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Wheezing in children and adolescents living next to a petrochemical plant in Rio Grande do Norte, Brazil

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Abstract

Objective: To examine the association between wheezing in children and adolescents and living downwind of the dispersion plume of atmospheric pollutants emitted by the Guamaré Petrochemical Complex, in the state of Rio Grande do Norte, Brazil.

Methods: Cross-sectional study of wheezing in children and adolescents (aged 0 to 14 years) living in the vicinity of the Guamaré petrochemical complex in 2006. The standardized International Study of Asthma and Allergies in Childhood questionnaire was used, with additional questions concerning tobacco use, income, living conditions, and educational achievement. Daily concentrations of PM_{10}, $PM_{2.5}$, black carbon, SO_2, NO_2, O_3, benzene, toluene, and xylenes were measured at a fixed monitoring station. According to their position relative to wind direction, communities present in the area affected by plant emissions were categorized into one of two groups, exposed communities and reference communities.

Results: Two hundred and nine children and adolescents took part in the study. Mean daily concentrations of the monitored pollutants were consistently below established acceptable upper limits. The prevalence of wheezing in the 12 months prior to study was 27.3%. After adjustment, statistically significant associations were found between wheezing and living in exposed communities (adjusted odds ratio [OR_{adj}] 2.01; 95% confidence interval [95%CI] 1.01-4.01), male gender (OR_{adj} 2.50; 95%CI 1.21-5.18), and age 0 to 6 years (OR_{adj} 5.00; 95%CI 2.41-10.39).

Conclusion: Even with low levels of atmospheric pollutants, respiratory symptoms in children and adolescents were associated with living downwind of a petrochemical plant. Male preschoolers were the most vulnerable group.

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Introduction

The main atmospheric pollutants emitted by oil refineries are sulfur and nitrogen oxides (SOx and NOx), carbon monoxide (CO), particulate matter (PM), and hydrocarbons.[1] These pollutants have been associated with several detrimental health effects – particularly on the respiratory system – in vulnerable populations, such as children[2-5] and persons with asthma.[6]

Studies have reported associations between living in the vicinity of highways and industrial plants and adverse respiratory outcomes in children, including wheezing and asthma exacerbations.[7-9] Smargiassi et al.[8] reported that episodic increases in sulfur dioxide (SO_2) emissions from a Canadian refinery were associated with increased frequency of asthma attacks in children living nearby. Wichmann et

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al.[9] reported that children living next to a petrochemical plant in Argentina had a higher prevalence of asthma, respiratory symptoms and reduced lung function than did children living elsewhere.

Early identification of recurring wheezing is important, as reduced lung function and severe disease may persist into adulthood.[10-12] In children under the age of 5, the diagnosis of asthma is quite complex, and the diagnostic approach is based on wheezing symptoms.[13] The presence of wheezing and associated risk factors over a 12-month period has been used as a measure of asthma prevalence in epidemiological studies.[14,15] Exposure to air pollutants has been discussed as an associated environmental factor.[6,15,16]

Little is known of the health impacts of living near petrochemical plants on Brazilian children. This adds to the relevance of the present study, which is an offshoot of a prior research project, "Social and environmental impact assessment of atmospheric emissions and their health effects in surrounding communities," conducted in partnership with the Guamaré Petrochemical Complex in Guamaré, Rio Grande do Norte; the Oswaldo Cruz Foundation (Fiocruz), Rio de Janeiro; and the University of São Paulo (USP), São Paulo.

The study sought to verificar the association between reported wheezing in children and adolescents and living downwind or upwind of the dispersion plume of pollutants emitted by the Guamaré complex.

Methods

Study design

Cross-sectional study of reported wheezing in children and adolescents living in the vicinity of the Guamaré Petrochemical Complex, in Rio Grande do Norte, Brazil, as of 2006.

Study population and area

The study included all children and adolescents (aged 0 through 14 years) who, as of 2006, had lived within a 5-kilometer radius of the petrochemical complex for at least 1 year. As all participants were underage, their legal guardians signed free and informed consent forms after agreeing to allow study participation. The project was approved by the Fiocruz Research Ethics Committee with request no. 153/06.

The chosen radius of influence was based on prior similar studies.[1,17] The study area comprised the five communities that surround the petrochemical complex, which produces natural gas (for domestic and industrial uses), diesel fuel, aviation fuel, naphtha, and gasoline. The sample included 209 children living in the communities of Lagoa Doce (A), Mangue Seco I (B), Mangue Seco II (C), Ponta de Salina (D), and Salina da Cruz (E).

The municipality of Guamaré, totaling 259 km^2 in area, is located on the northern coast of Rio Grande do Norte, 180 km from the state capital of Natal, at latitude 5° 06′ 27″S and longitude 36° 19′ 13″W, 3 m above mean sea level. It is bordered by the Atlantic Ocean to the north.[18]

Estimated population was 9,678 in 2006 (49% females and 51% males), with 56% of the municipality's inhabitants living in rural areas. As of 2000, its Human Development Index (HDI) was 0.645.[19]

The municipality is in a hot semi-arid climate zone. The rainy season runs from February through May, and average annual precipitation, relative humidity, and temperature are 711 mm, 68%, and 27.2 °C respectively.[18]

Environmental data

A continuous real-time air quality monitoring station and a weather station were set up and operated continuously between March 27 and July 18, 2006, which included the rainy season and periods of drought. Levels of PM_{10}, $PM_{2.5}$, black carbon (BC), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and benzene, toluene, and xylenes (BTX) were measured. The station was set up approximately 4 km from the petrochemical complex and downwind of it. Station placement was based on 5-year historical data obtained from the fixed weather station set up by the Petrochemical Complex and on local topography (we chose a flat area unimpeded by any obstacles).

Considering the small number of vehicles in the area and the absence of any other industrial activities in the region, all contaminant levels measures at the monitoring station were ascribed to petrochemical complex emissions.

Health data

We used the asthma module of the International Study of Asthma and Allergies in Childhood (ISAAC) Phase I questionnaire,[20] which has been internationally standardized for detection of asthma in schoolchildren and has been validated in Brazil.[21,22] Use of the International Study of Wheezing in Infants (Estudo Internacional de Sibilâncias em Lactentes, EISL)[23] is recommended in children under the age of 3; however, due to the small number of participants in this age range, we chose to use the ISAAC questionnaire, which places special emphasis on wheezing.

Questions on personal and family income, living conditions, educational achievement of the head of household, agricultural exposure, use of alternative energy sources, and exposure to tobacco smoke in the home were added.

We considered questions concerning respiratory symptoms and severity and clinical diagnosis of asthma. The questionnaire was administered by local health agents during visits to the participants' homes, and was answered by the participants' parents or legal guardians. Data quality control was accomplished by means of training, oversight, questionnaire review, and double data entry (two-pass verification).

Study variables

We investigated reports of wheezing, lifetime diagnosis of asthma, dry cough at night in the absence of respiratory infection, frequency of wheezing attacks in the last 12 months, and frequency with which wheezing disturbed sleep, as well as variables concerning demographic characteristics, socioeconomic status, living conditions, sanitation, and household exposure to energy sources and tobacco smoke.

For multivariate analysis, children were categorized into two age brackets: 0 to 6 years (preschoolers) and 7 to 14 years (schoolchildren and adolescents). Race was classified into one of two categories, defined by white or brown skin color, and the only black child in the sample was included in the brown skin color group. Socioeconomic status was defined by total family income, divided into minimum wage tertiles, and by per capita income (R$45.00 or less; R$45.00 to R$100.00; and R$100.00 or more per person). Educational achievement of the head of household was stratified into illiterate/literate and primary/secondary education.

Household exposure and living conditions were assessed by variables concerning the domestic environment itself (number of rooms, number of persons living in the house), availability of basic sanitation (water supply and disposition of household waste), and presence or absence of farming activities. Household-related variables included number of persons living in the house per room (fewer than 2, 2 or more). In terms of sanitation, homes were stratified into those served by mains water supply and waste collection and those not served by either.

We also assessed exposure to tobacco smoke in the home or during pregnancy, as well as the use of alternative energy sources for home lighting. The use of firewood (for cooking) was not addressed, as all communities receive gas vouchers.

In terms of environmental exposure, communities were classified according to their location in relation to the petrochemical complex and their wind exposure. Communities established downwind of the petrochemical complex, and thus under greater influence of its dispersion plume (A, B, C), were classified as "exposed communities" (ECs). Those upwind of the plant and thus less exposed to its dispersion plume (D, E) were used as reference communities (RCs). The results of pollution monitoring represent the approximate levels of exposure of ECs.

Categorization of communities in relation to wind direction was used as a proxy for exposure. Assessment of health outcomes used a 12-month recall period to reduce memory bias and avoid any seasonal influence.[15]

Data analysis

Mean daily levels of monitored pollutants were compared to the air quality standards established by the World Health Organization (WHO),[2] as these are more stringent than those set forth in National Environmental Council (Conselho Nacional do Meio Ambiente, CONAMA) Resolution 003/1990.[24]

The chi-square test was used for comparison of asthma symptom prevalence ratios between genders. The significance level was set at 0.05. Positive response to ISAAC questionnaire Q1 (presence of wheezing in the last 12 months) was used as a dependent variable for bivariate and multivariate analysis. Two study categories were therefore created: patients who experienced *wheezing* in the last 12 months and those with *no wheezing* in the same period. Crude odds ratios were estimated for the association between asthma symptoms and each study variable. Multivariate analysis using logistic regression analysis included all variables that reached the a significance level of 0.20 or less, and models were considered statistically significant with a 95% confidence interval (95%CI). All data were analyzed in the Statistical Package for the Social Sciences (SPSS) version 16.0 software package.

Results

Mean levels of PM, BC, and gaseous pollutants were within the acceptable range established in WHO air quality standards (Table 1). Mean daily concentrations of $PM_{2.5}$ and PM_{10} in the study area were 4.9 (±2.5) μg/m^3 and 9.8 (±7.7) μg/m^3 respectively, and mean BC levels were 0.18 (±0.20) μg/m^3. Mean O_3 concentrations were 10.13 (±4.99) ppb, and mean NO_2 concentrations were 5.48 (±4.75) ppb; SO_2 levels never reached 2.5 μg/m^3. Mean BTX values were 32.4 (±9.9) μg/m^3, 18.8 (±20.1) μg/m^3, and 18.1 (±10.7) μg/m^3, respectively.

The sample included 209 children and adolescents, 56% of whom were male; 15.6% were 0 to 1 years old, 33.5% were 2 to 6 years old, 17.2% were 7 to 9 years old, and 34.0% were between the ages of 10 and 14. Table 2 shows the frequency of positive responses to the ISAAC questionnaire, stratified by gender. The lifetime prevalence of wheezing was 39.9% higher among boys (42.2 vs. 37.0%; 95%CI 33.2-46.9). The prevalence of wheezing in the last 12 months was 27.3%, also higher among boys (33.3 vs. 19.6%; 95%CI 21.4-33.8). In the study sample, 21.1% of participants had received a diagnosis of asthma in their lifetime; again, the figure was higher among boys (23.1 vs. 18,5%; 95%CI 15.7-27.2). We found statistically significant gender differences in the presence of wheezing in the last 12 months (chi-square = 6.51; p = 0.011) and in having had 1 to 3 attacks of wheezing in the last 12 months (chi-square = 7.28; p = 0.007).

Table 3 shows the results of bivariate analysis of the dependent variable (wheezing in the last 12 months) and variables concerning demographic characteristics, household and environmental exposure, income, educational achievement (of the participant's parent or legal guardian), sanitation and living conditions. Children living in ECs were 81% more likely to have had wheezing in the last 12 months than those living in RCs (95%CI 0.94-3.50).

Male participants were twice as likely as female participants to have had wheezing in the last 12 months (OR_{crude} = 2.06; 95%CI 1.03-4.12). The likelihood of wheezing declined with increasing age. As for racial differences, white participants were 43% less likely to experience wheezing, although this finding did not reach statistical significance (p = 0.100). There was no statistical association between wheezing and exposure to tobacco

Table 1 - Environmental monitoring data obtained in the vicinity of the Guamaré Petrochemical Complex, Rio Grande do Norte, Brazil, 2006

Pollutant	Measured value	RV	Sampling	No. measurements	No. times measured value exceeded RV during study period
$PM_{2.5}$	4.9±2.5 μg/m^3	25 μg/m^3	Every 30 minutes with a TEOM mass monitor (Rupprecht & Patashnick Co. Inc., Albany, NY, USA)	> 5,000	13 isolated measurements > 25 μg/m^3, never exceeding mean reference values
PM_{10}	9.8±7.7 μg/m^3	50 μg/m^3*	Every 30 minutes with a DataRAM Scattering monitor (MIE Inc., Billerica, MA, USA), wich allows calculation of the size distribution of particulate matters	> 28,000	51 isolated measurements > 50 μg/m^3, never exceeding mean reference values
BC	0.18±0.20 μg/m^3	–	Every 30 minutes with an Aethalometer™ (Magee Scientific, Berkeley, CA, USA)	> 5,000	Only 3 isolated peak events
O_3	10.13±4.99 μg/m^3	100 μg/m^3†	Every 10 minutes with an ozone monitor (2B Technologies Inc., Boulder, CO, USA), which measures atmospheric O_3 levels by analyzing ultraviolet absorption	> 11,000	O_3 levels never exceeded acceptable standards during the study period
SO_2	< 2.5 μg/m^3	500 μg/m^3‡	Every 10 minutes, with a differential optical absorption spectroscopy (DOAS) device	> 11,000	SO_2 levels never exceeded 2,5 μg/m^3 throughout the study period
NO_2	5.48±4.75 ppb	40 μg/m^3*	Every 10 minutes, with a DOAS device	> 11,000	All values were very close to the DOAS detection threshold throughout the sampling period
Benzene	32.4±9.9 μg/m^3	–	Every 10 minutes, with a DOAS device	> 11,000	§
Toluene	18.8±20.1 μg/m^3	–	Every 10 minutes, with a DOAS device	> 11,000	§
Xylene	18.1±10.7 μg/m^3	–	Every 10 minutes, with a DOAS device	> 11,000	§

BC = black carbon; DOAS = differential optical absorption spectroscopy; O_3 = ozone; NO_2 = nitrogen dioxide; PM = particulate matters; RV = reference values; SO_2 = sulfur dioxide; TEOM = tapered oscillating microbalance.
* 24-hour mean.
† 8-hour mean.
‡ 10-minute mean (WHO Air Quality Guidelines 2005)[2].
§ Hydrocarbon concentrations varied during the study period, but were always lower than those measured in urban areas (1,25).
Inhalable particulate matter was collected by fine ($PM_{2.5}$) and coarse (PM_{10}) PM samplers. Fine and coarse sampling allowed separation of aerosols into two PM size fractions, for which total mass and elemental composition were calculated.

Table 2 - Percentage prevalence of asthma symptoms according to gender, Guamaré, Rio Grande do Norte, Brazil, 2006

Questions	Subtotal Positive responses (n = 117)	Male (%)	Subtotal Positive responses (n = 92)	Female (%)	Total (%) (n = 209)	95%CI	Chi-square (p)
1 - Have you ever had wheezing or whistling in the chest at any time in the past?	49	42.2	34	37.0	39.9	33.2-46.9	2.61 (0.1064)
2 - Have you had wheezing or whistling in the chest in the last 12 months?	39	33.3	18	19.6	27.3	21.4-33.8	6.51 (0.011)*
3 - How many attacks of wheezing have you had in the last 12 months?							
1–3	33	84.6	14	77.8	82.5	70.1-91.3	7.28 (0.007)*
≥ 4	6	15.4	4	22.2	17.5	15.4-22.2	0.02 (0.895)
4 - In the last 12 months, how often, on average, has your sleep been disturbed due to wheezing?							
< 1 night per week	16	41.0	2	11.1	31.6	19.9-45.2	–
≥ 1 night per week	17	43.6	9	50.0	45.6	32.4-59.3	1.24 (0.265)
5 - In the last 12 months, has wheezing ever been severe enough to limit your speech?	7	17.9	3	16.7	17.5	8.7-29.9	–
Have you ever had asthma?	27	23.1	17	18.5	21.1	15.7-27.2	2.00 (0.157)
Has your chest sounded wheezy during or after exercise?	10	25.6	5	27.8	26.3	15.5-39.7	0.31 (0.576)
Have you had a dry cough at night?	35	30.4	22	24.2	27.7	21.7-34.3	3.02 (0.082)

95%CI = 95% confidence interval.
* Chi-square test for difference between genders ($p < 0.05$).

smoke in the home or during pregnancy (OR_{crude} = 0.98; 95%CI 0.48-2.0 and OR_{crude} = 0.68; 95%CI 0.25-1.78 respectively).

The use of alternate energy sources for cooking or home lighting was not significantly associated with wheezing, nor was family income, per capita income, educational achievement, or sanitation status.

Participants living in homes with two or more rooms were 86% less likely to have had wheezing in the last 12 months than those living in homes with one or two rooms ($p = 0.000$).

Even after adjusting for age and gender, participants living in ECs were twice as likely to have had wheezing in the last 12 months as those living in RCs (OR_{adj} 2.01; 95%CI 1.01-4.01).

Gender was associated with wheezing in the last 12 months; boys were 2.5 times more likely to have experienced wheezing than girls (OR_{adj} 2.5; 95%CI 1.21-5.18), after adjusting for age and community.

Age, in turn, was fount do be significantly associated with wheezing ($p < 0.000$) after adjusting for community and gender. Preschoolers (children under 6 years of age) were five times more likely to have experienced wheezing in the last 12 months than older children and adolescents (OR_{adj} 5.00; 95%CI 2.41-10.39) (Table 4).

Discussion

Analysis of the dispersion plume of atmospheric pollutants emitted by the Guamaré Petrochemical Complex led to the identification of a set of communities which we considered "exposed" to air pollution. Although the environmental levels of monitored pollutants were consistently within acceptable limits for the duration of the study, respiratory symptoms were more frequent in children and adolescents living in exposed communities. In addition to place of residence, male gender and age under 7 years were also risk factors for wheezing among inhabitants of the Guamaré Petrochemical Complex area.

Fluctuations in mean levels were within established acceptable limits, rarely peaking but never exceeding acceptable thresholds. As health effect measurements were collected at a single point in time, we were unable to assess whether these minor peaks in pollutant levels were in any way associated with adverse health effects.

The use of alternative energy sources was not associated with wheezing in the present study; conversely, Prietsch

Table 3 - Distribution of asthma symptoms (wheezing in the last 12 months) by demographic and environmental parameters, living conditions, and educational achievement of the head of household (Guamaré, Rio Grande do Norte, Brazil, 2006)

Variables	Wheezing (n, %)	No wheezing (n, %)	OR (95%CI)	p
Community				
Exposed	32 (33.7)	63 (66.3)	1.81 (0.94-3.50)	0.057
Reference	25 (21.9)	89 (78.1)	1.0	
Gender				
Male	39 (33.3)	78 (66.7)	2.06 (1.03-4.12)	0.026
Female	18 (19.6)	74 (80.4)	1.0	
Age (years)				
0 to 1	15 (46.9)	17 (53.1)	1.0	
2 to 6	28 (40)	42 (60)	0.76 (0.30-1.91)	0.514
7 to 9	6 (16.7)	30 (83.3)	0.23 (0.06-0.78)	0.007
10 to 14	8 (11.3)	63 (88.7)	0.14 (0.05-0.44)	0.000
Skin color				
White	15 (20.3)	59 (79.3)	0.57 (0.27-1.18)	0.100
Brown	39 (30.9)	87 (69.1)	1.0	
Smoker(s) at home				
Yes	17 (27.0)	46 (73.0)	0.98 (0.48-2.00)	0.950
No	40 (27.0)	106 (72.6)	1.0	
Maternal smoking during pregnancy				
Yes	7 (20.6)	27 (79.4)	0.68 (0.25-1.78)	0.395
No	44 (27.7)	115 (72.3)	1.0	
Other power source available				
Yes	3 (13.0)	20 (87.0)	0.37 (0.08-1.38)	0.105
No	53 (29.0)	130 (71.0)	1.0	
Farming activities				
Yes	17 (25.4)	50 (74.6)	0.83 (0.41-1.69)	0.588
No	40 (29.0)	98 (71.0)	1.0	
Family income (in minimum wages)*				
< 1	21 (24.7)	64 (75.3)	0.81 (0.38-1.72)	0.543
1	9 (25.7)	26 (74.3)	0.85 (0.31-2.29)	0.724
> 1	22 (28.9)	54 (71.1)	1.0	
Per capita income (R$)				
0.00 to 45.00	18 (26.1)	51 (73.9)	0.79 (0.35-1.77)	0.534
45.00 to 100.00	18 (25.7)	52 (74.3)	0.77 (0.34-1.74)	0.500
100.00 or more	21 (30.9)	47 (69.1)	1.0	
Educational achievement of the head of household				
Illiterate/literate	38 (27.7)	99 (72.3)	1.01 (0.50-2.03)	0.975
Primary/secondary education	19 (27.5)	50 (72.5)	1.0	
No. persons living in home (per room)				
2 or fewer	53 (27.5)	140 (72.5)	1.0	
2 or more	4 (25.0)	12 (75.0)	0.14 (0.03-0.53)	0.000
House type				
Masonry	53 (29.0)	130 (71.0)	1.0	
Wood/mud/rammed earth	4 (15.4)	22 (84.6)	0.45 (0.12-1.46)	0.145
Water supply				
Mains	48 (28.4)	121 (71.6)	1.0	
Other	9 (22.5)	31 (77.5)	0.73 (0.30-1.75)	0.451
Waste collection				
Available	52 (29.7)	123 (70.3)	1.0	
Not available/other	5 (14.7)	29 (85.3)	0.41 (0.13-1.19)	0.072

95%CI = 95% confidence interval; OR = odds ratio.
* As of 2006, R$ 350.00.

Table 4 - Logistic regression models for presence of wheezing in the last 12 months, stratified by community, gender, and age

Variables	Wheezing	No wheezing	OR (95%CI)	OR_{adj} (95%CI)	p
Community*					
Exposed	32 (33.7%)	63 (66.3%)	1.81 (0.94-3.50)	2.01 (1.01-4.01)	0.045
Reference	25 (21.9%)	89 (78.1%)	1		
Gender†					
Male	39 (33.3%)	78 (66.7%)	2.06 (1.03-4.12)	2.50 (1.21-5.18)	0.011
Female	18 (19.6%)	74 (80.4%)	1		
Age (years)‡					
0 to 6	43 (75.44%)	14 (24.56%)	4.84 (2.32-10.21)	5.00 (2.41-10.39)	< 0.000
7 to 14	59 (38.81%)	93 (61.19%)	1		

95%CI = 95% confidence interval; OR = odds ratio.
* Adjusted for gender and age.
† Adjusted for community and age.
‡ Adjusted for community and gender.

et al.[11] reported a 2.6-fold risk of recurring wheezing in homes where other fuels were used. We also found no association between crowding and wheezing, even though other authors have reported a 59% higher likelihood of adverse respiratory outcomes in homes in which two or more persons share the same room.[11]

The prevalence of wheezing was higher among boys. This is consistent with previously published findings, and is likely due to gender differences in airway physiology and higher thresholds of methacholine airway response.[12]

The results of our atmospheric pollution measurements revealed low exposure, as reported by Kalabokas et al.,[1] who found that BTX levels in the vicinity of an oil refinery were lower than those detected in major Greek urban areas. Fluctuations in toluene levels were worthy of note, but levels were still lower than those found in urban areas.[1,25] Nonetheless, when in the atmosphere, pollutants occur as complex blends; therefore, the possibility of additive, synergistic, or antagonistic effects cannot be ruled out.[4,9]

The location of communities relative to industrial complexes and wind direction has been used as an exposure parameter.[17] The pollutant dispersion plume and the location of communities we considered "exposed" may account for the higher prevalences of wheezing in the 12 months prior to study, lifetime history of wheezing, and dry cough at night found in these communities. These results are consistent with prior studies, which have shown respiratory effects in children even when atmospheric pollution is within acceptable limits.[5,26]

Established exposure limits for atmospheric pollutants have been undergoing discussion, particularly as they apply to the protection of vulnerable groups, which led WHO to set more stringent limits for human exposure in 2005.[2] The prevalence rates of wheezing determined in our sample are consistent with those reported in other studies, which have shown a high prevalence of this symptom in Latin American nations, particularly Brazil, and even higher rates in the North and Northeast Regions of the county.[27-29]

Wichmann et al.[9] used the ISAAC questionnaire in their study of the respiratory effects of exposure to petrochemical pollutants in 1,212 Argentinean children aged 6 to 12. They found the prevalence of respiratory events to be higher in the area surrounding the plant than in urban areas, even when levels of exposure were similar. This suggests that not only the concentration of pollutants but also the source and makeup of particulate matter could be associated with respiratory effects. Solé et al.[6] also used this questionnaire in an assessment of the relationship between exposure to pollutant gases (O_3, CO, NO_2, and SO_2), socioeconomic status, and prevalence of asthma, rhinitis, and allergy symptoms in a sample of 16,209 13- and 14-year-olds from various Brazilian cities. Their results suggested an association between higher pollutant levels and higher prevalence of asthma, rhinitis, and allergy, with no difference in socioeconomic status between cities. In our study, socioeconomic conditions were also very similar in all communities, which may account for the lack of association between socioeconomic status and prevalence of wheezing, as reported in other studies.[27,30]

The communities studied herein were homogeneous in terms of dietary habits, lifestyle, and socioeconomic status. All were characterized by low levels of educational achievement, low literacy rates, poor sanitation and living conditions, a dearth of public services and employment, and low family income often boosted by welfare programs. This homogeneous profile makes it hard to distinguish any factors that may be associated with wheezing symptoms in the communities that surround the Guamaré Petrochemical Complex.

One potential limitation of the present study was use of the ISAAC questionnaire in identifying wheezing symptoms in age brackets for which this instrument has not been validated. However, the ISAAC questionnaire has been used before as a tool for assessment of the health effects of atmospheric pollution in ages and samples quite different from those for which it has been validated in the country.[5,9,15]

The present study sought to detect symptoms indicative of vulnerability (particularly wheezing), not diagnose asthma. The EISL questionnaire provides a more detailed approach to respiratory diseases and symptoms, such as bronchitis and wheezing. It is therefore likely that the ISAAC questionnaire failed to detect some symptomatic participants in the under-3 age range. However, considering the results reported by Dela Bianca et al.[23] and the fact that some detection failures likely occurred in every community, this does not invalidate our results.

The findings of this study underscore the relevance of air quality monitoring and health assessment of the groups most susceptible to the effects of atmospheric pollution in the vicinity of industrial areas, both from a public health standpoint and in terms of risk management and corporate social and environmental responsibility.

We conclude that, even with low levels of atmospheric pollutants, respiratory symptoms in children and adolescents from communities in the vicinity of a petrochemical complex were associated with living downwind of the plant. Male preschoolers were the most vulnerable group.

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