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REVIEW ARTICLE

Impact of air pollution in respiratory allergic diseases



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Abstract Allergic respiratory disease, which includes allergic rhinoconjunctivitis and asthma, is one of the most common diseases, with a major impact on a patient's quality of life. Air pollution is one of the main factors associated with the development of allergic respiratory disease, it has been shown to impair lung development in children and adolescents. The origins of particulate matter produced from various sources, including those issued by traffic and the burning of fuels such as coal, gasoline and diesel. Diesel emissions represent the majority of the particulate matter in urban air pollution. It has been found that the co-exposure of diesel emissions and airborne allergens increases allergen-specific IgE levels, severity of asthma, inflammation and airway hyper-responsiveness. *In vivo* and *in vitro* studies have reported the activation of anti-transcription and pro-inflammatory mediators. Polycyclic aromatic hydrocarbons, metal components or metabolites may increase due to the formation of oxygen reactive species that interact with DNA, producing different types of damage as oxidative damage.

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Introduction

Allergic respiratory disease (ARD) is a frequent atopic condition, manifesting through allergic rhinoconjunctivitis and

asthma. Affecting up to 40% of the population worldwide and with a significant impact over the quality of life of those who suffer from it.^{1,2} In recent years there has been a considerable increase of air pollutants due to the development of large cities with high industrial activity and linked to an ever increasing number of cars; thus becoming an emergent problem in many countries.³ In the US, the cost of asthma attributable to ozone and nitrogen dioxide exposure is 441 million dollars a year, 202 million dollars a year in Los Angeles alone.⁴ In a different American study, estimations suggest a cost of 18 million dollars a year in health services directly

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or indirectly attributable to asthma crises linked to exposure to traffic-derivate pollutants.⁵

The development of an allergic disease takes place due to the interaction of genetic predisposition and environmental determinants. Air pollution is one of the main environmental factors linked to the onset of ARD, as well as its exacerbations.⁶ Air pollution has been proven to alter the pulmonary development of children and teenagers.^{7,8}

Air pollution

Air pollution is defined as the alteration of the pureness and quality of air caused by the emission of chemical or biological substances released naturally or produced by man and his everyday activities. Among these are particulate matter (PM) with a diameter of less than 10 μm (PM 10), inhalable fine particulates if their diameter is less than 2.5 μm (PM2.5) and ultrafine particulates (UFPs) which are smaller than 0.1 μm .⁹ According to the World Health Organization (WHO), PM2.5 is 25 $\mu\text{m}/\text{m}^3$, and the daily allowed exposure limit for PM10 is 50 $\mu\text{m}/\text{m}^3$.¹⁰ As reported, every increase of 10 mg/m^3 of PM10 was linked to an 0.46% increase in the mortality rate in the US.¹¹ In Mexico, the Official Mexican Standard (NOM by its Spanish acronym) NOM-025-SSA1-2014 establishes the permissible limit values for concentrations of PM10 and PM2.5 suspended particles in the environment, which are, for particles under 10 micrometers (PM10) and 2.5 micrometers (PM2.5), an average limit of 24 h of 75 $\mu\text{m}/\text{m}^3$ and 45 $\mu\text{m}/\text{m}^3$ respectively.¹²

PMs are produced from several sources, including those emitted by traffic, carbon combustion, gas, diesel and other types of fuels. Secondary emissions from diesel represent the majority of particulate matter from urban air pollution.¹³ The size of the particle, its surface and its chemical composition determines the risk that it represents in a patient who is exposed to it regularly. According to their size, the MPs can easily access the airway, even reaching the alveoli and thereby causing direct damage as a result of irritation, or provoking oxidative stress by activating various signal transmission pathways and transcription factors.¹⁴

In 2008, Gluckman et al.¹⁵ showed that prenatal and postnatal exposure to air pollution negatively influences developmental plasticity, resulting in a wide range of diseases in childhood. Recently, Fleisch et al.,¹⁶ proved that exposure to contaminated air during pregnancy is associated with an increased risk of adverse birth outcomes. However, the negative impact of air pollution goes further. Deng et al.,¹⁷ found a significant association between the development of asthma and allergic rhinitis in Chinese children whose mothers were exposed to air pollution during pregnancy. All these findings could be explained by different epigenetic mechanisms, such as DNA methylation, where the different contaminants play an important role in the development of allergic diseases.

Ozone (O_3) is a molecule composed of 3 oxygen atoms. It is formed from the dissociation of an oxygen molecule (O_2) by joining a released atom to an O_2 molecule. Tropospheric ozone is a colorless gas created by photochemical reactions between nitrogen oxide and volatile organic compounds from the combustion of gasoline, diesel or fossil fuels.¹⁸ It acts as a strong oxidant that has been associated

with persistent structural damage and injury to lung tissue, which leads to exacerbation of asthma symptoms.⁸ Further epidemiological studies are needed to know and document the morbidity and mortality rates associated with ozone exposure.

Traffic smoke has been shown to have an association with accelerated growth of allergies and asthma in childhood.¹⁹ This process involves the residue oil fly ash (ROFA), which is a complex mixture of sulfates and metals, specifically vanadium, that have the potential ability to influence immunity and cause damage to various systems, being a critical factor in the hyper-responsiveness and injury of the airway.²⁰

Air pollution and aerospheric allergies

Air pollutants have the ability to modify the allergenicity of certain pollens. They facilitate dispersion of the pollen allergen into smaller fractions. Specifically ozone, in an experimental model, produced a structural change in the coating layers of the pollen, inducing modification in pollen-plant interactions, pollen-human cells and potentiating the allergenic properties of pollen.²¹

Kim et al.²² reported that exposure to ozone was significantly associated with the rate of new sensitization to outdoor allergens, which could explain the mechanism for the increase in the prevalence of allergic rhinitis. Likewise, it has been found that the co-exposure to diesel and airborne allergens emissions increases the levels of allergen-specific IgE, asthma severity, and airway inflammation and hyper-reactivity.²³

Air pollution and ARD

According to the World Health Organization (WHO), several million people around the world suffer from rhinitis, and an estimated 300 million have asthma, and these diseases significantly affect the patient's quality of life and family environment, leading to a negative impact on the socioeconomic well-being of society. The major problem of environmental pollution in industrialized countries is responsible for nearly 2 million deaths per year in developing countries.²⁴

Air pollutants have the ability to affect the presentation of asthma in different ways: acting as a stimulator or trigger, aggravating pre-existing airway inflammation, and modifying the response to aeroallergens or substances that act as irritants in the airways.²⁵

The way in which air pollutants impact the development of asthma and allergies has been the subject of investigation and controversy. Two studies in California found that contaminants related to vehicular traffic can cause asthma in older children. Another study reported that children exercising in areas with high concentrations of ozone were more likely to develop asthma.²⁶ A Japanese study looked for an association between asthma and nitrogen oxide (NO_2) levels, with a sample universe of 2506 children studied over a period of 4 years, and concluded that children living at a distance of less than 50 m from roads with heavy vehicle loads were more prone to asthma development.²⁷

There is a "modern" indicator of pollution, NO_2 , which has been attributed to an increase in the presentation of

asthma and wheezing.²⁸ However, in another study, the agent was unrelated to the prevalence of allergic symptoms. What was demonstrated was the increased risk of recent symptoms of both allergic rhinitis and asthma in schoolchildren associated with SO₂ and CO levels.²⁹

Diesel engine particles (DEP), the main constituents of urban air pollutants, have been shown to be able to modulate the pulmonary immune response by stimulating the function of dendritic cells and thus induce inflammatory processes in the airway.³⁰ Diesel emissions contain small particles of various sizes, ranging from nanoparticles to coarser particles, the latter of which are the most easily drawn into the lungs and can be kept suspended in the atmosphere for long periods of time. These consist of a carbonaceous core with a large surface area to which other chemicals are adhered, such as polycyclic aromatic hydrocarbons (PAHs) as well as heterocyclic, aldehydes and aliphatic hydrocarbons.³¹

These diesel particles are able to reach the cell's surface and activate molecular mechanisms by stimulating human airway epithelial cells to produce cytokines, which lead to inflammation. In *in vitro* studies, once these particles reach the epithelial cells, IL-8, macrophages, granulocyte colony stimulating factor, T cells and intracellular adhesion molecules (ICAMs) are released, which are found in significantly higher amounts in patients with asthma. It has also been shown to affect gene expression by inducing eotaxin from epithelial cells.³²

Salvi et al., studied the effects of high-level diesel inhalation in a chamber; a significant increase in inflammatory cells (neutrophils, B lymphocytes, mast cells, CD4 and CD8 lymphocytes) was demonstrated, along with the positive regulation of ICAM.³³ Reactive oxygen species, due to the effects of DEP and their consequent release of IL-8, ICAM-1, GM-CSF and RANTES, are inhibited on exposure to antioxidant agents such as N-acetylcysteine.³²

The mechanisms which cause double chain DNA break in pulmonary cells have been found to be secondary to the impact of air pollution in the mRNA expression in humans due to the activity of the telomerase and phosphorylation of H2AX histone. DNA damage induced by particulate matter made of metals (copper, iron, nickel, vanadium, zinc and lead) and polycyclic aromatic hydrocarbons (PAHs) is metabolized and then covalently bonded in the DNA.³⁴ The components of the metals or the metabolites of PAHs can be increased in the formation of oxygen reactive species that interact with the DNA, producing damage of different types, such as oxidative damage.³⁵

Variations in environmental influences on individual genotypes can lead to heterogeneous endotypes of asthma. Several phenotypes of severe clinical expression may overlap in one patient, and the same clinical phenotype may result in different endotypes, which would be reflected in the severity of the disease and its response to conventional treatments.³⁶

Intramural contaminants

Today, a large number of people from industrialized cities spend most of their time at either their home or their job. It has been reported that more than half of the air inhaled

during one's life comes from an intramural environment.³⁷ The sources of intramural contaminants come mainly from cigarette smoke, combustion products such as candles or incense, and volatile organic compounds emitted by building materials, paints, furniture with sponge cushions and products containing polyvinyl chloride (PVC). In a study of newborns in Germany, the concentrations of intramural contaminants (PM₁, PM_{2.5} and PM₁₀) were higher than the PM₁₀ extramural values recommended by the European Union.³⁸

Choi et al. found that the average concentration of individual compounds of volatile organic compounds was consistently higher in the households of children diagnosed with asthma, rhinitis, and eczema compared to the homes of children in a control group. These results suggest that intramural air exacerbates and/or induces the multiple symptoms of allergy, asthma, rhinitis and eczema.³⁹

Conclusions

Air pollution is a key factor in the development and increase of ARD exacerbations. The epigenetic, cellular and molecular mechanisms that directly or indirectly intervene in allergic diseases, and how they contribute to the negative impact of patients' quality of life have not yet been extensively described. Patients are advised to minimize prolonged exposure to pollutants by methods such as reducing extramural activities on days with high levels of air pollution and promoting reforestation of non-allergenic trees in urban areas. As health personnel, we have the obligation to unite our efforts, participate actively in forums and support national and international environmental policies with the purpose of reducing the impact and consequences of this health problem in the future.

Conflict of interest

The authors have no conflicts of interest to declare.

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