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Air quality and acute respiratory disorders in children

ABSTRACT

OBJECTIVE: To assess the relationship between air pollution and acute respiratory disorders in children.

METHODS: A time series ecological study was carried out in three public health posts in a region of the city of Rio de Janeiro (Southeastern Brazil), between April 2002 and March 2003. Data for PM10, SO_2, NO_2, CO and O_3 were analyzed daily and as closure variables, a total of 45,595 emergency pediatric consultations for respiratory symptoms or specifically for disorders in the upper and lower airways. To control for confounders, other variables were included in the model including those relating to weather, seasonality, temperature, relative air humidity, rain volume, respiratory infections and the calendar effects (such as holidays and weekends). A Poisson regression was applied using generalized counting models to estimate the effects of pollutants and confusing factors.

RESULTS: Only O_3 had a positive and statistically significant effect, both among emergency consultations for respiratory problems and consultations for symptoms relating to the lower airways. Effect and exposure occurred on the same day (lag 0). A significant negative association was found with CO and pediatric consultations for respiratory complaints. Other air pollutants were not found to have a significant effect.

CONCLUSIONS: There were found associations between outdoor air pollution and the number of emergency pediatric consultations for respiratory problems in the studied area, in spite of the fact that the levels of all pollutants monitored during the study period were below recommended levels.

DESCRIPTORS: Child. Air Pollution. Air Pollutants, adverse effects. Respiratory Tract Diseases, epidemiology. Ecological Studies.

INTRODUCTION

There remain a series of gaps in the understanding of physio-pathological conditions involving respiratory illnesses in children, and these represent a challenge for researchers from around the world. Exposure to particles found in the surrounding air – including micro-organisms, allergens and air pollutants – and the personal characteristics of those who are exposed to them are the key determinants of clinical symptoms.

At present, gases and ultra-fine particles released by the partial burning of fossil fuels in vehicles, particularly diesel cars, are the factors responsible for the greater prevalence of bronchial asthma and other allergic illnesses in populations that live in polluted areas.[18]

The interest in understanding the relationship between air pollutants and respiratory illnesses in children began at the end of last century. The harmful

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effects of air pollution were found in Ciudad Juarez,[15] Mexico City,[22] London,[1] Havana[20] and Atlanta,[19] where studies showed an increase in the number of emergency pediatric consultations for respiratory complaints. Similar results were found in Brazil in the cities of São Paulo[4,6,16] and Curitiba.[2] Inconsistencies in the magnitude and statistical significance of the results of these studies can be partially explained by the different methodologies used, in terms of measuring the pollutants, the characteristics of the health effect, or the sophistication of the statistical model that was used.

Few epidemiological studies addressed the upper parts of the airways as the focal point of the harmful effects of air pollution, in spite of increased prevalence rates in the infant population and greater frequencies in the diagnoses of sinusitis, pharyngitis, allergic rhinitis and colds at health care units.

Most studies concerned with the effects of air pollution on health were carried out in developed countries from the Northern Hemisphere. In general, these countries display important differences in terms of meteorological characteristics, the physical and chemical nature of the pollutants, and the socioeconomic profiles of their inhabitants when compared with other regions of the planet, thus preventing the extrapolation of their results to other locations.

Rio de Janeiro is the second most populous city in Brazil, but little is known about the influence that air pollutants have on respiratory problems among its population, particularly among children. The objective of the present study was to assess short-term links between levels of atmospheric pollutants and children's emergency medical consultations for respiratory problems in the municipality of Rio de Janeiro.

METHODS

This is an ecological study using a time series with daily indicators for health, air pollutants and meteorological factors.

The sample included all children aged between one month and 12 years who were treated for acute respiratory symptoms in the emergency department of three public hospitals during the period 1 April 2002 and 31 March 2003. Independently of the severity of the problem, the pediatric consultations in these hospitals were provided on the same day that they were requested. These children live in the administrative regions of Jacarepaguá (with the exception of the neighborhood of Vila Valqueire, since it was too far away) and Cidade de Deus (next to Jacarepaguá) in the west of the municipality of Rio.

The area of the study is 127.82 km^2, where air circulation is limited by the hills in Pedra Branca and Tijuca to the west and east respectively. Reasons for choosing this area include: the availability of an automatic monitor that measures the principal air pollutants without interruption, and the public network of health units with different levels of complexity that treats a large infant population.

A team of professionals who had received prior training selected on a daily basis the patient records that matched the criteria for inclusion at the health units. After this stage, the presence of respiratory signs, symptoms or diagnoses were noted in a separate instrument, with specific fields for the most common causes of respiratory problems at emergency pediatric consultations such as flu, otitis, irritation of the eyes, coughing and asthma. In addition, the reasons for the consultations can be grouped as follows: infections of the upper airways, infections of the lower airways and/or acute respiratory infections. The creation of this instrument was necessary because the medical records did not mention the International Classification of Diseases (ICD) or any other classification of the symptoms and clinical diagnoses that would allow for the organization of the data. Thus all respiratory problems were classified according to their location in the airways.

The air concentrations of particles with an aerodynamic volume of up to 10 microns (PM10), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3) were extracted from the registries of an automatic monitor, operated by the *Fundação Estadual de Engenharia do Meio Ambiente* (FEEMA – State Foundation for Environmental Engineering). Daily data on the relative humidity and temperature were measured at the Campo dos Afonsos military airbase, near to the study region. The meteorological conditions for the day of the consultation (D0), the day before (D1) and two days before (D2) were all noted. The cumulative effects were verified by averaging two or three days concentrations (M01, M12, M012). The daily volume of rain was taken from the arithmetic measure of the daily volumes at the three monitoring stations.

Failures in the monitoring of pollutants in Jacarepaguá during the course of the study resulted in gaps in the registries of particle concentrations, both on isolated days and several consecutive days. Thus in total, 246 days of PM10 were monitored, 201 days of NO_2, 244 days of CO, 237 days of O_3 and 194 days of SO_2. On account of a reduction in the information available about SO_2 and the low levels measured in the region during the study period, this pollutant was excluded from the analysis. For other pollutants, the missing data were imputed when failures occurred over short periods or on isolated days. Thus, the total study period was limited to 262 days, with three periods excluded: April 8-30/2002, December 1/2002 to January 15/2003

and February 10 to March 16/2003. The total period was less for NO_2 and O_3, since these pollutants were only measured for the stations of Jacarepaguá and the Central Region. The imputation of monitoring data from Jacarepaguá depended solely on information from the Central Region. However, on certain days, both were not functioning.

The procedure for the missing data imputation used the methodology[a] whereby the estimates are taken from the correlation between the environmental levels of a pollutant in different monitors and by the autocorrelation of their levels, on the same monitor, over time. In addition to the daily indices measured at the monitor located in Jacarepaguá, data taken from the monitors in the FEEMA (Central Region) were also used, as were those from the Municipal Secretariat for the Environment, located in the neighborhoods of São Cristovão, Tijuca, Central Region and Copacabana. The high correlation between the values of the environmental pollutants collected in Jacarepaguá and in the other regions of the city made this method feasible.

Semiparametric Poisson regression[15] was used to estimate the effects of pollutants and other confounding factors. This approach means that non-linear effects can be properly adjusted by means of nonparametric functions. Theses models were fitted using S-Plus version 6. Time trend, seasonality and meteorological variables were adjusted using *splines*,[13] which are smooth functions of the data.

The influence of the days of the week, of weekends, public holidays, long weekends and the days on which Brazil was playing football in the 2002 World Cup were controlled by including indicative variables in the statistical model. The same procedure was adopted for other days on which there were no pediatric consultations or on which the medical records were missing. The occurrence of these events was not dependent on the environmental concentration of pollutants.

Respiratory infections can confound the association between air pollutants and medical consultations for respiratory complaints.[9,18] However, due to the absence of such information, data on pediatric hospital admissions due to pneumonia were obtained directly from the archives of the *Departamento de Informática do Sistema Único de Saúde* (DATASUS – Information Department of the Brazilian Health System) and were used to control for acute respiratory infections. Diagnoses for pneumonias J12 and J18 of the ICD-10 were considered. Controlling for periods of epidemics was carried out using cubic polynomials for each period, instead of the usual indicator variables. This strategy not only allowed for adjusting for its effects but also for the observation of slight increases and decreases in epidemics relating to respiratory infections.[5]

There may sometimes be a latency period between the exposure to air pollutants and the appearance of acute respiratory symptoms. Thus, the study included an investigation into the effects on the respiratory system associated with pollution levels on the day of the consultation (D0), as well as on the three previous days (D1, D2, D3). The cumulative effect was evaluated by means of the moving averages of pollutant levels of between two and seven days (mm2, mm3, mm4, mm5, mm6, mm7). The estimated effects are the relative risks (RR) corresponding to an increase of 1000 $\mu g/m^3$ in the levels of CO and 10 $\mu g/m^3$ in other pollutants. To interpret the results, the RR were converted to percentage increases. The significance level used for all analyses was 5%.

The study proposal was approved by the Research Ethics Committee of the Instituto de Medicina Social at the Universidade do Estado do Rio de Janeiro.

RESULTS

The three hospitals provided 45,595 emergency medical consultations for respiratory problems during the study period. A total of 17,477 diagnoses or symptoms of the lower airways and 28,754 of the upper airways were registered; several children presented localized symptoms, both in the upper and lower part of the airways.

The average daily concentrations of PM10, CO, NO_2 and O_3 did not exceed the daily limits recommended by the National Commission for the Environment, CONAMA: 150 $\mu g/m^3$ for fine particles, an eight hours average of 10,000 $\mu g/m^3$ (9 ppm) for CO, and an hourly average of 160 $\mu g/m^3$ for O_3 and 320 $\mu g/m^3$ for NO_2.

In terms of the number of pediatric consultations, there was a clear increase at the start of colder months. The total number of consultations and consultations for symptoms of the upper airways increased at the start of October.

Table 1 shows the descriptive analyses of health and environmental variables. The daily arithmetic averages of each pollutant show the daily indicators for exposure. The Pearson correlation coefficients between the pollutants were statistically significant and positive, with the exception of the negative value between CO and O_3. Ozone was the only pollutant that was significantly associated with a greater number of consultations for respiratory symptoms. Table 2 shows the positive and statistically significant effects relating to O_3. The greater demand for medical care occurred on the same day of exposure to O_3 (lag 0) and did not persist during the days that followed.

[a] Junger WL, Narcisa MS, Ponce de Leon A. Imputação de Dados Faltantes em Séries Temporais Multivariadas Via Algoritmo EM. Cadernos do IME, Série Estatística. 2003;15:8-21.

Table 1. Descriptive analysis of environmental and health variables. Rio de Janeiro, Southeastern Brazil, 2002 – 2003.

Variable	N	% cal	average	sd	min	p25	p50	p75	max
LA and UA	365	0	126.54	38.85	40	99	123.5	156	218
LA	365	0	51.03	21.38	10	35	48	64.75	135
UA	365	0	81.1	28.69	14	62	79.5	97.75	166
Minimum time	365	0	22.14	2.97	15	19.8	22.5	24.4	28.6
Average time	365	0	26.31	3.08	18.01	24.34	26.36	28.64	32.7
Maximum time	365	0	31.16	4.04	19	29	31.3	34	40
Humidity (%)	365	0	76.42	8.11	52.58	70.75	76.37	81.54	95.5
Rainfall (mm)	365	0	3.59	10.30	0	0	0	0.72	76.87
PM10 (μg/m^3)	262	6.1	34.67	12.49	11.22	25.65	32.82	41.53	79.04
CO (1000 μg/m^3)	262	6.9	1.37	0.34	0.35	1.17	1.39	1.6	2.38
NO_2 (μg/m^3)	250	19.6	62.78	32.96	9.6	38.5	59	81.45	209.8
O_3 (μg/m^3)	248	4.4	36.78	21.75	4	19.87	31.85	50.17	123.9

% imp: percentage of data calculated
sd: standard deviation
p: percentile
LA – lower airways
UA – upper airways

The graphics showing the percentage variations and the respective confidence intervals for pediatric consultations are given in Figures 1, 2 and 3. As well as O_3, a statistically significant association, this time negative, was also noted with CO.

DISCUSSION

During the study period, only O_3 was found to have a statistically significant association with the increase in the number of emergency pediatric consultations for respiratory complaints on the same day of exposure. This effect was evident in the models that include all pediatric consultations for respiratory reasons and in those that include only the symptoms of the lower airways. In spite of the rigor involved in the collection and analysis of the health data, these results should be treated with caution, mainly because of the reduction in the number of days for which air pollutants were measured during the study period.

As well as O_3, the effects of other air pollutants, while of a small magnitude, could have been shown if the monitoring failures had not included long intervals. Further, in principle, the physiological breathing mechanism is not consistent with a response made by the organism to acute aggressions whose clinical manifestations appear during a limited period of 24 hours, unless the effects are of a very low intensity. In similar epidemiological studies, the greater demand for emergency services lasted for some days.[15,19] On the other hand, the environmental levels of O_3 remained low, meaning that it was possible that the effect of the increase in exposure had been immediate, low level and was rapidly resolved. Thus it is reasonable that this association is real.

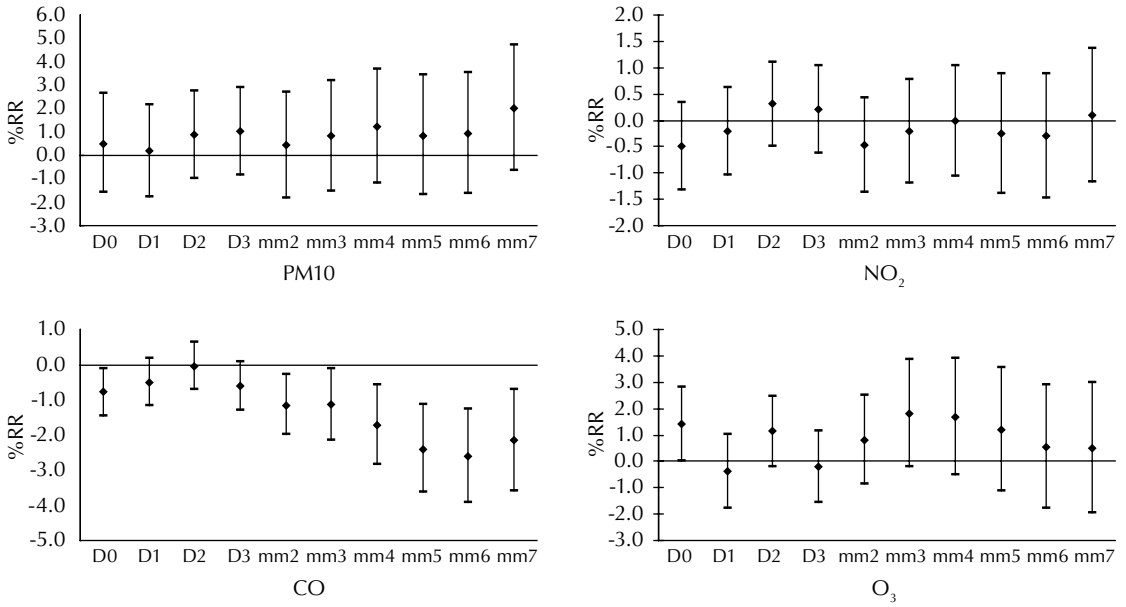
Table 2. Percentage increase and confidence interval of 95% in emergency pediatric consultations for respiratory symptoms relating to ozone. Rio de Janeiro, Southeastern Brazil, 2002 – 2003.

Location	Pollutant	Lag	Increase %	CI 95%	p
Airways	O_3	0	1.40	0.03;2.79	0.05
LA	O_3	0	2.65	0.69;4.64	0.007

LA – lower airways

The atmospheric components in a geographically limited region generally have a common origin and show a high linear relationship. The highest Pearson correlation (0.33) was found in PM10 and CO pollutants, while there was a negative result for O_3 and CO. The characteristics of the air polluting emissions in Jacarepaguá may justify, at least in part, the reduced colinearity. Jacarepaguá is a region whose topographic characteristics make air circulation difficult and the contribution of the large industrial park cannot be ignored. According to data from the Registry of Industries in the State of Rio de Janeiro, the number of industrial sited in the area is more than 200. The partially urban nature of Jacarepaguá is further compounded by the fact that it is one of the least urbanized regions of Rio de Janeiro municipality and is marked by large green areas.

The gaps in the monitoring of air quality were caused by operational failures and were not related to the levels of pollutants, which indicates the inexistence of a bias in the assessment of the exposure. However, the large number of continuous days excluded could have caused a systemic error in the estimation of effects. The magnitude of this error is uncertain due to



D0: same day of exposure
D1: 1 day after exposure
D2: 2 days after exposure
mm2: moving average for concentration of pollutants over 2 days
mm3: moving average for concentration of pollutants over 3 days
mm4: moving average for concentration of pollutants over 4 days
mm5: moving average for concentration of pollutants over 5 days
mm6: moving average for concentration of pollutants over 6 days
mm7: moving average for concentration of pollutants over 7 days

Figure 1. Percentage variation and confidence intervals of 95% in pediatric consultations for respiratory symptoms by increases in the concentrations of air pollutants on each day of the period considered and moving average. Rio de Janeiro, Southeastern Brazil, 2002 – 2003.

the lack of information about pollutants during the periods excluded. Nonetheless, some considerations are important. The environmental concentrations of O_3 are generally greater in summer, when emissions of ultraviolet light are greater. Although 80 days of summer had been excluded, O_3 was associated with a greater demand for respiratory consultations. In spite of the frequent interruptions in monitoring, the time series for O_3 suggests two hypotheses: a) the peak in the air levels of O_3 that occurred during winter (and also of its precursor, NO_2), caused an increase in exposure, capable of producing respiratory effects in children that are more susceptible; b) the increasing levels of O_3 at the end of spring continued during the summer months and caused a greater number of consultations in health units. However, the suspension of monitoring for a long period of time at the beginning of summer, limited the observation of an effect that may have been more relevant and more significant statistically.

The intensities of these effects suggest that the air pollutant did not cause a large impact on the respiratory organs of the infant population, and that the high demand for consultations for respiratory related issues during the study period can be attributed to other risk factors, such as infections and allergies. It is also possible that emergency medical consultations may not be an adequate indicator to estimate associations between air pollutants and health events.

According to some authors,[13] illnesses of the airways generally make up a heterogeneous group of pathologies, particularly those of the lower parts of the airways. The effects on illnesses that have more specific associations with O_3 could be diluted, such as bronchial asthma. This hypothesis would justify that low levels of evidence of the contribution of O_3 in this result. Even so, O_3 was associated with a greater number of pediatric consultations in some epidemiological studies in which hospitalization or emergency pediatric consultations for respiratory problems was the dependent variable, without indicating a specific diagnosis. In Santiago in Chile, a 5.4% increase in emergency pediatric consultations for respiratory illness was observed for an increase of 50 ppb in O_3.[17] In the city of São Paulo, daily hospital admissions for children with respiratory symptoms and specifically for pneumonia grew by 5% and 8% respectively for increases in the levels of O_3.[10] In Ciudad Juarez in Mexico, a 3% increase in emergency consultation for respiratory problems was observed for an increase in 20ppb of O_3.[15]

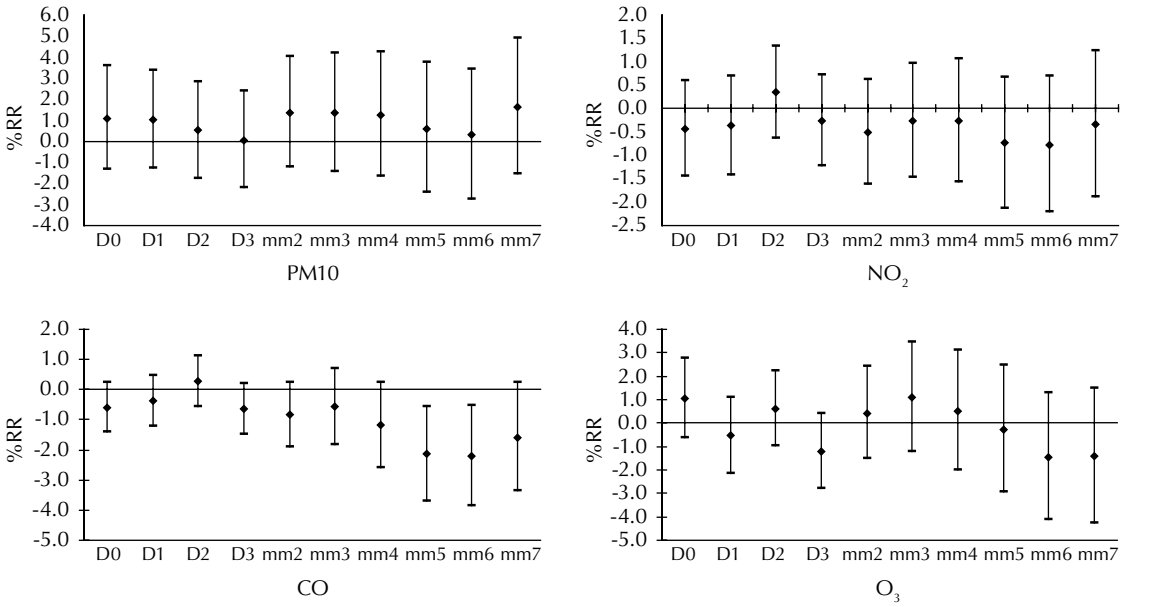


Figure 2. Percentage variation in confidence intervals of 95% in pediatric consultations for symptoms relating to the upper airways according to increases in the concentrations of air pollutants in each day of the period considered and moving average. Southeastern Brazil, Rio de Janeiro, 2002 – 2003.

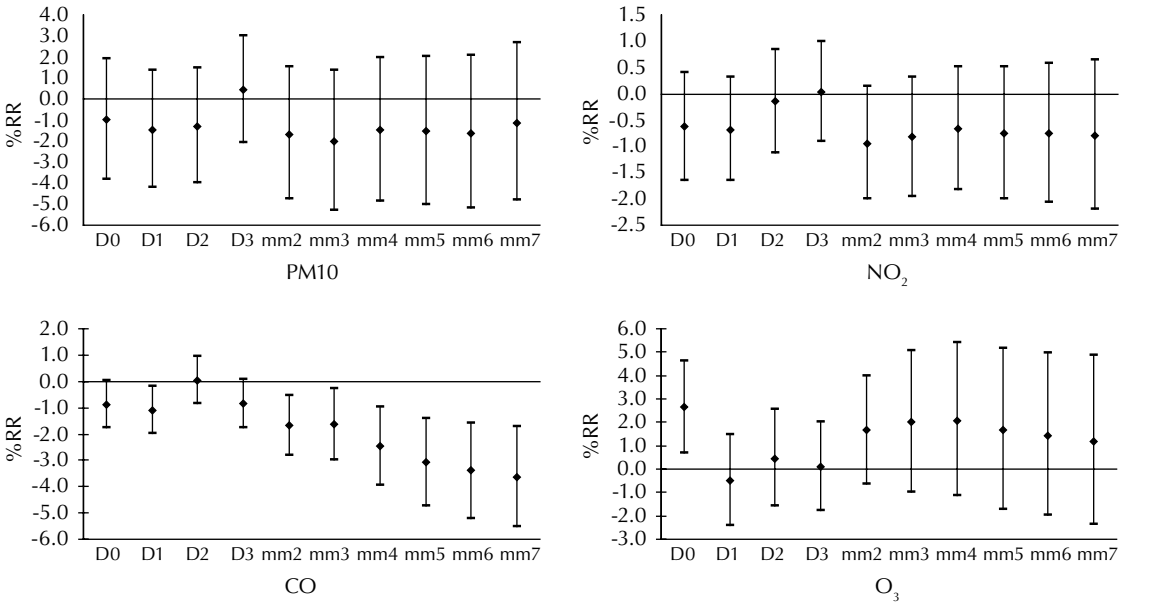


Figure 3. Percentage variation in confidence intervals of 95% in pediatric consultations for symptoms relating to the lower airways according to increases in the concentrations of air pollutants in each day of the period considered and moving average. Southeastern Brazil, Rio de Janeiro, 2002 – 2003.

In various epidemiological studies, O_3 figured among the air pollutants associated with emergency pediatric consultations for acute respiratory symptoms, characteristic of bronchial asthma, which arose up to one or two days after exposure to pollutants.[7,21] The results of the present study were similar both in terms of the contribution of O_3 and the timeframe of the effects, thus making possible to assume that the diagnosis for bronchial asthma had been frequent in many of those children that presented localized symptoms in the lower airways.

The relationship between the exposure to O_3 and respiratory events appears not to follow a linear pattern. For some authors, observation of the remission of symptoms in both humans and animals after repeated chronic exposure to low concentrations shows a level

of tolerance or adaption.[7] For others, even in concentrations considered to be safe, O_3 can cause adverse health effects.[3] In this way, it is a complex supposition to assume that the respiratory effects could have been observed if there had not been interruptions in the monitoring of pollutants during the study period.

While CO does not cause visible harm, it is an indicator of the presence of substances generated by the combustion of particles[8] and the burning of fossil fuels that are not usually monitored, such as hydrocarbons and fine particles. For this reason, the negative effect of CO in all results is not easily justifiable.

The association between air pollutants and health problems in the upper respiratory airways has been studied very little and still requires discussion. In a study[16] carried out in the city of São Paulo, the authors found statistically significant increases in these respiratory problems associated with PM_{10} and O_3. In London,[12] the increase in concentrations of SO_2 was found to be associated to an 24.5% increase in the number of pediatric consultations for allergic rhinitis after four days of exposure. An association between an increase in O_3 and a 37.6% increase in the number of consultations was also found, when measured for the day of the consultation and the three previous days. More consistent associations, some days after exposure, were justified by the non-emergency nature of the allergic symptoms.[12] In another study, using the same environmental and health data, and excluding the diagnosis for allergic rhinitis, only SO_2 showed a consistent association, principally during cold months.[11]

In the present study, although symptoms in the upper parts of the airways were present in many of the consultations, no association was found with environmental indicators for pollution. Perhaps the seriousness of the problems in the upper airways associated to exposure of the population to pollutants in the air, even in smaller children, had not been sufficient to justify a greater demand at the emergency units.

Two peaks can be identified in the time series of medical consultations for problems in the upper airways, corresponding with the beginning of winter and spring. During winter, vaso-spastic problems with the nasal mucus and the greater time spent in closed environments may lead to the greater incidence rates of respiratory infections. In spring, in many regions, pollination makes sensitive children more prone to a rise in allergic respiratory symptoms. However, there are no systematic registries of the environmental distribution of pollen in Rio de Janeiro, and the information relating to the characteristics of flowering are controversial. It was therefore not possible to estimate the interference of this allergen in the present study.

Adverse situations relating to medical care in emergency departments may lead to the occurrence of information bias and incorrect first medical impressions. To minimize this effect, in the study carried out in the city of São Paulo by Lin et al,[16] the clinical diagnoses were established by more than one health professional. On the other hand, emergency medical care is not limited by the availability of hospital beds.

In spite of the adoption of preventive measures, such as training and supervision of technical staff in charge of field work, misclassification of diagnoses may have occurred, since they are not classified according to the International Classification of Diseases at health units. Errors may have occurred in the fulfilling of criteria for inclusion of the child population, in the extraction of symptoms, signs and clinical diagnoses from the medical forms and in the filling out of the tool for data collection, due to the exhaustive and repetitive nature of this task, principally in the two large general hospitals.

Overall, the associations found in the present study related to concentrations of pollutants that are below recommended levels, as has already been shown by other authors. This fact points to a need to revise the levels that are considered safe. The mechanisms by which air pollution interferes with human health are still little known and it is essential that epidemiological studies that address this question are carried out, considering the different effects of these pollutants.

REFERENCES

1. Atkinson RW, Anderson HR, Strachan DP, Bland JM, Bremner SA, Ponce de Leon A. Short-term Association between outdoor air pollution and visits to accident and Emergency Departments in London for respiratory complaints. *Eur Respir J.* 1999;13(2):257-65.
2. Bakonyi SMC, Danni-Oliveira IM, Martins LC, Braga ALF. Poluição atmosférica e doenças respiratórias em crianças na cidade de Curitiba, PR. *Rev Saude Publica.* 2004;38(5):695-700.
3. Bell ML, Peng RD, Dominici F. The exposure–response curve for ozone and risk of mortality and the adequacy of current ozone regulations. *Environ Health Perspect.* 2006;114(4):532-6.
4. Braga ALF, Saldiva PHN, Pereira LAA, Menezes JJC, Conceição GMS, Lin CA, Zanobetti A, Schwartz J Dockery DW. Health effects of air pollution exposure on children and adolescents in São Paulo, Brazil. *Pediatr Pulmonol.* 2001;31:106-13.
5. Braga ALF, Zannobetti A, Schwartz J. Do respiratory epidemics confound the association between air pollution and daily deaths? *Eur Respir J.* 2000;16(4):723-8.
6. Farhat SCL, Paulo RLP, Shimoda TM, Conceição GMS, Lin CA, Braga ALF, et al. Effect of air pollution on pediatric respiratory emergency room visits and hospital admission. *Braz J Med Biol Res.* 2005;38:227-35.
7. Fauroux B, Sampil M, Quénel P, Lemoullec Y. Ozone: a trigger for hospital pediatric asthma emergency room visits. *Pediatr Pulmonol.* 2000;30(1):41-6.
8. Fusco D, Forastiere F, Michelozzi P, Spadea T, Ostro B, Arcà M, et al. Air pollution and hospital admissions for respiratory conditions in Rome, Italy. *Eur Respir J.* 2001;17(6):1143-50.
9. Galán I, Tobias A, Banegas JR, Aránguez E. Short-term effects of air pollution on daily asthma emergency room admissions. *Eur Respir J.* 2003;22(5):802-8.
10. Gouveia N, Fletcher T. Respiratory diseases in children and outdoor air pollution in São Paulo, Brazil: a time series analysis. *Occup Environ Med.* 2000;57(7):477-83.
11. Hajat S, Anderson HR, Atkinson RW, Haines A. Effects of air pollution on general practitioner consultations for upper respiratory disease in London. *Occup Environ Med.* 2002;59(5):294-9.
12. Hajat S, Haines A, Atkinson RW, Bremner SA, Anderson HR, Emberlin J. Association between air pollution and daily consultations with general practitioners for allergic rhinitis in London, United Kingdom. *Am J Epidemiol.* 2001;153(7):704-14.
13. Hajat S, Haines A, Goubet SA, Atkinson RW, Anderson HR. Associations of air pollution with daily gp consultations for asthma and other lower respiratory conditions in London. *Thorax.* 1999;54(7):597-605.
14. Hastie T, Tibshirani R. Generalized additive models. 2 ed. London: Chapman and Hall; 1990.
15. Hernández-Cadena L, Téllez-Rojo MM, Sanin-Aguirre LH, Lacasaña-Navarro M, Campos A, Romieu I. Relación entre consultas y urgencias por enfermidad respiratoria y contaminación atmosférica en Ciudad Juárez, Chihuahua. *Salud Publica Mex.* 2000;42(4):288-97.
16. Lin CA, Martins MA, Farhat CL, Pope III CA, Conceição GMS, Anastácio VM, et al. Air pollution and respiratory illness of children in São Paulo, Brazil. *Paediatr Perinat Epidemiol.* 1999;13(4):475-88.
17. Ostro BD, Eskeland GS, Sanchez JM, Feyzioglu. Air pollution and health effects: a study of medical visits among children in Santiago, Chile. *Environ Health Perspect.* 1999;107(1):69-73.
18. Pandya RJ, Solomon G, Kinner A, Balmes JR. Diesel exhaust and asthma: hypotheses and molecular mechanism of action. *Environ Health Perspect.* 2002;110(suppl 1):103-12.
19. Peel JL, Tolbert PE, Klein M, Metzger KB, Flanders WD, Todd K, et al. Ambient air pollution and respiratory emergency department visits. *Epidemiology.* 2005;16(2):164-74.
20. Romero-Placeres M, Más-Bermejo P, Lacasaña-Navarro M, Téllez Rojo-Sollis MM, Aguilar-Valdés J, Romieu I. Contaminación atmosférica, asma bronquial e infecciones respiratorias agudas en menores de edad, de La Habana. *Salud Publica Mex.* 2004;46(3):222-33.
21. Sunyer J, Spix C., Quénel P, Ponce de Leon A, Pönka A, Barumandzadeh T, et al. Urban air pollution and emergency room admission for asthma in four European cities: the APHEA Project. *Thorax.* 1997;52(9):760-5.
22. Tellez-Rojo MM, Romieu I, Polo-Peña M, Ruiz-Velasco S, Meneses-González F, Hernández-Avila M. Efecto de la contaminación ambiental sobre las consultas por infecciones respitatorias en niños de la Ciudad de México. *Salud Publica Mex.* 1997;39(6):513-22.

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