Review
Allergy Asthma Immunol Res. 2016 September;8(5):391-395.
http://dx.doi.org/10.4168/aair.2016.8.5.391
pISSN 2092-7355 • eISSN 2092-7363

Climate Change and Air Pollution: Effects on Respiratory Allergy

Gennaro D'Amato,[1,2]* Ruby Pawankar,[3] Carolina Vitale,[4] Maurizia Lanza,[4] Antonio Molino,[4] Anna Stanziola,[4] Alessandro Sanduzzi,[2,5] Alessandro Vatrella,[6] Maria D'Amato[4]

[1]*Division of Respiratory and Allergic Diseases, Department of Chest Diseases High Speciality, A. Cardarelli Hospital, Napoli, Italy*
[2]*University "Federico II", Medical School, Naples, Italy*
[3]*Division of Allergy, Department of Pediatrics, Nippon Medical School, Tokyo, Japan*
[4]*First Division of Pneumology, High Speciality Hospital "V. Monaldi" and University "Federico II" Medical School, Naples, Italy*
[5]*Second Division of Pneumology, High Speciality Hospital "V. Monaldi" and University "Federico II" Medical School, Naples, Italy*
[6]*Department of Medicine and Surgery, University of Salerno, Salerno, Italy*

A body of evidence suggests that major changes involving the atmosphere and the climate, including global warming induced by anthropogenic factors, have impact on the biosphere and human environment. Studies on the effects of climate change on respiratory allergy are still lacking and current knowledge is provided by epidemiological and experimental studies on the relationship between allergic respiratory diseases, asthma and environmental factors, such as meteorological variables, airborne allergens, and air pollution. Urbanization with its high levels of vehicle emissions, and a westernized lifestyle are linked to the rising frequency of respiratory allergic diseases and bronchial asthma observed over recent decades in most industrialized countries. However, it is not easy to evaluate the impact of climate changes and air pollution on the prevalence of asthma in the general population and on the timing of asthma exacerbations, although the global rise in asthma prevalence and severity could also be an effect of air pollution and climate change. Since airborne allergens and air pollutants are frequently increased contemporaneously in the atmosphere, an enhanced IgE-mediated response to aeroallergens and enhanced airway inflammation could account for the increasing frequency of respiratory allergy and asthma in atopic subjects in the last 5 decades. Pollen allergy is frequently used to study the relationship between air pollution and respiratory allergic diseases, such as rhinitis and bronchial asthma. Epidemiologic studies have demonstrated that urbanization, high levels of vehicle emissions, and westernized lifestyle are correlated with an increased frequency of respiratory allergy prevalently in people who live in urban areas in comparison with people living in rural areas. Climatic factors (temperature, wind speed, humidity, thunderstorms, etc.) can affect both components (biological and chemical) of this interaction.

Key Words: Air pollution; asthma; climate change; airway hypersensitivity; pollen allergy; weather

INTRODUCTION

In the last century, the massive increase in emissions of air pollutants due to the economic and industrial growth has made air quality a major problem in many industrialized countries, and an emerging problem for the rest of the world. Increased concentrations of greenhouse gases, especially CO_2, in the earth's atmosphere have already warmed the planet substantially, causing more severe and prolonged heat waves, temperature variability, air pollution, forest fires, droughts, and floods, all of which put respiratory health at risk.[1,2] These changes in climate and air quality have a quantifiable impact, not only on the morbidity but also on the mortality for respiratory diseases.[3-5] Global earth temperature has markedly risen over the last 5 decades due to the increase in greenhouse gas emissions. Global warming from anthropogenic-derived greenhouse gases has consequences, including climate change and public health risks.

As stated in the recent Working Group I Report of the Intergovernmental Panel on Climate Change, "most of the observed increase in globally averaged temperatures since the mid20th

Correspondence to: Gennaro D'Amato, MD, FAAAAI, University Professor of Respiratory Medicine, Chairman Committee on "Climate change and Allergy" World Allergy Organization. Director Division of Respiratory and Allergic Diseases, Department of Chest Diseases High Speciality A.Cardarelli Hospital, Napoli, Italy, Via Rione Sirignano10, 80121 Naples, Italy.
Tel: +39-3355915589; Fax: +39-0815353213
E-mail: gdamatomail@gmail.com
Received: May 7, 2015; Accepted: June 16, 2015
• There are no financial or other issues that might lead to conflict of interest.

century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."[1,2] Changes are also occurring in the amount, intensity, frequency, and type of precipitation as well as increases in extreme events, like heat waves, droughts, floods, thunderstorms and hurricanes, and these are real and daunting problems. A recent position statement on climate change and health impacts from the European Respiratory Society (ERS) was developed after a workshop co-organized by the HENVINET Project and the American Thoracic Society.[6] The position statement highlights climate-related health impacts, including deaths and acute morbidity due to heat waves; increased frequency of acute cardio-respiratory events due to higher concentrations of ground-level ozone; changes in the frequency of respiratory diseases due to transboundary particle pollution; and altered spatial and temporal distribution of allergens (pollens, moulds, and mites) and some infectious disease vectors. According to the report, these impacts will not only affect those with existing respiratory disease but likely increase the incidence and prevalence of respiratory conditions.[6]

"The annual economic cost of premature deaths from air pollution across the countries on the WHO European region stood at US $1.431 trillion, and the overall annual economic cost of health impacts and mortality from air pollution, including estimates for morbidity costs, stood at US $1.575 trillion."

Extreme temperature events

The effect of heat waves on mortality is well documented.[7] It has been observed a rapid rise in the number of hot days and severe meteorological events,[8,9] such as the 2003 and 2012 heat waves when temperatures reached or went above 35°C degrees, resulting in excess deaths across Europe.[8,9] In Europe, over 70,000 excess deaths were observed in 12 European countries in the heatwave summer of 2003. Such high summer temperatures are expected to be the norm by the middle of the century in Europe.[10] There is evidence of an increased number of deaths and acute morbidity, especially among respiratory patients due to heat waves. For every 1°C rise, the risk of premature death among respiratory patients is up to 6 times higher than in the rest of the population.[6] The increase in respiratory mortality (relative risk) is larger than total or cardiovascular mortality.[11] Although the association between heat and the number of hospital admissions is less studied and less evident, admissions are also more apparent for respiratory than for cardiovascular disease.[8] Moreover, climate scenarios for the next century predict that the warming will be associated with more frequent and more intense heat waves in wide areas of our planet with increased risk of wildfires and desertification. Heat and drought conditions contribute to wildfire risks. Smoke emissions can travel hundreds of kilometers downwind of fire areas, exposing people to a complex mixture of fine particles, ozone precursors, and other health-harming compounds[12,13] One recent worldwide estimate is that 339,000 deaths annually may be attributed to landscape fire smoke.[13] Respiratory and cardiovascular hospital admissions and emergency department visits increase in response to wildfire smoke exposure, strongly associated with PM levels.[13,14] Drought conditions create multiple health challenges: in dry conditions, more pollen, dust, particulates, and when present, wildfire smoke which can irritate respiratory epithelium, exacerbate chronic respiratory illnesses, and asthma, and increase risks for acute respiratory infection (Table 1).[15] In urban areas, the effects are higher because climate change influences outdoor air pollution because the generation and dispersion of air pollution is in strict correlation with local patterns of temperature, wind, and precipitation.[16]

Table 1. Effects of climate change on respiratory diseases

An increased number of deaths and acute morbidity, especially among respiratory patients, due to heat waves
An increased frequency of cardio-respiratory attacks due to higher concentrations of ground-level ozone
Changes in the frequency of respiratory disease due to transboundary long-range air pollution
Altered distribution of allergens and some infectious disease vectors

Outdoor and indoor air pollution

Air pollution is an alteration in the levels of quality and purity of the air due to natural or anthropogenic emissions of chemical and biological substances. It is the environmental factor with the greatest impact on respiratory health in Europe.[1,2] Pollutants affecting air quality include inhalable particles. To put it simply, inhalable particles can be defined as those whose aerodynamic diameter is less than 10 μm (PM10), while fine inhalable particles are defined as less than 2.5 μm (PM2.5) and coarse inhalable particles, between 2.5 and 10 μm.[17] The size of the particle, and surface and chemical composition of the particulate material determine the risk that exposure to this agent represents for human health. Fine particles, owing to their smaller size, penetrate deeply into the respiratory system and may affect the alveoli. Air pollutants show these effects by causing direct cellular injury or by inducing intracellular signaling pathways and transcription factors that are known to be sensitive to the oxidative stress.[18-23]

Degradation of air quality caused by 1 or more pollutants, which concentration levels and presence time vary, has been related to asthma. Outdoor air pollution exacerbates asthma in those who already have the condition.[24] Outdoor levels of air pollutants have been associated with asthma incidence but not neatly with asthma prevalence at the population level.

Particle pollution, vehicle exhaust, and ground-level ozone are the most important types of hazardous pollutants. Ozone is a strong oxidant that has been associated with persistent structural airway and lung tissue damage, as well as contributing to more severe symptoms of asthma and an increase in respiratory hospital admissions and deaths in Europe and the USA.[16] It is estimated that there will be an annual ozone level of >1,500 ppm associated deaths by the year 2020 in the UK alone.[16] Pollution models for climate change scenarios predict an increase in ozone concentrations over large areas, while the effect on particle concentrations is less clear.[24] The short-term effects of ozone on daily mortality and respiratory disease are extensively studied, while there is only limited documentation of long-term effects on mortality.[24,25]

Positive associations have been observed between urban air pollution and respiratory symptoms in children, and the literature contains many reports of relations between motor vehicle exhausts and acute or chronic respiratory symptoms in children living near traffic.[24-26]

Air pollution can negatively influence lung development in children and adolescents.[25,27,28] Most studies have suggested adverse effects of air pollution on children's lung function and respiratory symptoms. Deficits in lung function were associated with a correlated set of pollutants, including nitrogen dioxide, acid vapor, fine particulate matter (PM2.5), and elemental carbon. Deficits in lung function during young adulthood may increase the risk of respiratory conditions, such as episodic wheezing that occurs during a viral infection. However, the greatest effect of pollution-related deficits may occur later in life, since reduced lung function is a strong risk factor for complications and death during adulthood.[29] Prediction about the effects of climate change on health-related air pollution is hampered by several limits: future emissions depend on numerous factors, such as population growth, economic development, energy use, and production; current knowledge about weather effects on air pollution is still unsatisfactory; there is still a need of better emission inventories and observational datasets; long-term effects and actual enforcement of international agreements to reduce air pollution and greenhouse gases emissions (*e.g.* Kyoto protocol) are unpredictable.

Regarding indoor pollution, indoor levels of air pollutants other than environmental tobacco smoke have also been related to asthma prevalence or symptoms by sparse studies.[30-32]

Consistent results support short-term (aggravation) and, although more rarely, long-term (prevalence augmentation) effects on asthma of poor air in indoor settings.[30-32] Environmental tobacco smoke is one of the most important risks for respiratory symptoms and diseases worldwide. The evidence is also reliable for indoor nitrogen dioxide and particulate matter, which have been associated with asthma. Whereas formaldehyde and volatile organic compounds seem to be the main pollutants in indoor settings, relevant papers on asthma are still scarce and limited to asthma and bronchitis. Molds have been associated with an increased risk of asthma and COPD.

Allergens and allergic responses

The effects of climate change on respiratory allergy are still unclear, and studies addressing this topic are lacking. Global warming is expected to affect the start, duration, and intensity of the pollen season on the one hand, and the rate of asthma exacerbations due to respiratory infections and/or cold air inhalation on the other.[33] Data provided by 30 years of observations within the International Phenological Gardens Network showed that spring events advanced by 6 days, the highest rate of phenological changes being observed in Western Europe and Baltic regions. Conversely, phenological trends appear to be different in the eastern border of Europe, sometimes showing a 1-2 weeks later start of the phases. Due to the earlier onset, the pollen seasons are more often interrupted by adverse weather conditions in late winter/early spring.[33-35] Duration of the pollen season is also extended, especially in summer and in late flowering species. The climate change projected during next century will influence plant and fungal reproductive systems and alter the timing, production, and distribution of aeroallergens. Increased exposure to allergens as a result of global warming, combined with exposure to pollutants that act synergistically to intensify the allergic response, could point to increased respiratory problems in the future. In fact, climate change is likely to influence vegetation, with consequent changes in growth and reproductive cycles and in the production of allergenic pollen (seasonal period and intensity). In addition, weed species are expected to proliferate. These changes can vary from one region to another, since some areas receive greater amounts of UV radiation and/or rainfall than others (Table 2).

Table 2. Why climate change is correlated with pollen allergy?

Rapid growth of plants
Increase in the amount of pollen produced by each plant
Increase in the amount of allergenic proteins contained in pollen
Increase in the start time of plant growth and therefore the start of pollen production and earlier and longer pollen seasons

Asthma epidemics related to thunderstorms.

An increasing body of evidence shows the occurrence of severe asthma epidemics during thunderstorms in the pollen season, several epidemics of asthma have been reported following thunderstorms in various geographical zones, prevalently in Europe and Australia.[36] Asthma epidemics related to thunderstorms are limited to seasons when there are high atmospheric concentrations of airborne allergenic pollens (subjects with pollen allergy who stay indoors with the window closed during thunderstorms are not involved); further there are no observations on the involvement of asthma in nonallergic subjects. Much remains to be discovered about the relationship between asthma attacks and thunderstorms, but there is reasonable evidence in favor of a causal link between them in patients suffering from pollen allergy. In particular, during the

Table 3. The evidence for thunderstorm-related epidemics of rhinitis and asthma exacerbations

The occurrence of epidemics is strictly linked to thunderstorm
The epidemics related to thunderstorm are limited to late spring and summer when there are high levels of airborne pollen grain
There is a close temporal association between the arrival of thunderstorm, a major rise in the concentration of pollen grains, and the onset of outbreak
Subjects with pollinosis, who stay indoors with the window closed during thunderstorms, are not involved
There is a major risk for subjects who are not under correct antiasthma treatment, but subjects with allergic rhinitis and without previous asthma can experience severe bronchoconstriction

first phase of a thunderstorm, that is, the first 20-30 minutes, there is evidence of high respirable allergen loadings in the air. This is due to dry updrafts that, during thunderstorms, entrain whole pollens into the high humidity at the cloud base where pollens may rupture and cold downdrafts carry pollen fragments (pollen grains are too large to penetrate the deeper airways) to the ground level where outflows distribute them. Due to strong electric fields that develop during thunderstorms, positive ions are released from the ground and could attach to particles and/or electric charge may enhance pollen rupture, thus enhancing bronchial hyperresponsiveness.[36-39]

In the light of the above, subjects affected by pollen allergy-not only asthmatic patients but also subjects affected by seasonal rhinitis without asthma symptoms-should be alert to the danger of being outdoors during thunderstorms in the pollen season, as such events may be an important cause of severe exacerbations (Table 3).

CONCLUSIONS

Health effects of climate change include an increase in the prevalence of allergic respiratory diseases, exacerbations of chronic obstructive lung disease, premature mortality, and declines in lung function.[41,42] Climate change, mediated by greenhouse gases, causes adverse health effects in the most vulnerable patient populations, such as the elderly, children, and those in distressed socioeconomic strata.

In these aspects, government worldwide and international organizations, such as the World Health Organization and the European Union, are facing a growing problem of respiratory effects induced by gaseous and particulate pollutants arising from motor vehicle emissions.

In addition, climate change may significantly worsen health inequities within and among countries and put additional stress on poorer groups.

The terms "adaptation" and "mitigation" are 2 important terms that are fundamental in the climate change debate. Climate mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life and property. Climate adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) in order to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. Strategies for mitigation and adaptation can create co-benefits for both individual and community health, by reducing non-climate-related health hazard exposure and by encouraging health promoting behaviors and lifestyles (Table 4).[41]

Table 4. What can we do?

Decreasing the use of fossil fuels and controlling vehicle emissions
Reducing the private traffic in towns Improving the public transport
Planting non-allergenic trees in cities
Minimizing outdoor activities on days with high pollution
Suggesting patients live in remote areas from heavy traffic

In conclusion, strategies to reduce climate change and air pollution are political in nature, but citizens, especially health professionals and societies, must raise their voices in the decision process to give strong support for clean policies on both national and international levels.

Policy changes are beginning to impact greenhouse gas production in many parts of the world.

These efforts are crucial for reducing future impacts; however because over-all global emissions continue to raise, adaptation to the impacts of future climate variability will also be required.

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