

# Progress in the impact of polluted meteorological conditions on the incidence of asthma

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**Abstract:** It has been revealed by many studies that air pollution is one of the important inducements of asthma exacerbations. In addition, meteorological conditions such as high atmospheric pressure, low temperature, low humidity and large diurnal amplitude can directly induce asthma. Meanwhile, meteorological conditions play an important role in the diffusion, dilution and accumulation of air pollution. This article reviewed research progress in the impact of polluted meteorological conditions on the incidence of asthma.

**Keywords:** Asthma; air pollution; meteorological conditions

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In recent years, there is a marked increase in the incidence of bronchial asthma in China's large cities. In Beijing, the prevalence of childhood asthma in 2000 is 2.6 times of that in 1990 (1). The influence of atmospheric pollution should not be ignored. The particulate matter (PM), Ozone (O<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>) and sulfur dioxide (SO<sub>2</sub>) may trigger or aggravate asthma; meteorological conditions determine diffusion and aggregation of the pollutants in the atmosphere, thus the conditions play a key role on real human exposure. At the same time, some meteorological factors can also directly induce asthma. This article reviewed research progress in the impact of polluted meteorological conditions on the incidence of asthma.

## Air pollution (PM<sub>10</sub>, PM<sub>2.5</sub>, O<sub>3</sub>, SO<sub>2</sub> and NO<sub>2</sub>) may trigger or aggravate asthma

Asthma can occur in the patients of different ethnicity. There is evidence to suggest that environmental factors are more important than ethnicity, though genetic factor is an important factor in controlling asthma. The Clean Air Act Amendments of 1990 includes six kinds of air pollutants, which are O<sub>3</sub>, SO<sub>2</sub>, NO<sub>2</sub>, PM, Carbon monoxide and lead. Studies have confirmed the previous four air pollutants may

induce or aggravate asthma.

Air pollutants interact with fungal spores, pollen, other air pollutants antigen and modified antigen properties of these antigens. The air pollution makes existing airway inflammation aggravate, and prompts a twitch in bronchus, which triggers asthma attack or worsen asthma symptoms. 90% of oxidant pollutants in the air are O<sub>3</sub>. About 40% to 60% O<sub>3</sub> is absorbed within the nasal cavity, the rest part get into the trachea and alveolar. Studies have shown that inhalation of high concentration of O<sub>3</sub> compromise lung function in the patients with asthma, and increase bronchial response to specific and nonspecific allergen, which eventually lead to asthma attacks (2). O<sub>3</sub> also lowers the threshold of specific antigen concentration to trigger asthma, thus to promote asthma attacks.

Same as O<sub>3</sub>, NO<sub>2</sub> is another oxidant pollutant, but it is less chemical active compared with O<sub>3</sub>. NO<sub>2</sub> is a precursor of photochemical smog. It exists in the atmosphere of urban and industrial region, producing O<sub>3</sub> under the effect that sunlight interacts with hydrocarbon. Exhaust of motor vehicle is the main source of NO<sub>2</sub> in the air. NO<sub>2</sub> has the largest effect on people indoor, which mainly comes from the kitchen that uses gas. The epidemiological survey suggests that long time NO<sub>2</sub> exposure is associated with the

increased incidence of asthma and rhinitis (3).

Burning coal and oil contain sulfur will release  $\text{SO}_2$  in the atmosphere. It has been proved that certain concentration of  $\text{SO}_2$  can induce bronchial inflammation and bronchospasm in healthy people.  $\text{SO}_2$  induces bronchospasm for the patients with asthma even the concentration of it is very low. Moreover, patients with asthma inhale high flow of  $\text{SO}_2$  in a short time (such as motion), which is more likely to induce bronchospasm compared to  $\text{O}_3$ .

PM is one of the major components of air pollutants in the city, and does great harm to human health. It's a mix of all kinds of sources, components, sizes of solid particles, including pollen and mold spores. PM includes PM10 (aerodynamic equivalent diameter  $\leq 10 \mu\text{m}$ ) and PM2.5 (aerodynamic equivalent diameter  $\leq 2.5 \mu\text{m}$ ). PM gets into the lower respiratory tract when people are breathing. Transitional metals in PM such as iron, cobalt, copper, zinc, manganese, nickel and vanadium, titanium, etc., can damage epithelial cells in the airway and induce epithelial cells producing free radicals, as demonstrated in animal experiments. Moreover, these free radicals release all kinds of inflammatory mediators (4). In a number of relevant epidemiological surveys, PM has the strongest correlation with asthma as air pollutants.

Ninety percent of the world's PM in large cities comes from the diesel exhaust particles (DEP). Although the carbon dioxide exhausted from diesel engine is much less, its emissions of  $\text{NO}_2$ , aldehyde and PM is 10 times of unleaded gasoline engine, and is 100 times of the gasoline engine installed with catalytic conversion machine. DEP plays an important role in inducing asthma via a variety of special chemicals such as aromatic hydrocarbons. DEP stays in the airway mucosa. Epithelial cells and pulmonary macrophages in airway can ingest DEP, and the aromatic hydrocarbon in DEP is easy to penetrate the cell membrane, integrating with the receptor complexes in the cytoplasm, and producing inflammation factors, such as IL-26, IL-28 and GM-CSF, etc. IL-28 is chemotactic for neutrophils, eosinophils, lymphocytes to accumulate, it triggers the release of histamine, leading to an increase in plasma's leakage and the contraction of airway smooth muscle. A number of epidemiological investigations suggested PM10 has the strongest correlation with asthma (5,6). The source and composition of PM10 are complicated, it can adsorb allergen released by pollen in the air and extend retention time of allergens in respiratory tract like DEP, thus promoting the IgE mediated immune responses, which is one of the main pathogenesis of asthma.

In addition to aggravating or inducing asthma, research demonstrated  $\text{O}_3$ ,  $\text{SO}_2$ ,  $\text{NO}_2$  and aeroallergen have combined effect in patients with asthma, which increase airway response to inhaled allergens and aggravate induced asthma (7). As  $\text{O}_3$  and fungal spores aggravating asthma symptoms as a co-factor, organic pollutants in atmosphere can also synergize dust mite allergen, which makes adverse effects enhanced significantly for vulnerable groups (8). In addition, air pollution damage epithelial cells in the airway, results in a decreased clearance rate of mucosa cilia and produces airway inflammation, which makes it easier for the antigen to get into the respiratory tract and contact with immune cells, and finally induces asthma or worsen the condition (9).

### **High atmospheric pressure, low temperature, low humidity and large diurnal amplitude may directly induce asthma**

The role of meteorological factors (including atmospheric pressure, temperature and humidity) in the mechanism of inducing and aggravating asthma is still not clear. Inhalation of cold air can compromise lung function in patients with asthma and induce bronchospasm. Whether the pressure rise or fall, it still appears to trigger asthma attacks. Emissions of greenhouse gas accelerate global warming, affecting the growth and development of plants directly or indirectly, and rising of temperature in the winter and spring will make pollination period of plants earlier. The result is to make the total time period of pollination longer. The rising of temperature also makes autumn become longer. This created the conditions for fungal spores to extend residence time in the air. The pollen and spores often carry large amounts of allergen, which is the most common pathogenic factor of asthma (10).

The interaction between air pollutants and plants is very complicated and is associated with the species of pollutant, the species of plants, nutritional balance of soil and climatic factors. Air pollution damage epithelial cells in the airway, making clearance rate of mucosa cilia decreased and producing airway inflammation in the airway, which is advantageous for the antigen to get into the respiratory tract and contact with immune cells, thus inducing asthma or worsening condition (9,11).

Under different conditions of air pollution, it remains to be further studied that the influence of meteorological factors on asthma groups, as well as the synergy between meteorological factors and atmospheric composition.

## Meteorological conditions play a key role in air pollution and human exposure

Meteorological conditions play an important role in the spread of the atmospheric pollutants, as well as the dilution and accumulation of atmospheric pollutants. For the local area, in certain conditions of restricted pollutants the regional sources, the concentration of the pollutant depending on weather conditions, such as wind direction, wind velocity, wind turbulence, solar radiation, atmospheric temperature stratification, atmospheric stability, cloudiness, atmospheric pressure, etc. All have effects on the diffusion of atmospheric pollutants and the increase in local accumulation and concentration. Different meteorological conditions can significantly reduce or aggravate atmospheric pollution, which have an impact on human exposure in real situation directly. The appropriate temperature, humidity and early pollution condition are necessary in causing heavy pollution of PM<sub>10</sub> in Beijing. The atmospheric stability, boundary layer thickness, persistent weak wind and the stability of the pressure situation are conditions affecting the intensity of pollution. The heavy pollution commonly arises when the atmospheric pressure is stable.

In addition, weather conditions such as the liquid flow, air direction, speed and so on can significantly affect pollution in the suburban area, making it transfer to the central area of the city. In meteorological conditions with the favorable pollutants for transport, the pollution sources of suburban area may aggravate urban air pollution.

With the rapid development of economy, air pollution has become one of the most significant environmental problems in China. For example, Despite the remarkable progress has been made in the air pollution control in Beijing since 1998 and the trend of air pollution by gaseous pollutants has been effectively curbed in suburbs, the ownership of motor vehicle and the concentration in PM<sub>10</sub>, PM<sub>2.5</sub>, O<sub>3</sub>, SO<sub>2</sub> and NO<sub>2</sub> is still high at present. Its change of concentration, vertical distribution profiles and peak level of concentration have significant impact on the thermal conditions of atmospheric boundary layer structure (characteristics of inversion layer) and the human exposure.

## The analysis and outlook of domestic research

For example, Beijing is located in the north China plain which is not only an active region of rapid development, but also is a region of ecological imbalance and disasters. Climate and environment are the most important restriction

factors for sustainable economic and social development. The development of Beijing's urban area and the changes in the environment are significantly representative. Research indicated that there are the increase in temperature and decrease in rainfall these years in north China. Foggy days increased significantly in recent years. Aerosol index showed high correlation with local fog. The areas of high correlation coincide with the foggy day's interdecadal variations. From the view of pollution meteorology, heavy pollution in the Beijing area is characterized by the static stability of autumn and winter season, as well as the dusty spring and the photochemical summer. PM<sub>10</sub> is regarded as the main pollutant in autumn and winter, while ozone in spring or summer. The static stability heavy pollution type in adverse weather conditions (small wind, calm wind, high humidity and stable inversion, etc.) is regarded as extreme of atmospheric environment. Attention should be taken for its long duration and serious damage.

In addition, the concentration of PM<sub>10</sub> and PM<sub>2.5</sub> can be as high as 900–300 µg/m<sup>3</sup> around (12). Since dusty weather becomes more and more frequent recently in the spring in Beijing. The daily and annual average concentrations of the PM are much worse than the National secondary air quality standard. It has become a main pollutant in Beijing. Fine particles (PM<sub>2.5</sub>) is a bigger threat to human health, whose logarithm concentration is greater than the coarse particle (13), the annual average mass concentration in Beijing is far more than the air quality standards that newly promulgated by the American National in 2006 (PM<sub>2.5</sub> daily average is 35 µg/m<sup>3</sup>, annual average is 15 µg/m<sup>3</sup>). In terms of gaseous pollutants, its concentration fluctuates sharply in Beijing: the average SO<sub>2</sub> is 6.12 ppb in late summer or early autumn. In winter, it can achieve 160 ppb. Influenced by motor vehicle exhaust emission, the mean NO<sub>x</sub> in downtown is relatively high in Beijing with daily average 22.40 ppb and maximum average 141.74 ppb, which is more than National secondary standard. The motor vehicle owner increases at a rate of about 15% in Beijing, and the rate is still growing.

Some studies have shown that the change in the concentration of PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>2</sub>, O<sub>3</sub> and SO<sub>2</sub> have significant correlation (14,15) with the mortality of the patients with chronic respiratory disease in Beijing from 2000 to 2005. As for asthma, there has been investigation (16) in children as well as the indoor pollution or living environment in Beijing. In addition, there has been preliminary study on the relationship between the occupational air pollution and the population

with adult asthma. A survey of ten different industry working group of asthma prevalence in Beijing suggested the prevalence of asthma in chemical and petrochemical workers was significantly higher than that of farmers in suburbs, indicating the prevalence of asthma is related to occupational environment, and air pollution is an important factor in the increasing asthma prevalence.

In order to ensure air quality during the 2008 Beijing Olympic Games, the Beijing municipal government adopted strict pollution control measures, it also provided research opportunities for Li *et al.* (17,18) to assess the effects of atmospheric pollution on human health at the same time. Li *et al.* reported the clinic effects of adult asthma patients under the pollution of meteorological conditions around the time period of Olympic Games. The study showed that an increase of 10  $\text{vg}/\text{m}^3$  in  $\text{PM}_{2.5}$  caused the number of outpatient visits for asthma increased by 2.0%, each increase of air pollution index caused the number of outpatient visits for asthma increased by 8.5%, and an increase of 10 ppb in  $\text{O}_3$  caused the number of outpatient visits for asthma increased by 4.0%. Other pollutants have no significant effect. In addition, the average number of outpatient visits for asthma was 12.5 per day at study baseline (6.5–6.30 visits) and 8.9 per day during the Olympics (8.8–9.30 visits), indicating a significant reduction in asthma visits compared to baseline (RR 0.64, 95% CI: 0.58–0.70). Asthma visits were also significantly higher, during the pre-Olympic period (RR 1.24% CI: 0.96–1.61).

The preliminary research showed that the air pollution in Beijing has certain influence on the onset of asthma, air pollution has become one of the most significant environmental problems in Beijing. Researching on air pollution further on human health is an important national requirement.

Genetics has confirmed interaction between genetic and environmental factors. Genes would vary with the change of environmental factors in order to adapt to changes in the environment. Therefore, it is plausible to speculate that the increasingly serious air pollution will inevitably make genetic variation. It has been found that there is extensive gene polymorphism in the determining genes of asthma, there are significant difference between different ethnics, different regions, as well as different individuals. Changes in genetic polymorphism determine the sensitivity of different regions, different ethnics, different individual to specific antigens and specific pollutants (12,13).

The Asia-Pacific region accounted for only 1.9% of asthma patients in the control level according to data

in 2008. And the mortality of asthma is the highest in China. The 2010 Global Asthma Prevention Guidelines (GINA) clearly indicated the goal of asthma treatment is not only to achieve and maintain clinical control of asthma abbreviation, but also to pay attention to the future risk assessment when conducting the evaluation. The basis of all control approaches is the environmental control. Better prevention and treatment of asthma to provide decision support for pollution control. In-depth studies are required to quantitatively evaluate the impact of atmospheric pollution on asthma.

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## Footnote

*Conflicts of Interest:* The author has no conflicts of interest to declare.

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