Air Quality, Energy and Health
Science and Policy Summaries

Climate change, air pollution, pollen and health

Technical brief

Key messages

Air pollution and climate change, by enhancing health impacts of allergens such as pollen and airborne biological particles, exacerbate inflammatory and allergic conditions. Key take away messages include:

- **The effects of air pollution on inflammatory allergic conditions**, such as asthma, are well-known.
- Air pollution and its health effects are **exacerbated by climate change**, which impacts levels and distribution of outdoor air pollutants such as ground-level ozone and particulate matter.
- **Climate change also increases carbon dioxide levels and raises temperatures**, which result in an earlier start to the growing season of plants, longer pollen seasons and higher pollen production, **increasing overall pollen exposure**, which contribute to **more severe allergy symptoms**.
- **Particulate matter alters the pollen surface**, increasing its **allergenicity**.
- Both air pollution and higher allergen levels, influenced by climate change, contribute to **increased inflammation and respiratory diseases** such as asthma and allergic rhinitis.
- These factors place a **greater burden on health care systems and reduce the quality of life for individuals with allergies or respiratory conditions**.

World Health Organization

Future priority actions

- **Continue monitoring pollen** globally to help health systems.
- **Implement environmental justice policies** to protect vulnerable populations in polluted regions.
- **Establish health impact information** on pollen and create early warning systems.
- **Educate patients** on how to check pollen and air quality levels.
- **Public awareness** – promote education campaigns on air pollution, climate change, and their effects.
- **Integrated policy and cross-sector collaboration** – strengthen partnerships across the health care, urban planning, agriculture and environmental sectors.
- **Research and One Health approach** – continue studying climate change's health impacts and integrate the One Health approach.
- **Global cooperation and data sharing** – enhance efforts by sharing data, best practices and funding initiatives.

In summary, climate change and air pollution are amplifying the severity and frequency of allergies, often increasing the duration of the allergy season and making allergies a growing public health concern worldwide.

Key definitions

Pollen: Pollen is a fine yellowish powder (smaller than the width of a human hair) that is released by plants and transported by the wind, birds, insects or other animals. The spread of pollen helps to fertilize plants *(1)*.

Allergy: An allergic reaction is an overreaction by our immune system to normally harmless substances *(2)*.

Overview

Impact of air pollution on allergic disease

More than 2000 studies have been published between 2000 to 2024 on the effects of air pollution on various inflammatory allergic conditions, including allergic rhinitis, atopic dermatitis, asthma, allergic conjunctivitis and anaphylaxis in adults and children. These effects have been observed even with short-term exposure, such as during wildfire smoke exposure *(3–10).*

See SPS[1]: *Health effects of air pollution – evidence and implications*

Air pollution and its health effects are exacerbated by wildfires, sandstorms and heat waves, which have increased in frequency and intensity with climate change. The changing climate has altered weather patterns, which have, in turn, impacted the levels and distribution of outdoor air pollutants, such as ground-level ozone and fine particulate matter *(11).*

See SPS: *The impacts of wildfire smoke on health*

See SPS: *Understanding the health impacts of sand and dust storms*

Role of climate change on air pollution and pollen production

One of the consequences of climate change is increased carbon dioxide levels and rising temperatures. These changes in climate are expected to lead to higher levels of certain airborne allergens, such as pollen, resulting in an increase in asthma episodes and other allergic conditions *(11).*

An increase of 1.5°C is expected to have major consequences for human health, including a higher prevalence and severity of allergic disease due to increased pollen and air pollutants predominantly caused by increases in sand and dust storms and wildfires *(12).* These effects are further exacerbated by climate-driven changes in pollen patterns, such as a longer pollen season, increased spread, higher concentrations and enhanced allergenicity, all of which contribute to a greater pollen burden *(13, 14).* For example, between 1995 and 2011 the length of pollen season for ragweed, a type of grass, increased by as much as 11 to 27 days in parts of Canada and the United States *(15).*

Increased carbon dioxide concentrations, together with rising temperatures and altering precipitation patterns, promote and extend the growing season of plants that release pollen, enhance both the quantity and allergenicity of pollen (i.e. a measure of how much particular allergens, such as pollen, affect people), and broaden the geographical spread of pollen *(11)*, leading to earlier flowering *(16).* In some regions, such as the Mediterranean, pollen seasons are already shifting, sometimes by more than a month. Climate change is shifting the timing of seasonal events like flowering, leading to earlier and unpredictable pollen exposure throughout the year *(16).*

[1] Science and Policy Summary

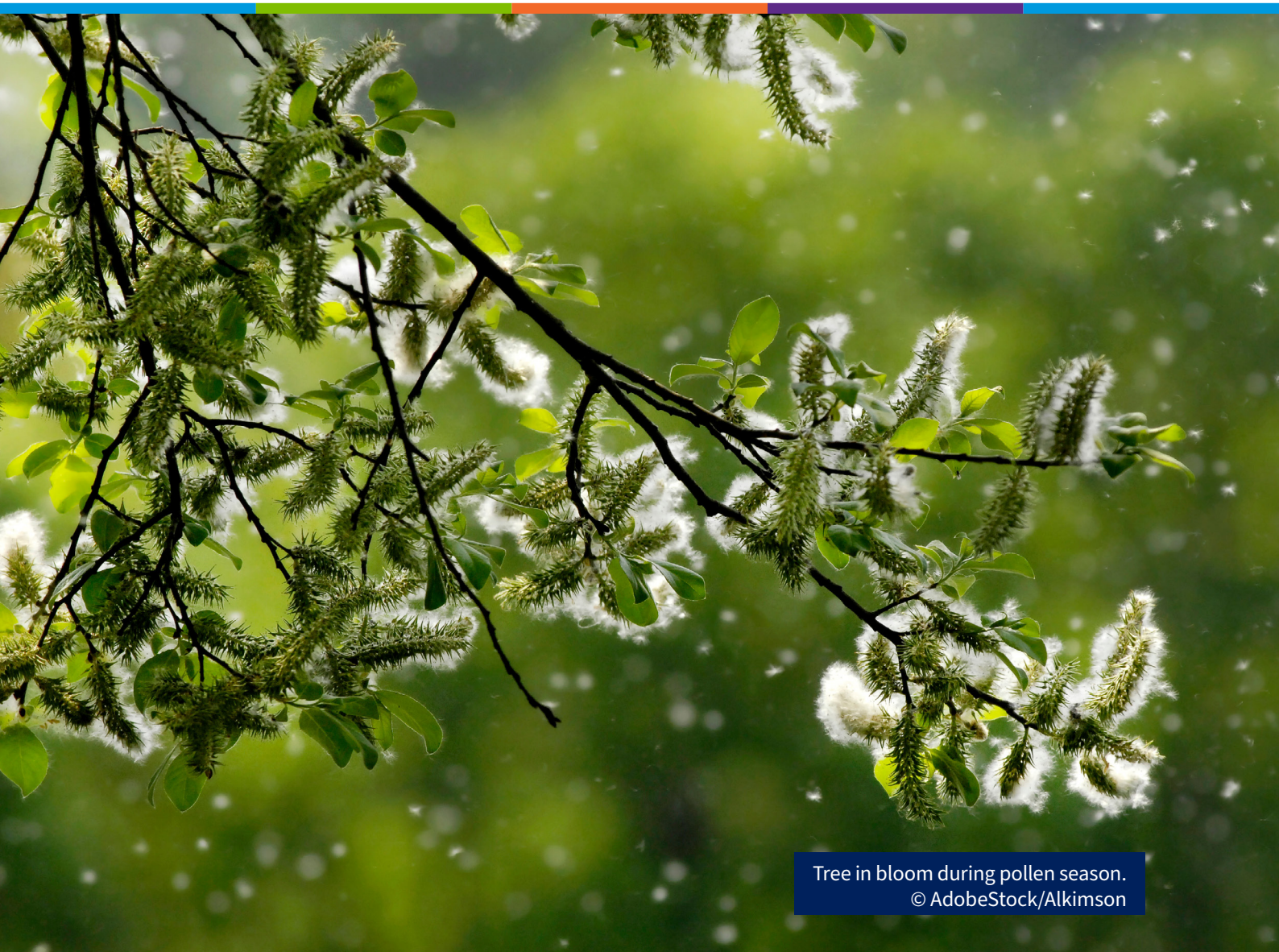
Effects on pollen production: Climate change may alter the production of pollen, contributing to the severity and prevalence of allergic diseases in humans *(11)*. Pollen production varies by species and is influenced by factors like pollination type, plant type and environmental conditions. Variations can occur within the same species, with weather and climate impacting pollen production *(17–21).*

Effects on pollen dispersion: Pollen can spread through water, animals (insects, birds or bats), and wind, with wind being the most relevant for allergies. Pollen dispersal distances vary from a few meters to over 1000 kilometres, influenced by factors like flowering time, weather and landscape features *(22, 23)*. Climate change alters atmospheric processes, which can intensify conditions that help spread larger airborne particles, such as strong winds, turbulence, heat-induced updrafts and higher boundary layer.

Due to climate change, there are many greening projects being implemented to mitigate heat waves and for carbon sequestration; however, care is needed to select tree and grass species which do not increase allergenic pollen counts.

See SPS: *Green spaces – sectoral solutions for air pollution and health*

See SPS: *The synergies of heat stress and air pollution and its health impacts*



Tree in bloom during pollen season.
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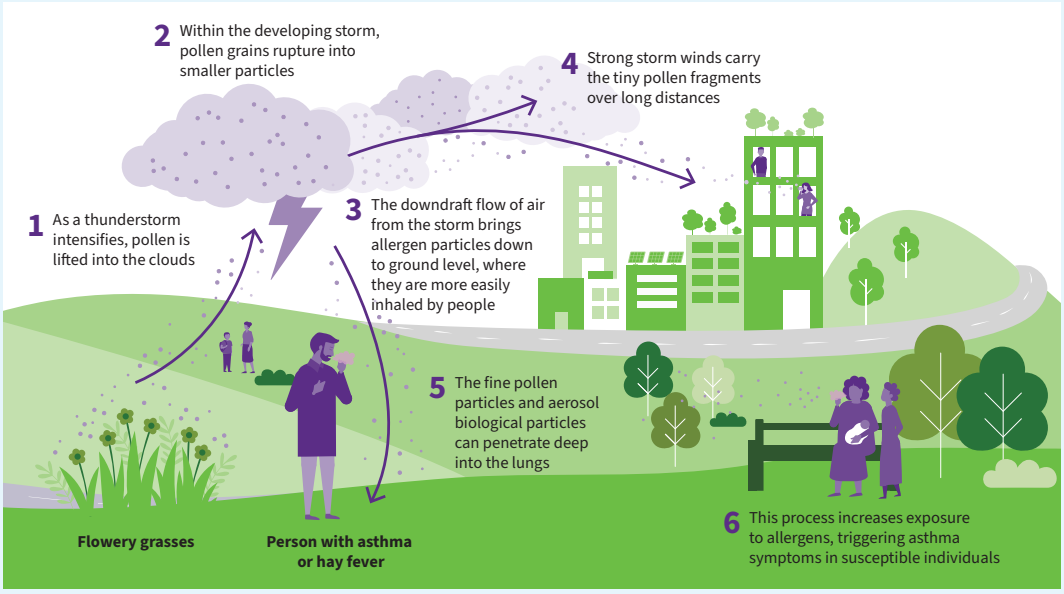
Box 1. Case study: thunderstorm-induced asthma

One classic example of an extreme weather condition is thunderstorm-induced asthma. While the exact mechanism of thunderstorm asthma is debated, it is hypothesized that pollen particles are split into smaller particles during thunderstorm conditions enabling them to reach deeper into the airways causing acute asthma symptoms in those who normally have only mild allergic rhinitis (see fig. below). Smaller particles can also be easily carried at greater distances thus affecting a larger population. First described nearly 40 years ago, this phenomenon is being reported almost yearly in Australia, China, Europe, the Middle East and North America *(24, 25).* Overcrowding in emergency rooms of epidemic proportions have been reported during thunderstorm asthma.

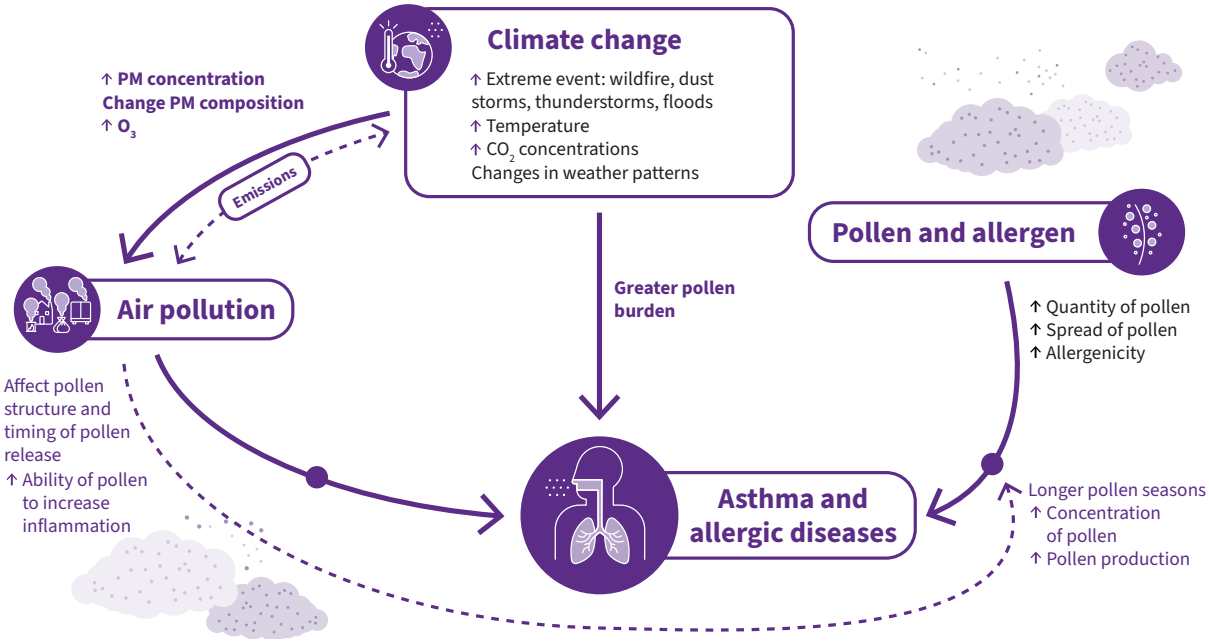


Source: Adapted from Luschkova et al.; 2022 *(26)*.

Health effects of pollen exposure driven by air pollution and climate change

Increased pollen concentrations and longer pollen seasons, influenced by air pollution and climate change, lead to greater allergic sensitization and more asthma episodes *(11)* (Fig. 1). Studies show that air pollution increases the ability of pollen to increase inflammation *(19).* Allergens such as pollen can bind to $PM_{2.5}$ and increase inflammatory reactions *(27, 28).* Also, pollutants can change pollen structure, protein and lipid content, and timing of pollen release, all of which can influence allergenicity *(29).* Further, pollutants such as $PM_{2.5}$ and ground-level ozone also irritate the airways and make asthma worse *(30).*

Fig. 1. Effect of climate change and air pollution on pollen and allergic diseases



Source: Adapted from Jacquemin et al.; 2023 *(31)*.

Land use changes and allergy-relevant pollen

Land use changes pose one of the major threats of climate change according to the latest IPCC report *(32)* – global warming affects habitat and biodiversity loss, habitat shifts and fragmentation and overall plant distribution by shifting species to higher elevations or latitudes, leading to variability in pollen seasons.

See SPS: *Land use planning – sectoral solutions for health*

Some allergy-relevant plants in Bavaria, Germany, such as birch, may lose their habitats *(33)*, while Mediterranean species such as olive trees and pellitory-of-the-wall could spread to higher latitudes, increasing sensitization rates. Emerging plant species (species sensitive to climate change and dramatically increasing their pollen production and/or allergenicity) and invasive plant species (weeds, ragweed, species tolerant to or favoured by soil and air pollution, urbanization and greenhouse gases) are expected to significantly contribute to the prevalence of allergies in the future, with the spread of such plants across the globe *(34–37)*.

At-risk populations

Infants and children are uniquely sensitive to air pollution because their organs are developing, and they have higher air per body weight intake. Air pollution also disproportionately affects those who have limited access to health care and few resources to mitigate unhealthy air quality. Low-income communities, often situated in more polluted areas, also face a higher risk of severe allergic reactions and respiratory issues. Pregnant women, older adults and individuals with pre-existing respiratory conditions are immune compromised and more at risk of allergic disease.

Success stories

Changes in transport behaviour and policy, even short term, have been shown to decrease allergies. This was observed for both the 1996 and 2008 Olympic games in Atlanta and Beijing, respectively. In both cities, major changes in transportation were implemented, for example, increased public transport and temporary vehicle restrictions. In Atlanta, these changes resulted in a reduction in ozone pollution as well as significantly lower rates of asthma events in children 1–16 years *(38)*. Similarly, in Beijing, during the 2008 Olympic Games, a prolonged reduction in air pollution and significantly lower rates of adult asthma events were observed *(39)*.

Another success story is the existence of a pollen database, created by the European Aeroallergen Network (EAN).[2] This is fundamental tool for pollen forecasting and essential for pollen information services in Europe. It is also important for international research projects and clinical studies. EAN currently includes information from more than 400 active and 300 historical pollen traps across Europe, including 39 countries, not all of which are on the European continent. The network has now been extended to the North American continent.

[2] European Aeroallergen Network (https://ean.polleninfo.eu/info/en/about-us).

Airborne particles and pollen suspended in sunlight.
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Way forward

Climate change is increasing air pollutants and may lead to higher levels of pollen, having negative consequences for human health, including the increased risk of allergies and asthma. Therefore, there is an urgent need to adapt and mitigate to these changes.

Monitoring allergen (pollen and biological particles) and air pollution exposures will be important to implement throughout the globe now and in the future to aid health systems prepare for increases in visits and admissions due to allergies and asthma and other immune-mediated and inflammatory diseases. Airborne pollen has been monitored for almost a century now, with quite consistent and comparable methods and acquired data. However, airborne pollen monitoring is an arduous task and there are challenges associated with sustaining pollen monitoring and pollen monitoring network management *(40).* In the last 10–15 years, there have been efforts to automate the task. These modern automated measurement methods are still experimental in terms of validation and comparability *(41–43)*.

Exposure to greenness and greyness also influences allergy in urban settings, in addition to air pollution. Monitoring these exposures in order to understand how best to design urban landscapes to minimize allergies is needed *(44).* Such systems and the associated biomonitoring networks have to show common grounds: comparability, reliability and free access to all individuals.

A better understanding of the environmental factors that mediate allergy and how to prevent the onset of allergenic reactions is urgently needed *(45).*

Environmental justice policies should be put in place in order to protect vulnerable populations, who, living in more polluted regions have higher risk of severe allergic reactions and lower resilience and capacity to adapt to climate change *(46–49).*

Information of the health effects of pollen and early warning systems should be put in place to tackle weather- and climate-related risks and hazards of pollen-related diseases. Better risk knowledge, coupled with improved detection, monitoring, analysis, forecasting, warning dissemination, communication, preparedness and response capabilities, are needed.

Health care professionals should strive to incorporate environmental exposure counselling, environmental health precepts and education into their practice, for both themselves (especially younger practitioners) and their patients *(50–52)*. Educating patients to check for pollen and air quality; providing them with strategies for reducing exposure on high pollen and air pollution days, and information on how to adjust their allergy and asthma medications for optimal health; advocating for policies promoting clean air, water, soil and green spaces; and promoting sustainable practices should aid patients' short- and long-term health.

Innovative economic models of climate change interventions *(53)* not relying on individual methods in estimating health damages, incorporating a broader range of cause-specific mortality impacts, using improved climate parameters and accounting for socioeconomic trajectories and adaptation factors are also urgently needed.

Public education initiatives and campaigns for creating greater awareness on the effects of air pollution, global warming and climate change on allergic and respiratory diseases should be promoted to encourage preventive measures during peak seasons.

Policy-makers should integrate health considerations into climate action plans. This includes promoting policies that reduce emissions, enhance public transportation and support green infrastructure.

Continued research on the impacts of climate change on health is needed. Integration of One Health into public policy and climate action and recognizing the interconnectedness between human, animal and environmental health is the way forward.

Cross-sector collaboration fostering partnerships among health care, environment, urban planning and agricultural practices to address health policies is crucial. Global cooperation is essential to address these global challenges. Sharing data, best practices and funding initiatives can enhance efforts to combat air pollution and its effects on health and the environment.

Methodology

The World Health Organization (WHO) defined the scope of the document and collaborated with the Scientific Advisory Group on Air Pollution and Health (SAG), and other experts from various research institutes and universities, which cover a wide range of expertise, who prepared the initial draft. The draft was led by a key expert in the field of air pollution and health – based on an overview of climate change, air pollution, pollen and health, supplemented by expert advice. This process consisted of exploring the most recent evidence and selecting key documents as reference for the development of this SPS, prioritizing systematic reviews and meta-analysis.

The draft underwent peer review by specialists from the WHO Global Air Pollution and Health – Technical Advisory Group (GAPH-TAG), various research institutes, universities, public organizations and United Nations agencies. Feedback was addressed by the main contributors. Finally, WHO staff and consultants from the WHO Air Quality, Energy and Health Unit reviewed the report to ensure alignment with the WHO requirements for the collection of WHO Air Quality, Energy and Health SPS. This series synthesizes current knowledge and evidence on air quality, energy access, climate change links and health, primarily to inform intergovernmental discussions.

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Declarations of interest

All external experts submitted a declaration of interest to WHO disclosing potential conflicts of interest that might affect, or might reasonably be perceived to affect, their objectivity and independence in relation to the subject matter of the report. WHO reviewed each of the declarations and concluded that none could give rise to a potential or reasonably perceived conflict of interest related to the subjects covered by the report.

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