Arquivos de Asma, Alergia e Imunologia

Air pollution and respiratory health

Poluição do ar e saúde respiratória

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ABSTRACT

The increase in the prevalence of chronic respiratory diseases coincides with that of exposure to air pollutants due to the growing industrialization process, increased vehicular traffic and population migration to urban areas. Air pollution is a complex mixture of pollutants and other toxic and non-toxic chemical compounds and its effect on health can derive from this mixture and the interaction with meteorological parameters. Despite this, it seeks to establish the role of a specific pollutant separately and considers the meteorological parameters as confounding factors. There is evidence that exposure to pollutants contributes to greater morbidity and mortality from respiratory diseases, especially in children, even at concentrations within the standards established by legislation. Identifying the effects of pollutants on the respiratory system, alone and in association, is a challenge and studies have limitations due to the variability of individual response, the presence of pre-existing diseases, socioeconomic factors, exposure to indoor, occupational and environmental pollutants as well tobacco. Most of the evidence on the effect of pollutants on the respiratory system of children comes from studies that include lung function outcomes. However, these studies differ in terms of design, method of assessing exposure to pollutants, measures of lung function, covariates considered capable of altering the response to pollutants, and types of models used in data analysis. Considering all these differences is fundamental in interpreting and comparing the results of these researches with data already existing in the literature.

Keywords: Air pollution, respiratory tract diseases, particulate matter, environmental pollutants, child.

RESUMO

O aumento da prevalência de doenças respiratórias crônicas coincide com o da exposição aos poluentes atmosféricos pelo crescente processo de industrialização, aumento do tráfego veicular e migração da população para áreas urbanas. A poluição do ar é uma mistura complexa de poluentes e outros compostos químicos tóxicos e não tóxicos, e o efeito na saúde pode derivar dessa mistura e da interação com parâmetros meteorológicos. Apesar disso, busca-se estabelecer o papel de um poluente específico em separado e consideram-se os parâmetros meteorológicos como fatores de confusão. Há evidências de que a exposição aos poluentes contribui para maior morbidade e mortalidade por doenças respiratórias, especialmente nas crianças, mesmo em concentrações dentro dos padrões estabelecidos pela legislação. Identificar os efeitos dos poluentes no sistema respiratório, isoladamente e em associação, é um desafio, e os estudos têm limitações devido à variabilidade de resposta individual, a presença de doenças pré-existentes, aos fatores socioeconômicos, às exposições a poluentes intradomiciliares, ocupacionais e ao tabaco. A maioria das evidências sobre o efeito dos poluentes no sistema respiratório de crianças deriva de estudos que incluem desfechos de função pulmonar. Entretanto, esses estudos têm diferenças quanto ao desenho, ao método de avaliação de exposição aos poluentes, às medidas de função pulmonar, às covariáveis consideradas como capazes de alterar a resposta aos poluentes e aos tipos de modelos utilizados na análise dos dados. Considerar todas essas diferenças é fundamental na interpretação e comparação dos resultados dessas pesquisas com os dados já existentes na literatura.

Descritores: Poluição do ar, doenças respiratórias, material particulado, poluentes atmosféricos, criança.

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Introduction

The economic and industrial growth that has taken place in recent decades has caused a significant increase in emissions of atmospheric pollutants and air quality has become a public health problem. The trend of population migration to the urban environment increased exposure to atmospheric pollutants, which contributed to greater morbidity and mortality from causes related to this exposure, such as respiratory diseases.[1-5] These outcomes are mainly described in children, the elderly and those with chronic diseases. Children are more vulnerable to the effects of air pollution due to anatomical characteristics of the airways, the immaturity of the immune system and greater exposure due to being outdoors for a long time.[4,6]

In recent decades, there has been a significant increase in the prevalence of chronic respiratory diseases such as asthma and allergic rhinitis, which coincides with the growing process of industrialization, the increase in vehicular traffic and migration to urban areas, especially in Western countries.[3-5,7,8] At the same time, and in light of the global warming issue, evidence emerged about the influence of temperature on health-related outcomes, such as hospitalizations and emergency room visits due to respiratory diseases, including asthma.[9,10]

In this context, several studies have related not only air pollution, but also other environmental factors, such as exposure to aeroallergens and increased temperature, to greater morbidity and mortality from respiratory diseases.[1,3-5] Studies carried out in different regions have observed that the increase in temperature can reduce lung function, and also that there is an association between increased temperature and concentration of pollutants, in the reduction of parameters of lung function in children.[11-16]

In Brazil, studies relating air pollution and respiratory diseases are scarce. In a systematic review, Froes Asmus et al.[17] analyzed 17 time series studies carried out in urban areas of Brazil, all in the Southeast region. The authors observed an increased risk for wheezing, asthma, and pneumonia in children and adolescents living in areas with high concentrations of nitrogen dioxide (NO_2) and ozone (O_3), and a reduction inpeak expiratory flow (PEF) measurement in children exposed to particulate matter (PM) with an aerodynamic diameter smaller than 10 μm (MP10), particulate matter with an aerodynamic diameter smaller than 2.5 μm (MP2.5) and black carbon (soot). Studies carried out in Rio de Janeiro and São Paulo showed a decrease in pulmonary function related to PM10 and NO_2, although they were within acceptable standards by current legislation most of the time.[17]

A study carried out in Greater Vitória evaluated the relationship between the number of hospitalizations for respiratory diseases, in the period from 2005 to 2010, and observed, through the Generalized Additive Model (MAG), that the increase of 10.49 μg/mm^3 in the levels of PM10 was associated with a 3% increase in the relative risk value for this outcome, even with pollutant concentrations within the limits recommended by the National Council for the Environment (CONAMA) and the World Health Organization (WHO).[18]

In Espírito Santo, the studies carried out revealed, over the last decades, the coexistence of a high prevalence of respiratory diseases in children[19] and a relationship with unfavorable environmental conditions in Vitória, probably due to the increase in vehicular traffic and the existence of industries with polluting potential within the city. of the urban fabric.[20-23] Most of these studies used secondary health data, that is, hospitalizations and emergency care, from Health Information Systems (SIS). These data have the advantages of wide population coverage, the low cost of collecting information and the ease of longitudinal follow-up. However, the limitations of these data are related to the lack of standardization in the collection that affects the quality of the records, the coverage that can vary in time and space, and the lack of information that may be important for the analyzes of interest, which include outcome, explanatory, mediating, confounding or effect-modifying variables.[24] These limitations motivate studies that provide subsidies for the analysis of primary health data with the objective of evaluating the effect of pollution on the respiratory system of children and adolescents living in urban areas in Brazil.

Air pollution

Air pollution can affect human beings at all stages of life, from conception to old age. Since the first reports on the effects of pollution on health occurred in 1930 (Meuse Valley, Belgium) and in 1952 (London, England), many studies have been carried out in an attempt to elucidate the real impact of air pollution on human health.[25-27]

Emissions generated by industries and motor vehicles are the main sources of air pollutants in urban areas and are clearly involved in the genesis of clinical symptoms, as well as in the greater number of hospitalizations and deaths from respiratory diseases.[28-30]

It is well established that ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and PM are the main air pollutants and that even at concentrations within the established limits by regulatory agencies and the WHO pose a risk to human health.[22,27] However, recently the WHO, when reviewing studies on the influence of exposure levels to air pollutants, especially PM10, PM2.5, O_3 and NO_2, and the development and/or worsening of cardiovascular and respiratory diseases, revised these limits and reduced them as shown in Table 1.[31]

PM is a heterogeneous and complex mixture of particles that vary in size, weight, shape, chemical composition, solubility and origin.[31] The particles are classified according to their aerodynamic diameter as: ultrafine (particles with a diameter smaller than 0.1 µm - MP0.1), fine (particles with a diameter between 0.1 and 2.5 µm - MP2.5) and coarse (particles with a diameter between 2.5 and 10 µm – MP10).[32]

MP10 does not reach the lower airways, however, it is the one with the most frequent and consistent relationship with diseases of the respiratory system. MP2,5 and ultrafine particles reach the lower airways and have a greater potential to trigger or worsen respiratory diseases. The ultrafine particles reach the alveoli, reach the blood circulation and generate biological effects (oxidative stress and systemic inflammation) that can be negligible or intense, depending on the characteristics of the individual, the degree of exposure and the chemical composition of PM.[27,33]

The gaseous pollutants SO_2, O_3, NO_2 and CO, when inhaled, trigger a series of biological events. When SO_2 enters the airways and is exposed to water, it forms sulfuric (H_2SO_4) and sulfuric acid (H_2SO_3), which induce bronchoconstriction and bronchospasm.[34] O_3, when inhaled, causes the death of ciliated cells of the respiratory epithelium, compromising the protective function of the epithelium.[35] NO_2 causes inflammation, oxidative stress and hyperreactivity in the airways.[36] CO attaches to oxygen binding sites in hemoglobin causing hypoxia and oxidative stress.[37]

In practice, air pollution is a mixture of these main pollutants and other toxic and non-toxic chemical compounds and the effect on human health can be derived from this mixture.[6] However, most studies seek to establish the role of a specific pollutant or of several pollutants separately on human health. Identifying the possible effects of pollutants on the respiratory system, alone and in association, is a challenge, and studies have limitations due to the variability of individual response, the presence of pre-existing diseases, socioeconomic factors, exposure to indoor and occupational pollutants and tobacco.[27,38-39] In this context, some authors have described deleterious effects when multivariate analysis models are incorporated into data analysis.[21]

Meteorological parameters, temperature, wind, humidity and precipitation act in the transport and dispersion of pollutants and play an important role in the dispersion and deposition of pollutants in the environment, as well as in human health, influencing biological events related to contact with pollutants.[40] Therefore, these parameters are usually considered as confounding factors in pollution studies. Although the negative impact of pollutants and temperature rises on health is well established, few studies have investigated the interactive effect between temperature and air pollution on health outcomes.[11] Some studies have observed over time that exposure to atmospheric pollutants and meteorological parameters are related to the occurrence of acute respiratory infections and greater severity of asthma.[41,42]

Those most susceptible to the effects of pollutants and temperature variations are children, the elderly and those with chronic diseases, especially cardiovascular and respiratory diseases.[12] The strongest evidence for the effects of air pollution on children's health, for example, comes from studies of lung function. The oxidative stress generated by pollutants causes inflammation in the lungs, which can contribute to a decrease in lung function in the short and long term.[43,44] Recent studies have observed a relationship between temperature elevation, concentration of pollutants and reduction in pulmonary function parameters, both in children with preexisting lung disease[12] and in healthy young adults,[14] which reinforces the need for a better understanding of this interaction.

Air quality

The interaction between pollution sources and the atmosphere determines the air quality of a given region. Monitoring air quality allows estimating exposure in the population by measuring the concentration of pollutants. According to WHO data, more than 90% of the world's population lives in places where pollutant levels are not in accordance with previously established limits.[45] The systematic measurement of air quality is restricted to a number of pollutants, defined according to their importance and the resources available for their monitoring.

In Brazil, air quality standards were established by the resolution of the National Council for the Environment - CONAMA nº 03, of 1990. These standards are divided into primary and secondary, and represent the concentrations of atmospheric pollutants that, when exceeded, can affect the health, safety and well-being of the population, as well as causing damage to flora and fauna, materials and the environment in general, and were updated in 2018.[46] The *primary* air quality standards are the concentrations of pollutants that, when exceeded, can affect the health of the population and *secondary* standards are the concentrations of pollutants below which the minimum adverse effect on the well-being of the population is expected, as well as the minimum damage to fauna, flora, materials and the environment in general. In this first resolution, it was established that the monitoring of air quality is the responsibility of the States.[46]

The limits of some air pollutants[41] were revised based on clinical studies that evaluated the relationship between the level of exposure and the development and/or worsening of diseases, reducing them.[31] It is also noteworthy that the knowledge accumulated over the years allows us to infer that the harmful effects of pollutants on the health of the population can occur at concentrations lower than those previously established.[41]

The WHO guidelines and national air quality standards present reference values associated with the health effects caused by short and long exposure for each pollutant, in order to prevent acute and chronic effects, respectively. However, for the pollutants SO_2, O_3 and CO, the WHO establishes a guideline only for reference values for short exposure.[31]

Table 1 shows the air quality standards in Brazil[46] and those recently established by the WHO in 2021.[31] In it, we see that there was a reduction for almost all of the pollutants.

Effects of air pollution on human health

Air pollution causes harmful effects to human health even when pollutant levels are within the standards established by regulatory agencies.[31] These effects range from physiological changes, which do not cause relevant clinical manifestations and affect a greater proportion of people, to outcomes with greater impact, such as death, which affects a smaller percentage of the exposed population.[31] Thus, the WHO illustrates these outcomes as a pyramid, which considers the magnitude and severity of the effects of exposure to air pollutants (Figure 1).

The effects of air pollution on health are considered to be short-term or long-term, depending on the time of exposure to pollutants (Table 2). Studies on the short-term effects (days or weeks) on children's respiratory health have increased in recent years compared to those evaluating the effects of long-term exposure (one or more years). The latter are, in most cases, carried out in North American and European cities, with moderate levels of atmospheric pollution.[47-50]

Effects of air pollution on the respiratory system

The strongest evidence on the effects of air pollution on the health of the respiratory system is obtained from studies in children and with monitoring of lung function. Children are more susceptible to these effects due to inherent characteristics of the age group: (1) immaturity of the immune system predisposing the occurrence of respiratory infections; (2) greater area of airway extension in relation to body size; (3) higher ventilation rate per unit of body weight; (4) anatomically smaller peripheral airways, which results in greater obstruction in the face of an inflammatory process; and (5) higher prevalence of chronic respiratory diseases such as asthma and rhinitis.[6]

In addition, children engage in outdoor activities, usually during the day, when pollutants may be at higher levels, increasing the chance of harmful effects on the respiratory system.

At birth, the lungs are not fully developed and 80% of the alveolar area responsible for gas exchange will form by approximately 6 years of age. The functional development of the lungs extends until adolescence, and contact with pollutants during this period can cause loss of lung function, with the consequent emergence of respiratory diseases in childhood or adulthood.[6] Therefore,exposure to air pollutants can negatively affect lung development in children, causing a deficit in lung function, which is considered a risk factor for the development of lung disease and death in adulthood. Thus, studies to assess the relationship between lung function and air pollution are complex because characteristics inherent to the individual and the intra- and extra-domestic environment contribute to variations throughout life.

A long-term study evaluated the effects of exposure to air pollutants on lung development in American children. At the end of four years, there was a significant association between exposure to PM10, NO_2 and inorganic acid vapor, with a reduction in lung growth, with no relation to sex, different from what was

Table 1
Air quality standards in Brazil according to the National Council for the Environment (CONAMA)[46] and the new recommendations of the World Organization of Health (WHO)[31]

		Air Quality Benchmarks									
		CONAMA					WHO 2021				
		Intermediaries			Final		Intermediaries				Level
	Reference	PI-1	PI-2	PI-3	PF		1	2	3	4	AQG
Pollutant	period	µg/m³	µg/m³	µg/m³	µg/m³	ppm	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
PM10	24 hours	120	100	75	50	–	150	100	75	50	45
	Annual [a]	40	35	30	20	–	70	50	30	20	15
PM2.5	24 hours	60	50	37	25	–	75	50	37.5	25	15
	Annual [a]	20	17	15	10	–	35	25	15	10	5
SO_2	24 hours	125	50	30	20	–	125	50	–	–	40
	Annual [a]	40	30	20	–	–	–	–	–	–	–
NO_2	1 hour [b]	260	240	220	200	–	–	–	–	–	–
	Annual [a]	60	50	45	40	–	40	30	20	–	10
O_3	8 hours [c]	140	130	120	100	–	160	120	–	–	100
Smoke	24 hours	120	100	75	50	–	–	–	–	–	–
	Annual [a]	40	35	30	20	–	–	–	–	–	–
CO	8 hours [c]	–	–	–	–	9	7	–	–	–	4
TSP	24 hours	–	–	–	240	–	–	–	–	–	–
	Annual [d]	–	–	–	80	–	–	–	–	–	–
Pb [e]	Annual [a]	–	–	–	0.5	–	–	–	–	–	–

ppm = parts per million, PM10 = particulate matter with a diameter of less than 10 µm, PM2.5 = particulate matter with a diameter of less than 2.5 µm, SO_2 = sulfur dioxide, NO_2 = nitrogen dioxide, O_3 = ozone, CO = carbon monoxide, TSP = total suspended particles, Pb = lead, a = annual arithmetic average, b = hourly average, c = maximum moving average obtained in the day, d = annual geometric average, e = measured in TSP, AQG = Air Quality guidelines.

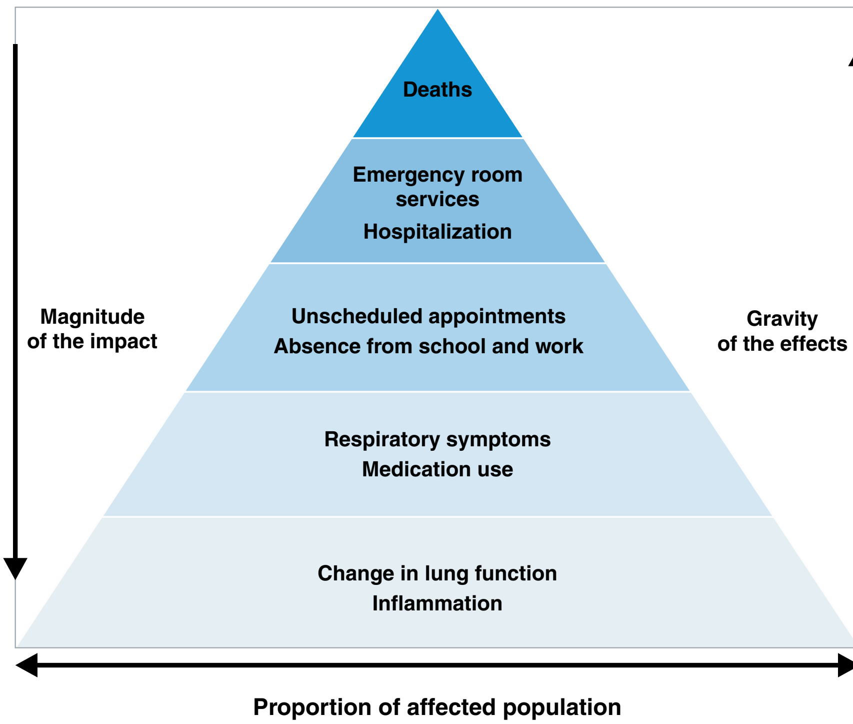

Figure 1
Effects of exposure to pollutants on the respiratory system[31,45]

observed by the same authors in a previous study.[51] There was a cumulative reduction of 3.4% in forced expiratory volume in one second (FEV1), and of 5% in maximum expiratory flow (MMEF).[52] With the follow-up of these patients, the authors found that children living in more polluted communities had a deficit of 100 mL in FEV1 (7% females and 4% males), when compared with children from non-polluted areas,[53] and who were five times more likely to present clinical manifestations of pulmonary function deficit at age 18 than those who lived in non-polluted areas.[54]

Rojas-Martinez et al. followed 3,170 8-year-old schoolchildren from schools located within 2 km of 10 air quality monitoring stations over a 3-year period and studied the relationship between long-term exposure to PM10, NO_2, and O_3 and lung development. The authors observed a deficit in lung growth (forced vital capacity, FVC and FEV1) related to the concentrations of O_3, PM10 and NO_2, with girls being the most affected.[55] Similar results were observed by other studies.[56]

Liu et al. investigated the acute effects of pollutants PM2.5, SO_2, NO_2 and O_3 on lung function, oxidative stress and inflammation in children and adolescents with asthma, during 4 weeks.[39] The increase in the level of PM2.5, SO_2 and NO_2 was associated with a decrease in FEV1 and forced expiratory flow between 25% and 75% of FVC (FEF25-75%), and with an increase in inflammation markers, indicating that the Air pollution can increase oxidative stress and reduce small airway function. The estimated risk was lower in children treated with inhaled corticosteroids.[39]

A study carried out in Taubaté, in the interior of the state of São Paulo, showed a higher prevalence of asthma among adolescents who lived close to a highway with very heavy vehicle traffic.[57]

Table 2
Effects of air pollution on health[45]

Exposure to air pollutants
Short term
• Daily mortality
• Hospital admissions for respiratory or cardiovascular disease
• Emergency care for respiratory or cardiovascular disease
• Primary care services
• Activity restriction days
• Absenteeism at work
• Absenteeism from school
• Acute symptoms (wheezing, coughing, respiratory infections)
• Physiological changes (eg lung function)
Long term
• Mortality from cardiovascular or respiratory disease
• Hospital admissions for respiratory or cardiovascular disease
• Chronic changes in physiological functions
• Lung cancer
• Cardiovascular disease
• Intrauterine growth problems (low birth weight, intrauterine growth retardation, low weight for gestational age)

Other studies have shown a relationship between exposure to higher levels of air pollutants and impaired lung function.[49,50,58-61]

In Brazil, a study conducted in the Amazon with children and adolescents observed that for an increase of 10 μg/m³ in the concentration of PM2.5, there was a significant reduction in PEF (0.26 to 0.38 L/min).[62] In Espírito Santo, in an area exposed to industrial emissions from a mining company, daily monitoring of the PEF of children and adolescents documented a significant negative association of this parameter with the concentration of PM10. A 14 μg/m³ increase in PM10 concentration was associated with a reduction in morning (-1.04%) and evening (-1.2%) PEF measurements, even after adjusting for temperature and humidity.[63]

In summary, in recent decades the environment has undergone profound changes due to increased emission of atmospheric pollutants and climate change. At the same time, there was an epidemiological transition and chronic respiratory diseases, such as asthma and rhinitis, became more prevalent than infectious diseases. In this context, it is well established that particulate matter and gaseous pollutants cause damage to the respiratory system, especially in children. However, the studies have differences in design, in the method of assessing exposure to pollutants, in pulmonary function measurements, in the covariates considered capable of altering the response to pollutants, and in the types of models used in data analysis.

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