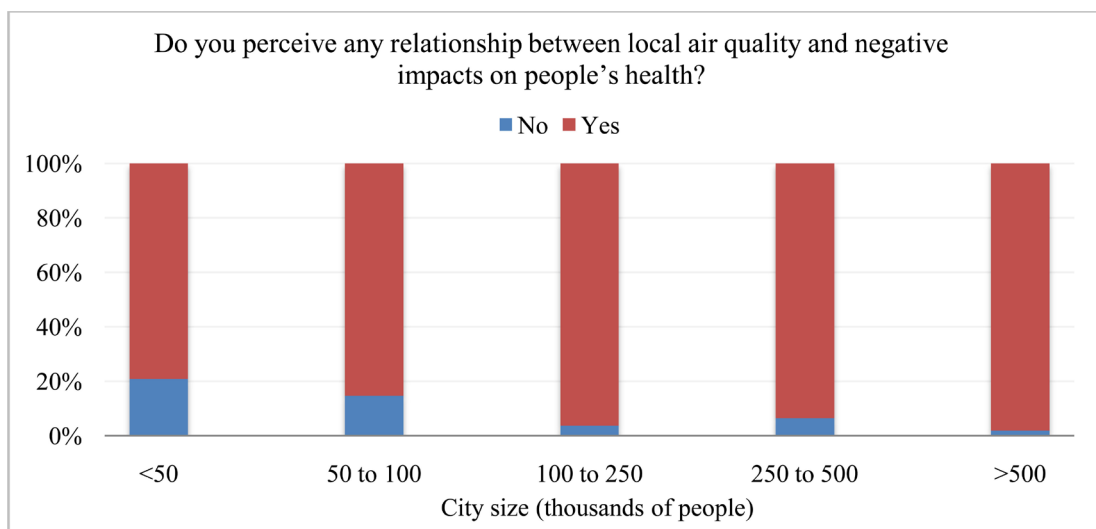


Figure 7. Perception on air pollution negative impact on people's health ($\chi^2 = 74.41, p < 0.001$).

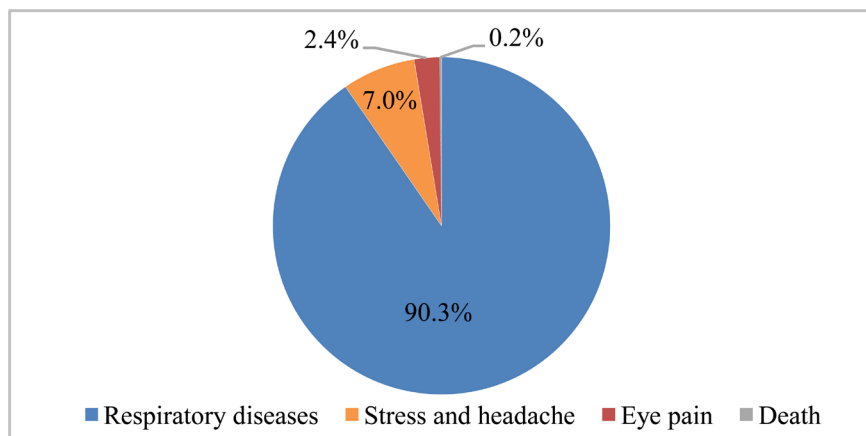


Figure 8. Perception on the primary air pollution impact on people's health.

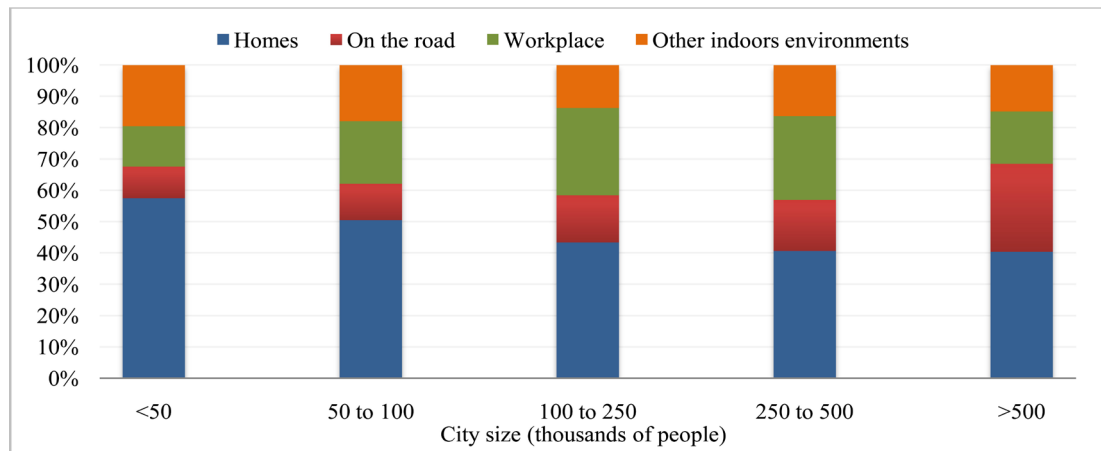


Figure 9. Perception on the place where public is more exposed to air pollution ($\chi^2 = 62.96$, $p < 0.001$).

More than 90% of the responders perceive air pollution as a negative factor affecting people's health (see **Figure 7**). Statistical evidence ($p < 0.001$) demonstrates that the largest the city, the higher the participants' perception on the link between air quality and negative health impacts. Between those who perceive such relationship, more than 90% identified respiratory diseases as the main effect on health. The remaining percentage is distributed among other impacts such as eye pain, stress, headache and premature deaths (see **Figure 8**).

Figure 9 shows the participants perception regarding the places where they think they are more exposed to air pollution (inside their town of residence), classed by the size of the city ($\chi^2 = 62.96$, $p < 0.001$). About 60% of those living in towns with less than 50,000 inhabitants associate their homes with high levels of air pollution exposure. Participants from bigger cities perceive roadsides as an important place to be exposed to bad air quality. When asking about the scale of the impacts of air pollution, 62% of those recognizing the link between bad air quality and negative health effects, mentioned that impacts are predominantly manifested at a local level (*i.e.*, in the city area), 20% at regional level (*i.e.*, beyond the municipality) and 18% at a microscale level (*i.e.*, neighborhood or village).

4. Discussion

These results contribute with evidence about citizens' perception on environmental issues in Latin American urban areas. As well as previous studies [33]-[38], our findings aim to improve the understanding of Colombia's urban air pollution condition and to highlight the potential of including citizen's perception as a way to support local action to address environmental problems. Taking advantage of the distance-learning-methodology of the undergraduate academic programs, we were able to have about 1000 respondents' sample, from different geographical regions in Colombia. As far as we are aware, this is the first study in the country and one of the few in Latin America with this number of participants, from different locations, examining opinions about air quality, its causes and impacts.

There is a widespread concern about air quality within the participants. What local environmental authorities have identified regarding air pollution as a major problem in Colombian cities, is also perceived by the community. Contrary to preceding research [39] [40], no associations were found between perception on air quality and the three first factors in **Table 2** describing respondents' personal characteristics (e.g., gender, age-group and socioeconomic strata). The fact that all participants were undergraduate students from environmental programs is of course giving a certain homogeneity to the sample, but it must however be noticed that it covers people from a broad range of ages and different socioeconomic levels.

One factor we found associated with participant's perception was the size of the municipality. With OR different and higher than one, confidence intervals not crossing one and p -values less than 0.05, the bigger the city of residence, the higher the probability to perceive air quality issues. This is consistent with previous research that highlights how town or city features have a significant influence on perceived levels of air pollution at the local level [41] [42] [43]. In particular, city size in terms of population appears to be a predictive factor, for the physical, social and cultural characteristics that it implies.

Despite most small and mid-sized cities do not have air quality monitoring networks and the fact that in Colombia air quality data is limited [5] [44] [45], 80% of respondents rated their local air quality condition as poor or fair. This means that citizens are aware of their own local environmental deterioration expressed as dust or some kind of smog and offensive odors [46] [47], but also that media (newspaper, television, online technical reports) might have an effect on participants' perception [38] [48] [49] [50]. These results provide an additional reason for local environmental and health authorities to implement measuring systems in those cities where air quality is not yet monitored.

Other authors have previously remarked that air quality problems are especially critical in large cities with high population density [51] [52]. Consistently with that, about 60% of the responders from cities with more than 500,000 inhabitants perceived air pollution as the major environmental problem. When asking about the main local air pollutant, the majority (65%) identified it with PM. This is also consistent with international and national reports that highlight the concern about the importance of PM levels in Latin American urban areas [4] [45] [53] [54] [55] [56] and its implications on human health [57], climate change [58], economy [59] and infrastructure [60]. Species such as greenhouse gases, associated to climate change, do not appear in the responses, which is interesting because it shows the level of knowledge of the respondents on this topic.

There is a statistical evidence for the relationship between perception on the emission sources and size of the city ($X^2 = 166.98$, $p < 0.001$). In general, local area sources and forest fires have more relevance in small cities, while the importance of vehicular traffic as a source of air pollution, rises as the size of the city increases. Industries are more frequently mentioned as the main source of air pollution in mid-size cities (population between 100,000 and 250,000 inhabi-

tants) (**Figure 6**). This is in accordance with results from previous studies, where characteristics such as the predominant economic activities in small and intermediate cities, and urban transport in larger cities, highly influence participants' perception on air quality [42] [43] [61].

Regarding the consequences of air pollution, although more than 90% of the total responders associated negative impacts on people's health, those living in major cities were more likely to recognize such harmful effect. Similarly, when asked about the place where people are more exposed to air pollution, participants of the largest cities mentioned roadsides in greater percentage in comparison to those in small and mid-size cities. However, in both small towns and large cities, respondents coincide on the household as the place where they are more exposed to air pollution. Such results reinforce the suggestion about the importance of considering concepts of healthy-home when designing housing projects.

Air pollution problems are complex and multidimensional, which demands to involve different perspectives for its analysis and management [17] [62] [63]. It is not about reducing the discussion to relativistic approaches, but a complete understanding of the local air quality scenario should include people's perception of the problem as a part of its indicators. In Colombian, and in more Latin American cities, it is time to start building local environmental polices together with people. We consider this is crucial since citizen participation in such public agenda can lead to generate strategies for a better environment. One first thing we suggest to do is to make environmental authorities more visible for the public, letting them know its presence, social objectives and institutional goals. Another key action should be to start monitoring air quality where it is not done today and make such data publicly available. An informed citizenry can make better decisions and will be empowered to follow the progress of the air pollution control actions [64] [65] [66].

5. Conclusions

Citizens' perception on local air pollution, its causes and consequences were explored in different municipalities in Colombia. Limitations notwithstanding, the authors want to highlight the questionnaire design and implementation process as a replicable instrument for broader studies in Colombia and Latin America. It is motivating the fact that participants were university students since they are called to later hold decision-making positions, in both public and private sectors.

The widespread perception of poor air quality should be a call for the authorities to initiate or intensify monitoring, and emissions control programs. Particulate matter was identified as a critical pollutant and people recognized adverse health effects as a main air pollution impact. Such findings suggest people's opinion can be a way to have indicators in cities without data, but also a way to track local air quality management. Moreover, this type of data may be used by environmental authorities to prioritize cities/regions to start acting.

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