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The effects of air pollution on the development of allergic diseases

Wpływ zanieczyszczenia powietrza na rozwój chorób alergicznych

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Additional key words:
air pollution
allergy
asthma
allergic rhinitis

Dodatkowe słowa kluczowe:
zanieczyszczenie powietrza
alergia
astma
alergiczny nieżyt nosa

During the past years, air pollution created by humans has become a major problem increasing the public awareness. The incidence of allergic disease is high and continues to increase in populations of urban areas of Westernized countries throughout the world. The aim of this article is to summarize current knowledge of the effects of air pollution on the development of allergic diseases. In the paper the effect of outdoor and indoor air pollution is described with potential and proven mechanisms of action on the development of allergic diseases.

W ciągu ostatnich lat zanieczyszczenie powietrza wynikające z rozwoju cywilizacyjnego stało się poważnym problemem, a świadomość związanych z tym zagrożeń ciągle rośnie. Częstość występowania chorób alergicznych jest duża i stale rośnie w populacjach obszarów miejskich krajów zachodnich na całym świecie. Celem niniejszego artykułu jest podsumowanie aktualnej wiedzy na temat wpływu zanieczyszczenia powietrza na rozwój chorób alergicznych. W pracy przedstawiono wpływ zewnątrz- i wewnątrzpochodnego zanieczyszczenia powietrza poprzez potencjalne i udowodnione mechanizmy na ich rozwój tych chorób.

Introduction

Air pollution is a general term used to describe undesirable amounts of particulate or gaseous matter in the atmosphere. The United States Environmental Protection Agency (EPA) defines air pollution as “any visible or invisible particle or gas found in the air that is not part of the natural composition of air” [1]. Air pollution can be natural or anthropogenic. During the past years, air pollution created by humans has become a major, persistent problem increasing the public awareness. The aim of this article is to summarize current knowledge of the effects of air pollution on the development of allergic diseases.

Epidemiology

The incidence of allergic diseases is high and continues to increase in populations of urban areas of Westernized countries throughout the world [2]. Globally, 300 million people suffer from asthma and about 200 to 250 million people suffer from food allergies [3]. One tenth of the global population suffers from drug allergies and 400 million from rhinitis [3]. Moreover, allergic diseases commonly occur together in the same individual, one disease with the other [2].

Approximately 20% of Europeans have symptoms of allergic rhinitis (15-20% severe) and 5-11% are diagnosed with asthma [4]. It has been estimated that 12% of the population of Poland (4.5 million) suffer from asthma [5]. This prevalence of asthma in children is estimated at 8.6% (95% CI: 7.7-9.6) and 5.4% (95% CI: 5.0-5.8) in adults [6]. According to ECAP (Epidemiology of Allergic Diseases in Poland) study, which started in Poland in 2005, allergic diseases affect about 40% of Poles, with allergic rhinitis affecting 25% and asthma 12% of inhabitants [7].

Environmental factors

Changes in genetic factors are unlikely to be the underlying cause of the rise in allergic diseases, since the increases in allergic rhinitis and asthma occurred relatively rapidly [8]. Instead, multiple environmental factors may have played a role. These include improvements in hygiene, eradication of most parasitic worm infections, changes in home heating and ventilation, and a decline in physical activity and alterations in diet due to lifestyle changes [8].There is also increasing literature on potential mechanisms by which environmental exposures associated with specific epigenetic changes could lead to allergic phenotypes [8,9].

Allergic diseases are more common in highly developed countries. This suggests that there must be a factor associated with urban life that promotes allergy. There is mounting evidence from epidemiologic and laboratory research of an important cause of allergy in Westernized civilizations: protection from bacterial exposure and bacterial infection in childhood through hygiene and liberal use of antibiotics (the hygienic theory of allergy proposed in 1958) [10,11]. Certain bacterial products appear to affect the developing immune system in childhood by diverting immune responses away from allergy [11].

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Outdoor air pollution

The increased rates of allergy and asthma in city environments and in those living close to increased road traffic has drawn attention to the role of outdoor pollution. Traffic and power generation are the main sources of urban air pollution [12]. Common air pollutants, such as ozone, sulphur dioxide, and nitrogen dioxide probably act as irritants as well as promoters of sensitization.

Exposure to elevated ozone levels is a contributor to the exacerbation of lung disease estimated by lower lung function [13]. It increases the rate of newly developed sensitization to outdoor allergens [14]. High ozone levels increase allergic response of nasal mucosa, and the increased mucosal sensitivity in allergic rhinitis leads to a greater response to ozone [15]. Ozone exposure was found disproportionately dangerous for children comparing to adults [16].

Sulphur dioxide was found to amplify allergic inflammation, and potentially promote neurogenic inflammation due to chemical irritant properties. It is also responsible for bronchoconstrictionin asthmatics [17]. Exposition to sulphur dioxide and benzene in polluted air is significantly positively associated with asthma incidence in urban children [18]. Apart from asthma, bronchitisand pulmonary infections were found to be related to the long-term benzene exposure [19].

An interesting conclusion was proposed by researchers analysing the effect of rising carbon dioxide emission. It may increase plants pollination and therefore contribute to a rise in allergic diseases of the airways [20]. Animal model and human subjects studies imply that nitrogen dioxide seems to be of less importance than combustion particles in the development of allergic diseases after exposure to traffic--related air pollution (TRAP) [21,22].

With respect to health effects the most important TRAP is particulate matter. Particulate matter has compartmental deposition, the smallest particles reach the lower airways [12]. In Europe, exhaust from motor vehicle traffic is considered to contribute to more than 50% of ambient particulate matter with a mass median aerodynamic diameter less than 10 μm (known as PM10) [23-25]. The contribution of automobile traffic is even higher for black smoke fine particles (particulate matter with a diameter below 2.5 μm, known as PM2.5) and ultrafine particles (diameter below 0.1 μm) [26].

Diesel exhaust particle (DEP) could play a part in causing allergy in human populations. It was demonstrated that exposure to DEP, even at a dose that alone causes no inflammation, exacerbates allergic asthma in young animals suggesting the importance of preventive measures to reduce the exposure of children to traffic related air pollution [27]. A potential explanation may be found in a fact that DEP exposure may result in accumulation of allergen-specific TH2/TH17 cells in the lungs, potentiating secondary allergen recall responses and promoting the development of allergic asthma [28]. Most of these immune responses are mediated by the carbon core of diesel exhaust particulates. Polyaromatic hydrocarbons (e.g., anthracene, fluoranthene, pyrene, phenanthrene) are major chemical components of diesel exhaust particulates, and they have enhanced the production of immunoglobulin E [29].

Indoor air pollution

By far the most important indoor pollutant is tobacco smoke. Exposure to environmental tobacco smoke (ETS) levels depend on the intensity of smoking, room size and air exchange [30]. Environmental tobacco smoke is produced from the sidestream smoke released from the burning tobacco product and mainstream smoke exhaled by the smoker [30]. The amounts of different compounds emitted from a cigarette are greater in the sidestream smoke, 2–5 times higher than in the mainstream smoke, having a potential for contamination of indoor air [31]. Tobacco can also act as an allergen, and has the ability to induce the production of specific IgE antibodies [32] which favour the development of allergic diseases in both children and adults [33].

Smoking is strongly associated with respiratory illnesses. Both active and passive (secondhand, SHS) smoking is highly correlated with the incidence of asthma [7]. SHS can trigger asthma episodes and increase the severity of attacks [34]. SHS was found to be a risk factor for new cases of asthma in preschool-aged children [35]. It is very important since at least in Poland every day about 4 million children passively inhaled tobacco smoke in the home or in public places [36]. The rate of asthma in an infant of a smoking mother is double that of a non-smoking mother. Smoking during pregnancy and breastfeeding results in a higher risk for the children to develop atopic eczema (atopic dermatitis) [37]. It is estimated that 15 to 25% of women smoke during pregnancy [38]. Therefore EPA has issued a warning that children receiving high doses of SHS, such as those with smoking parents, run the greatest relative risk of experiencing damaging health effects [39].

Other indoor pollutants are observed outdoors, but in different concentrations. Indoors there is more aldehydes (formaldehyde), carbon oxides, fibres, bacteria, virus, parasites, and less pollution connected with traffic and industry activity. Indoor pollution mixed with physical factors (temperature, low humidity, ionized particles emitted by copying machines etc.) cause sick building syndrome that can influence allergy symptoms.

Summary

In summary, air pollution might contribute to the development and exacerbation of allergic inflammation by oxidative stress and damage, mucosal remodelling, enhancement of inflammatory pathways and immunological responses, and increase in risk of sensitisation to aeroallergens which in a genetically predisposed individual could result in clinical allergic disease [12,25,40].

Air quality, at least in Europe, has improved markedly in recent decades but air pollution remains the principal environmental factor linked to preventable illness and premature mortality in the EU [41]. It seems that without taking legal actions that would contribute to the achievement of the necessary emissions reductions the quality of the air and morbidity related with it will not improve.

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