Original article

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Consultations for acute respiratory diseases in the pediatric population and their relationship with atmospheric particulate matter in Bahía Blanca: an ecological study

Ignacio R. Buffone[a], *Horacio J. Romano*[b]

ABSTRACT

Introduction. Particulate matter (PM) is one of the air pollutants most involved in the onset or exacerbation of respiratory conditions in children.

Objective. To describe the characteristics of consultations for acute respiratory diseases in children younger than 15 years and the levels of PM in the air and to analyze their association in a sector of Bahía Blanca between April 2019 and March 2020.

Population and methods. Ecological, time-series study with multiple groups. Descriptive analysis of total number of consultations, by area, diagnosis, and PM. Generalized linear correlation and regression model to determine the relationship among variables. The SPSS® software was used.

Results. Data from 4787 consultations were collected. Of these, 38.6% (1846) were related to rhinitis and 21.1% (1011), to bronchospasm. PM of 10 nm (PM_{10}) exceeded its limit value on 31% (115) of the study days, and PM of 2.5 nm ($PM_{2.5}$), on 3% (8). A 10% increase in $PM_{2.5}$ showed increases of 1.3% in total consultations; the increase reached 2.1% in the area closest to the industrial sector ($p < 0.05$). In the latter, a 10% increase in PM_{10} was associated with an increase of 1.8% in consultations ($p < 0.05$).

Conclusion. A positive association was evidenced between consultations for acute respiratory diseases and PM levels in the air, especially with $PM_{2.5}$ and in the area closest to the industrial sector.

Key words: *particulate matter, respiratory diseases, child, adolescent.*

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[a] Department of Epidemiology and Quality, Secretariat of Public Health, Municipality of Bahía Blanca, Argentina; [b] Unit of Health Information Technology, Hospital Municipal de Agudos Dr. Leónidas Lucero, Bahía Blanca, Argentina.

Correspondence to *Ignacio R. Buffone: buffoneignacio@gmail.com*

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INTRODUCTION

According to the World Health Organization (WHO), more than 2 million premature deaths per year can be attributed to the effects of urban air pollution. Half of such burden of disease affects populations in developing countries.[1] Numerous epidemiological studies have shown how exposure to pollutants related to road traffic and the chemical and petrochemical industries produces adverse health effects.[2–4] Particulate matter (PM) is one of the most studied pollutants globally. Its components range in size from a few nanometers (millionths of millimeters) to tens of microns (thousandths of millimeters). The smaller this material is, the greater the power of entry into the distal airways, and the higher its concentration in the air, the greater its health effects on people.[5]

Children are vulnerable to the toxic effects of air pollution on the airways due to their developing and maturing condition, which is worsened by a higher frequency of exposure associated with their outdoor activity patterns.[6] Previous studies have found that living in areas with high air pollution is associated with a poor lung function.[7,8] In addition, there is evidence of an association between atmospheric pollutants and the increase in visits to the Emergency Department due to acute respiratory diseases, such as asthma, bronchitis, pneumonia, rhinosinusitis, etc.[9]

The city of Bahía Blanca is located in the southwest of the province of Buenos Aires. It has a petrochemical industry sector located in the district of Ingeniero White, 10 km from Bahia Blanca's urban center and even closer to surrounding neighborhoods. There is a team assigned to monitoring PM levels, both PM of 2.5 nanometers (nm) and 10 nm ($PM_{2.5}$ and PM_{10}) in this sector.

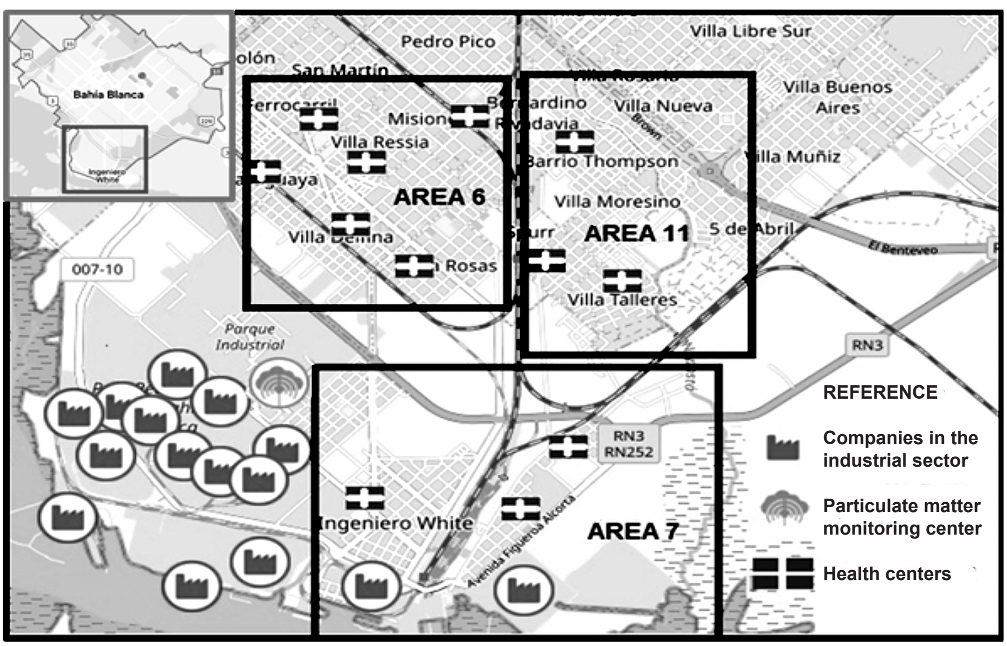
The basic paradigm for working on air pollution exposure and its influence on human health requires a better understanding of the sources of exposure and the damage they can cause to the respiratory system.[10] For this reasons, we decided to conduct this research study to describe the characteristics of consultations for acute respiratory diseases in children younger than 15 years and the levels of PM in the air and to analyze whether there is an association in a sector of Bahía Blanca between April 2019 and March 2020.

METHODOLOGY

Design

This was an ecological, time-series study with multiple groups.

Figure 1. Geographic area where the three study programmatic areas and health centers are located in the southern area of the city of Bahía Blanca, province of Buenos Aires, Argentina



Study location

District of Ingeniero White (Bahía Blanca) and surrounding neighborhoods located within 5 km (*Figure 1*). This area includes 12 health centers within 3 programmatic areas (areas 6, 7, and 11). In addition, we included consultations to the Emergency Department of Hospital Municipal Dr. Leónidas Lucero in Bahía Blanca, which is not located within the predetermined area but whose recording system allowed us to identify children whose current address was within the study areas.

Study sample

Data about children and adolescents younger than 15 years who attended the health centers between April 1st, 2019 and March 31st, 2020 were collected. This information was obtained from a digital recording system (called "SiSalud"), dependent on the municipality's Secretariat of Public Health. Data about consultations at the Emergency Department of Hospital Municipal Dr. Leónidas Lucero were requested to the hospital's Division of Epidemiology.

The following variables were recorded: date and type of consultation, patient's age in years, home address, place of consultation, and diagnosis at consultation.

Age groups

- Infants: younger than 2 years.
- Pre-school children: 2 to 5 years.
- School-aged children: 6 to 11 years.
- Adolescents: 12 to 14 years.

Diagnoses

- Catarrhal rhinitis.
- Influenza-like illness (ILI).
- Pneumonia
- Acute bronchitis.
- Acute bronchiolitis.
- Acute laryngitis.
- Asthma.
- Bronchospasm.

Daily averages of particulate matter ($PM_{2.5}$ and PM_{10}) were provided by the city's Technical Executive Committee. Excessive PM levels were considered to be those values where the daily average exceeded 50 μg/m^3 for PM_{10} and 25 μg/m^3 for $PM_{2.5}$.[7] These limits were only taken into account for the descriptive results, since for the correlation results they were taken as continuous variables.

Weekend and climatic variables were regarded as adjustment factors. Data about climatic variables were provided by the Meteorological Center of Bahía Blanca, dependent on the National Scientific and Technical Research Council.

Climatic data

- Mean temperature (°C): (maximum temperature + minimum temperature)/2.
- Relative humidity (%): daily average of the values obtained from hourly results.
- Wind speed (km/h): daily average of the values obtained from hourly results.

Data analysis plan

Measures of central tendency (mean, median, and mode) were used for the analysis of quantitative variables, whereas qualitative variables were expressed as proportions.

The association between consultations for respiratory diseases and daily changes in PM levels was analyzed using multiple linear regression models. The models sought to validate the positive relationship between particulate matter pollution ($PM_{2.5}$ and PM_{10}) and each disease group. In order to smooth the amplitude of the variance for the time-series and to facilitate the analysis, variables were log transformed. Climatic variables were used as model adjustment factors in order to reduce biases in the results, taking into account the importance of these variables in the development of respiratory diseases.

The representation of the model is as follows:

Inyt = c + β1 Inxt + β2 Inhumx1t + β3 Invientx2t - β4 Intempx3t - β5 dsabt - β6 ddomt + μt

Where *Inyt* accounts for each of the consultation variables expressed as logarithm (total consultations, consultations by programmatic area, consultations by diagnosis). *Inxt* corresponds to the logarithm of PM levels ($PM_{2.5}$ and PM_{10}). Humidity (*Inhumxt*), wind (*Invienxt*), and temperature (*Intemxt*) expressed as a logarithm showed an adequate adjustment with consultation variables after obtaining Spearman's correlation coefficient, so they were included in the model. Saturday and Sunday (*dsabt* and *ddomt*) were also considered but served as dummy variables because they include weekend effects, related to the lower average number of consultations.

Table 1. Characteristics of main study variables

Variables expressed as proportions	n (%)	n (%)	n (%)	n (%)
Sex	Male	Female		
	2418 (50.5)	2369 (49.5)		
Age range	Infants	Pre-school children	School-aged children	Adolescents
	1761 (36.8)	1748 (36.5)	966 (20.2)	312 (6.5)
Consultations by area	Area 6	Area 7	Area 11	
	1095 (22.9)	1864 (38.9)	1828 (38.2)	
Variables expressed as measures of central tendency	**Mean**	**Minimum**	**Maximum**	**Standard deviation**
Number of daily consultations	13.3	0	70	12.8
PM_{10} (µg/m^3)	47.2	0	356	37.6
$PM_{2.5}$ (µg/m^3)	9.6	0	60	6.4

PM: particulate matter.

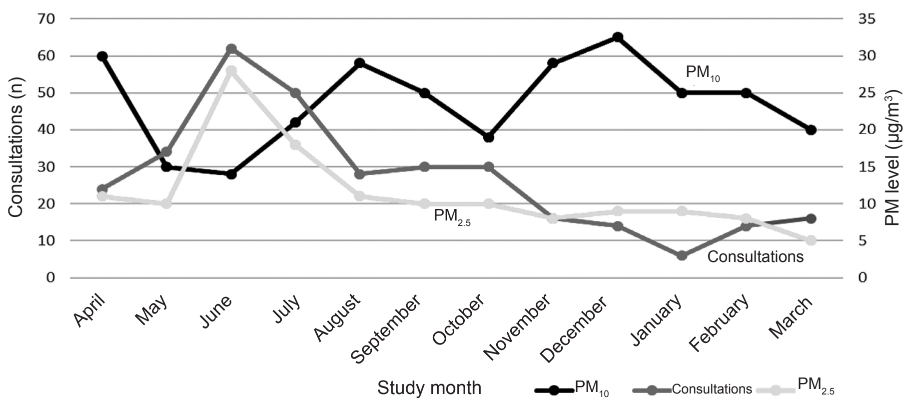
For each model developed, delays of up to 5 days were introduced to determine whether PM levels influenced consultations for respiratory diseases on days following their increase.

The data statistical analysis was performed using the SPSS® 17.0 software package.

Ethical considerations

This study was submitted before and approved by the Ethics Committee of Hospital Municipal Dr.

Figure 2. Mean monthly levels of particulate matter (µg/m^3) and consultations for acute respiratory diseases over the study period



Leónidas Lucero. The patients' personal data were excluded from the consultation records in order to respect their privacy.

RESULTS

Information from a total of 4787 consultations for respiratory diseases in the study geographic area was collected. Males represented 50.5% of the sample (n: 2418). Participants' mean age was 3.8 years; median: 3 years, minimum of 1 year and maximum of 14 years. *Table 1* summarizes the main descriptive results of the variables of interest.

PM_{10} exceeded its limit value of 50 µg/m^3 on 115 of the 365 study days (31%), while $PM_{2.5}$ exceeded its daily limit of 25 µg/m^3 on 8 days (3%). *Figure 2* shows the linear behavior of these variables throughout the study period.

Figure 3 shows the number of consultations by clinical diagnosis. It shows that catarrhal rhinitis was the leading diagnosis, with a total of 1846 consultations (38.6%), followed by bronchospasm with 1011 consultations (21.1%), and acute bronchiolitis with 508 consultations (12.1%).

In relation to the regression models developed, a significant correlation between total consultations and $PM_{2.5}$ levels was observed; this evidenced that, for every 10% increase in $PM_{2.5}$ levels, total consultations for respiratory diseases increased by 1.3%, and the model accounted for 44% of the events that occurred during the study period (B: 0.13, 95% CI: 0.01–0.26, p = 0.04). In addition, a positive correlation was observed on the 4th and 5th days of $PM_{2.5}$ regarding the total number of consultations (*Table 2*). PM_{10} only showed a significant relationship with total consultations on the 4th day after its levels increased.

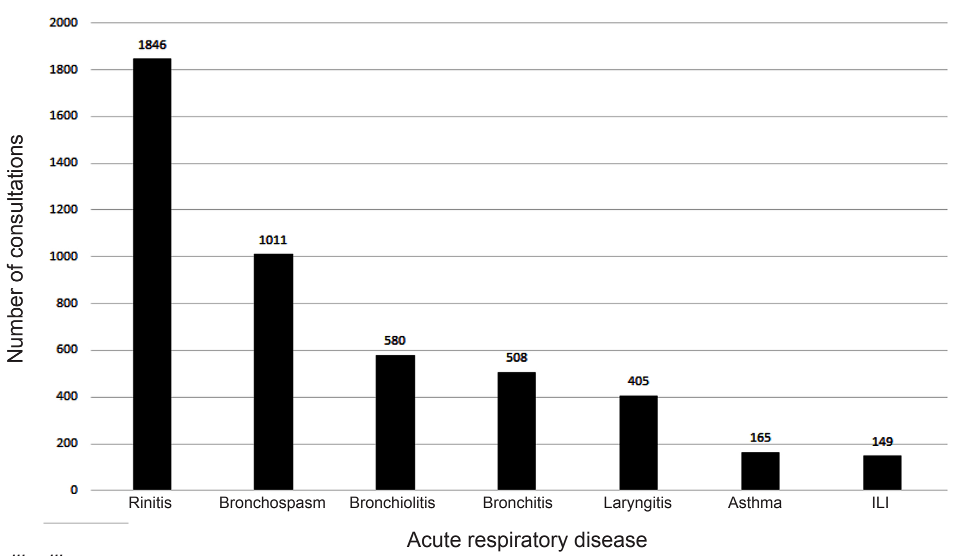
The analysis of the model according to the study programmatic areas, significant differences were observed in the consultations made in area 7, both in the increase of PM_{10} and $PM_{2.5}$. A 10% increase in $PM_{2.5}$ increased the number of consultations by 2.1% in that programmatic area (B: 0.21, 95% CI: 0.08–0.34, p = 0.01).

In relation to diagnosis at the time of consultation, the models developed showed a significant correlation to ILI and catarrhal rhinitis for $PM_{2.5}$, and to pneumonia and rhinitis for PM_{10}. The increase in the number of consultations for bronchospasm in relation to $PM_{2.5}$ levels was evident on later days (days 1, 2, 3, and 5), together with a significant increase in laryngitis on day 4, although the percentage of the adjusted coefficient of determination (R^2) that accounts for the events was low compared to the rest of the significant models (*Table 3*).

DISCUSSION

This study showed a positive association between consultations for respiratory diseases in children younger than 15 years and PM levels in the air, especially with the smaller size ($PM_{2.5}$).

Figure 3. Frequency of consultations for acute respiratory diseases as per clinical diagnosis (n: 4787)



ILI: influenza-like illness.

Infants were the age group with the highest number of consultations. It is critical to recognize this age group as the one with the highest morbidity and mortality and, therefore, the most important one at the time of establishing preventive measures.[11,12]

PM_{10} levels exceeded its limit value on a significant percentage of days of the study period, while $PM_{2.5}$ did so to a lesser extent. In spite of this, studies that compared PM values in our city to those of other cities in Argentina with similar characteristics found much higher values. One study showed average PM_{10} levels in the industrial sector of Bahía Blanca twice as high as those detected in the same area of the city of La Plata (117 versus 62 μg/m^3) and three times higher when comparing average $PM_{2.5}$ levels (105.5 versus 33.8 μg/m^3).[13]

PM_{10} showed a correlation to the total consultation variables for acute respiratory diseases in the programmatic area closest to the industrial sector (area 7) and especially to catarrhal rhinitis, which showed a stronger association than pneumonia and bronchospasm, which also showed statistically significant results. These results are consistent with the evidence showing that the inhalation of larger particles is associated with upper respiratory conditions, but a weaker association with lower airway conditions due to entry difficulties.[14,15]

Table 2. Models of correlation between consultations for acute respiratory diseases and air pollutants

	PM_{10}						$PM_{2.5}$					
Variables	B	SD	*p* value	95% CI		R^2 (%)	B	SD	*p* value	95% CI		R^2 (%)
Total consultations without delays	0.11	0.07	0.11	-0.03	0.26	44	0.13	0.06	0.04	0.00	0.25	44
Total consultations with delays												
Delay 1	-0.02	0.06	0.74	-0.16	0.11	40	0.14	0.06	0.02	0.01	0.27	47
Delay 2	-0.02	0.07	0.78	-0.18	0.13	45	0.06	0.07	0.42	0.08	0.20	47
Delay 3	-0.15	0.07	0.05	-0.29	0.01	11	0.01	0.07	0.52	0.10	0.20	10
Delay 4	0.16	0.07	0.02	0.02	0.29	44	0.18	0.06	0.01	0.05	0.3	44
Delay 5	0.08	0.08	0.36	-0.09	0.25	17	0.20	0.08	0.01	0.04	0.36	18
Consultations by area												
Area 6	-0.02	0.07	0.77	-0.17	0.13	25	0.06	0.07	0.37	0.08	0.21	45
Area 7	0.18	0.07	0.01	0.04	0.32	29	0.21	0.06	0.01	0.08	0.34	29
Area 11	0.05	0.09	0.51	-0.11	0.23	29	0.01	0.82	0.93	0.01	0.16	29
Consultations by diagnosis												
Asthma	0.02	0.07	0.79	-0.13	0.17	2	0.05	0.06	0.35	0.06	0.18	2
Bronchospasm	-0.02	0.09	0.76	-0.17	0.13	24	0.08	0.06	0.22	0.05	0.21	23
Bronchiolitis	0.02	0.09	0.82	-0.21	0.17	22	0.02	0.09	0.82	0.02	0.16	20
Bronchitis	0.11	0.08	0.19	-0.05	0.28	18	0.05	0.07	0.57	0.02	0.19	17
ILI	0.13	0.13	0.32	-0.13	0.40	5	0.33	0.11	0.07	0.09	0.56	13
Laryngitis	0.01	0.08	0.94	-0.14	0.16	9	0.13	0.13	0.32	0.13	0.40	5

B: constant coefficient, SD: standard deviation, CI: confidence interval, R2: coefficient of determination, ILI: influenza-like illness.

In addition, our study found significant differences when establishing a correlation between total consultation variables and $PM_{2.5}$ levels. In this context, several studies agree with the influence of $PM_{2.5}$ on the exacerbation of respiratory diseases.[16–18] Two major studies in China showed that an increase of 10 μg/m^3 in $PM_{2.5}$ levels corresponded to an increase in outpatient visits for respiratory diseases of 0.66% and 0.16%, respectively.[19,20]

The analyses conducted in Latin American countries also showed a positive correlation between $PM_{2.5}$ and consultations. In the city of Lima, for example, for an interquartile increase in $PM_{2.5}$, there was a 6% increase in acute lower respiratory tract infections, a 16-19% increase in pneumonia, and a 10% increase in bronchiolitis/asthma.[21] A correlation study was conducted in the city of Medellin, where the estimated models also established a positive relationship between PM pollution and consultations for asthma, bronchitis, rhinitis, and total diseases.[22]

In our study, consultations for bronchospasm, ILI, laryngitis, and rhinitis showed a statistically significant relation to $PM_{2.5}$, but no association was found for the bronchiolitis and asthma group, as observed in the studies described above.

The strength of this study was the availability of data on daily $PM_{2.5}$ behavior, since not all national monitoring centers provide such information. In addition, having considered climatic variables as an adjustment factor allowed us to optimize the model and thus reduce the biases in the results regarding the role of these pollutants in the consultations. It was important to schedule delays so as to determine what happens on later days because, although the effects may occur on the same day as the increase in PM levels, often the onset of symptoms may occur on later days. For its part, having a digital data entry system allowed us to carry out this study without excluding patients due to lack of recording of variables of interest. In addition, it enabled the inclusion of a significant number of diagnoses of respiratory diseases, involving both the upper and lower respiratory tracts, which provided data on the global correlation and also specific for each disease.

It is worth mentioning that the study period was not affected by the COVID-19 pandemic, since it only included 10 days of the month of March 2020 considering the date when the

Table 3. Correlation models of variables with statistically significant results when the corresponding delays are introduced

Variables		PM_{10}						$PM_{2.5}$					
		B	SD	*p* value	95% CI		R^2 (%)	B	SD	*p* value	95% CI		R^2 (%)
Delay 1	Area 7							0.16	0.06	0.01	0.04	0.28	21
	Area 11							0.14	0.07	0.04	0.01	0.28	28
	Bronchospasm							0.14	0.06	0.01	001	0.27	16
Delay 2	Area 7							0.15	0.06	0.02	0.02	0.27	14
	Bronchospasm							0.12	0.06	0.04	0.01	0.25	8
	Area 11							0.14	0.06	0.02	0.01	0.27	13
Delay 3	Bronchospasm							0.15	0.06	0.02	0.01	0.28	11
Delay 4	Area 7							0.17	0.06	0.01	0.03	0.30	26
	Bronchospasm	0.17	0.07	0.01	0.03	0.31	26						
	Laryngitis							0.14	0.07	0.04	0.01	0.29	14
	Rhinitis	0.11	0.07	0.04	-0.02	0.25	29	0.20	0.06	0.01	0.07	0.33	30
Delay 5	Area 7							0.21	0.07	0.01	0.08	0.35	20
	Bronchospasm							0.18	0.07	0.01	0.03	0.34	11
	Rhinitis							0.23	0.07	0.02	0.08	0.37	11

B: constant coefficient, SD: standard deviation, CI: confidence interval, R^2: coefficient of determination.

preventive and mandatory social isolation policy was first established.[23] This is important because, if the study had been performed later, there could have been a bias in the number of consultations, which would have influenced the results.

One of the study limitations is its ecological nature, which prevented us from obtaining individualized results. Furthermore, the low r^2 percentages found indicate that the model developed does not account for the total number of events, leaving out other important factors, such as personal and family background, intramural environmental contamination, socioeconomic level, among others.

Finally, as seen in the graphs, the periods with the highest number of consultations for respiratory diseases are consistent with the winter months. This may have affected the association results, especially considering the evidence supporting the relationship between consultations for respiratory diseases and increased viral circulation at that time of the year.[14,24]

CONCLUSION

This study demonstrates the association between PM levels in the air and consultations for respiratory diseases, especially with $PM_{2.5}$ and in the area closest to the industrial sector. The greatest association was observed with catarrhal rhinitis and bronchospasm. ■

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