

Weather conditions and climate change have an effect on allergies

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Abstract

Climate change particularly affects the health of vulnerable groups, such as children, the elderly, and socially disadvantaged individuals. Asthmatics are also at greater risk from the results of climate change due to their non-specific and allergen-specific bronchial hyperreactivity. Climate change affects the production, release, and number of allergenic pollens throughout Europe. Tree pollen in particular is being seen earlier and in greater numbers, while little effect is seen on grass pollens, and mugwort pollen is showing a downward trend. The ragweed that is spreading

throughout Europe is still only of regional relevance in Germany. Thunderstorm periods represent a risk for pollen asthmatics. Although little is known about changes in molds, an increase in mycelium growth and spore formation is anticipated. Warmer winters may result in changes to mite populations.

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– molds – thunder-
storm-related
asthma

Introduction

The prevalence of allergic respiratory diseases such as allergic rhinitis and asthma has risen in industrialized countries worldwide in recent decades. While the hygiene theory and the effect of altered microbial exposure still carry weight, and the air pollution from road traffic and industry is still also to blame, the effects of climate change must be considered. This includes the increase in atmospheric and sea temperatures as a consequence of increased levels of greenhouse gases, carbon dioxide especially.

These changing temperatures, which result in heat waves, forest fires, droughts, and floods, can affect the incidence and frequency of respiratory diseases. In some regions of the world, air pollution has taken on such proportions that not only morbidity, but also mortality has been altered.

A statement issued by the World Allergy Organization (WAO) in 2015 emphasized the significance of climate-related health risks, including: fatalities and acute disease as a result of heat waves and other

extreme meteorological changes, an increase in acute cardiorespiratory events as a result of higher ozone concentrations at ground level, trans-border air pollution, altered spatial and temporal distribution of allergens (pollen, molds, and mites), as well as a number of infectious diseases [1]. Although the effect of climate change on respiratory allergies is a long way from being fully understood, a number of

Abbreviations

AR	Assessment report
CO ₂	Carbon dioxide
Ig	Immunoglobulin
IPCC	Intergovernmental Panel on Climate Change
PID	German Pollen Information Service
PM	Particulate matter
WAO	World Allergy Organization

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observations point to the significance of changes in the climate [2].

Climate change and extreme temperature events

Weather refers to the state of the atmosphere at a specific time and in a specific region and is associated with manifestations such as rain, thunderstorms, and snow. Weather conditions refer to the typical weather patterns over a longer or shorter period of time, which can last from a few days to an entire season. The climate, on the other hand, refers to the typical, average weather conditions over the course of a year. Statistical average and extreme values are used to describe climate. Ideally, these are based on long-term measurements.

Climate change denotes an alteration in climate over a long period of time. The climate has been in flux for as long as the earth has existed; however, for the first time, the global warming we are currently seeing is attributed primarily to human influences, in particular greenhouse gas emissions.

The following are seen as indicators of climate change and its effects, which vary from region to region:

- A global rise in greenhouse gas levels
- A global rise in air and sea temperatures
- The melting of polar ice caps and inland glaciers
- The rise in the average global sea level

According to data in the 5th Assessment Report (AR5) compiled by the Intergovernmental Panel on Climate Change (IPCC), the average global temperature between 2003 and 2012 was 0.78 °C higher than in the second half of the 19th century [3]. Extreme heat is one of the most important weather-related causes of death [4]. The 2003 heat wave in Europe resulted in an excess mortality of over 70,000 deaths in 12 countries, and it is assumed that summer temperatures of this kind will become normal by the middle of this century [5].

Tab. 1: The effects of climate change on respiratory diseases (from [2])

- Increased rate of fatalities and acute diseases among the population with chronic respiratory diseases during heat waves
- Increased incidence of cardiorespiratory episodes due to ground-level ozone
- Changes in the incidence and type of respiratory diseases as a result of long-range air pollution
- Changes in the type, count, and temporal occurrence of allergenic pollen, with effects on sensitization to and onset of respiratory tract allergies
- Changes in the occurrence of a number of disease vectors

The number of fatalities and acute diseases due to heat waves consist largely of patients with respiratory disease; every rise of 1 °C increases the risk of premature death in this group by six-fold compared with the healthy population [6]. The increase in relative risk for respiratory mortality is greater than for the likewise rising total or cardiovascular mortality [7]. Forest fires, which are associated with increased particulate matter (PM) concentrations, result in more frequent hospitalizations and visits to emergency departments among patients with respiratory disease [8].

On the other hand, dry periods also cause a range of health problems (Tab. 1), since dust, particularly smoke and fumes from forest fires, irritates the epithelium of the respiratory tract and induces exacerbations of chronic respiratory diseases and the risk of acute respiratory infections [9].

Who is most affected by climate change?

At-risk groups

Although the entire population of a country or continent is affected by changes to the climate and the resulting air quality, individuals with particularly sensitive respiratory tracts are more at risk than others.

Children are sensitive to air pollution; their respiratory tracts and lungs are still developing, therefore they have a higher respiratory rate than adults, and inhale larger quantities of pollutant particles and gases. Among children, it is in turn those children with asthma that are at particular risk due to inflammation and hyperreactivity of the respiratory tract.

The elderly represent the age group at the other end of the scale at greater risk for health effects from air pollution. In addition to age itself, tobacco use, diet, lack of physical exercise, weight, and genetic factors, above all the presence of chronic disease, in particular of the respiratory tract, can represent factors that affect individual sensitivity.

Socioeconomically weaker groups are also at greater risk of reacting to air pollution and climate change [10].

Allergens

Changes in climate cause changes in botanical conditions; most notably temperature and CO₂ levels are important parameters to be considered here. Numerous investigations have clearly demonstrated that the time courses in plant phenology are good indicators of alterations caused by climate change [11].

Pollen

Changes to the weather in the context of climate change play an important role in the development

of pollen-associated diseases (pollen rhinitis, pollen asthma, and oral allergy syndrome) [12]. In Germany, 14.8 % of adults will receive a medical diagnosis of hay fever in the course of their lives, i. e., 11 million individuals. This figure does not take unidentified cases into consideration. These changes affect both the production and the maturation of pollen, as well as the time course of their presence in the air and their allergen content (**Tab. 2**). Altered climatic conditions also result in the increased or persistent occurrence of pollen-producing plants and, thereby, to new allergen exposure, as evidenced by the example of ragweed.

Experimental studies have documented a positive correlation between rising CO₂ levels, temperatures, and the pollen level or biomass of plants that produce allergenic pollen [15].

Increased pollen levels cause a rise in the frequency of sensitizations, as seen with the example of ragweed.

Pollen-level trends in Europe

Year-on-year measurements of airborne allergenic pollen show sharply fluctuating levels due to varying weather conditions, as highlighted by a comparison of 2015 and 2014 in Germany in **Fig. 1**.

The largest summary published to date on trends in airborne pollen in Europe revealed a rising trend for numerous pollens, including those of allergological relevance [17]. The investigation set out to analyze whether there are more or fewer airborne pollens and whether differences can be identified between urban and rural areas as a result of climate change in Europe. The following findings were made:

- A significant increase was seen in the levels of nine pollen types (all allergenic), whereas only two decreased (**Fig. 2**).
- Changes in the annual amount of tree pollen (hazel, alder, birch, and also ash) generally showed a more pronounced trend toward higher pollen counts than did those for herbs (ragweed increased, while mugwort decreased).
- Grass pollens showed no significant increase or decrease. Although they showed a downward trend in Germany over a number of years, they have been rising again since 2010, as evidenced by annual measurements taken by the German Pollen Information Service (Stiftung Deutscher Polleninformationsdienst, PID) (**Fig. 3**).
- The increase in pollens is more pronounced in urban compared with rural areas. It is possible that the resuspension of settled pollen caused by road traffic is a causal factor here, among others.
- An increase in allergenic pollens has not been documented for all European countries (**Fig. 4**).
- A greater number of certain trees (e. g., birch and members of the cypress family) have been plant-

Table 2. Climate change and pollen allergy

- increased and more rapid plant growth
- higher number of pollen produced per plant
- altered and, in some cases, higher allergen content per pollen
- earlier start of plant growth and pollen production, as well as earlier and longer pollination periods

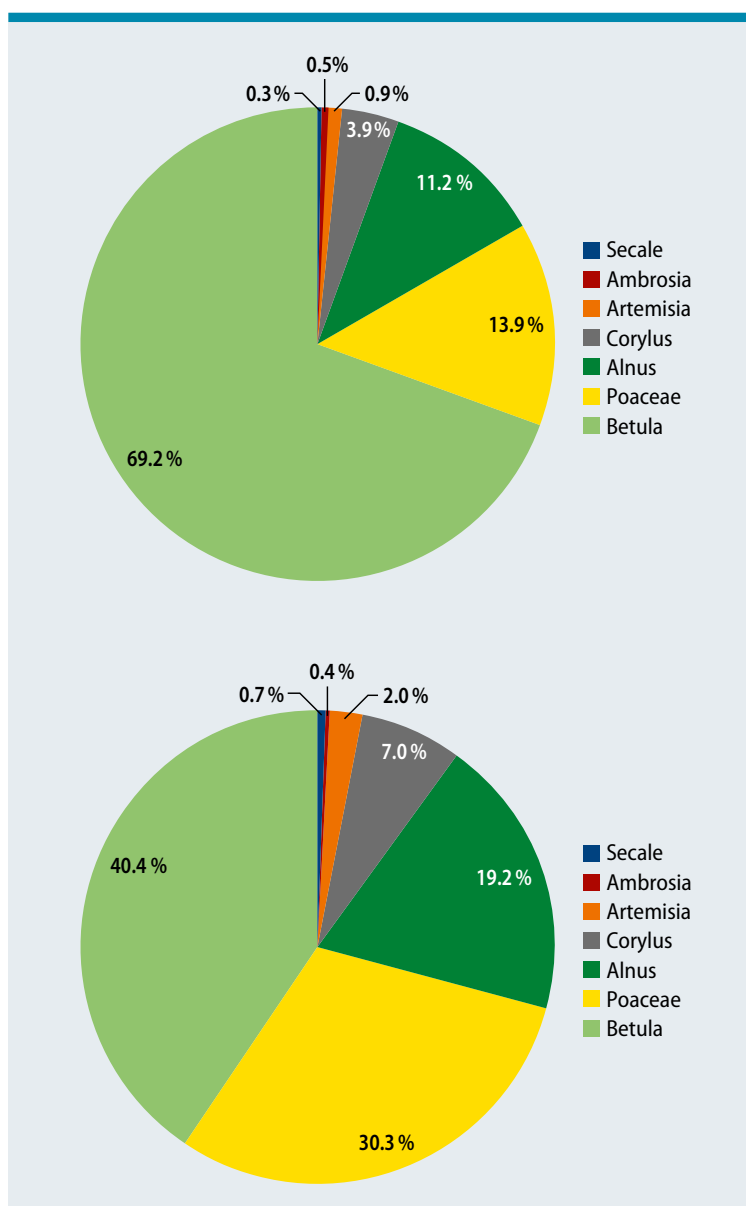


Fig. 1: A comparison of the distribution of allergenic pollen in Germany over a 2-year period (top, 2014; bottom, 2015)



Fig. 2: An overview of increased (to the right of zero) or decreased pollen counts for individual species in Europe (from [17])

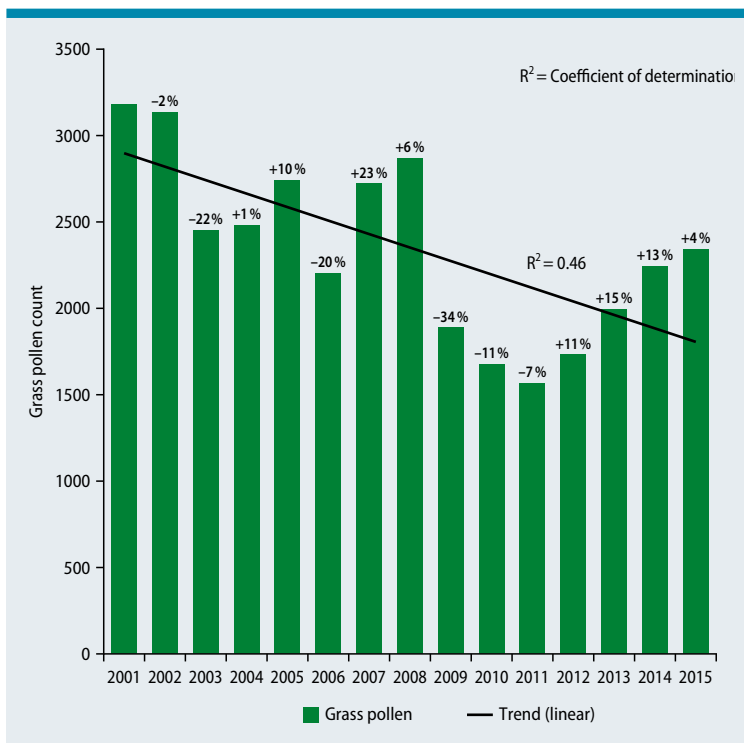


Fig. 3: An overview of the trend in grass pollen counts in Germany showing annual totals measured at monitoring stations for the German Pollen Information Service (Stiftung Deutscher Polleninformationsdienst, PID)

ed in urban areas in recent years, resulting in a possible effect on pollen levels in these towns.

Is common ragweed a prime example of climate change?

Ambrosia artemisiifolia (Ambrosia: common ragweed) is an invasive neophyte that originated in the US and is now found in Europe and Germany. Germany has been home to small, wild populations for more than 150 years due to the sowing of clover seeds from the US; ragweed then went on to spread throughout Europe, particularly in warmer regions. Although human activity promotes its distribution (construction activities, the prevalence of bird food containing ragweed seeds), climate change is apparently intensifying the spread of ragweed from south to north [18].

The frequency of ragweed sensitization in the US is approximately the same as for grass pollen, and the extent of ragweed-related disease could also rise markedly in Germany unless countermeasures are taken. Exposure to around 10 ragweed pollen induces symptoms [19]. At present, the ragweed pollen count only reaches this level sporadically in most German federal states [20].

Common ragweed cross-reacts with mugwort (*Artemisia vulgaris*) and accurate diagnosis is only possible using the ragweed-specific allergen, Amb a 1. However, due to this cross-reactivity with mugwort, new sensitizations to ragweed are not needed to induce allergic symptoms to ragweed.

Approximately 8 % of adults in Germany are sensitized at present and 0.4 % have IgE-specific antibodies to Amb a 1, the major ragweed pollen allergen [21]. A sensitization rate of around 15 % can be expected among patients attending outpatient allergy centers [22].

In Germany, ragweed affects a population already sensitized to mugwort, prolongs the pollen season and hence also the symptomatic period for mugwort-allergic individuals, and can cause new sensitizations to ragweed. For these reasons, it is essential to combat *Ambrosia artemisiifolia*. Since ragweed seeds can survive for up to 40 years in soil, long-term efforts at eradication and monitoring are required.

Thunderstorm-related asthma

The first article on the increased incidence of asthma exacerbations [23] during thunderstorm periods, characterized by an increase in the use of first aid centers and inpatient services was published in 1985. Worldwide observations followed.

These asthma outbreaks during and after thunderstorms were believed to be the result of an increase in the level of airborne allergens from pollen, caused by the osmotic rupture of pollen and spores in the air [24].

According to current prognoses on climate change, one expects to see an increase in the intensity and frequency of periods of severe precipitation, including thunderstorms, over the course of the next few decades [3].

Molds

The effect of climate change on allergy-relevant molds and their spores is less well documented than it is for pollen.

It is believed that the combination of increased CO₂, the early onset of spring, warmer winters, and regionally higher levels of precipitation promotes mold growth [25].

Increased rainfall generally results in greater mold growth. Areas affected by thunderstorms and the resulting increase in air humidity have seen the number of airborne fungal spores double, which could be related to the increase in asthma attacks [26]. The combination of regionally elevated ozone levels and higher spore counts also results in more pronounced asthma symptoms and the increased use of short-acting beta-agonists [27].

Only a handful of investigations are available on the effect had by increased CO₂ levels on the growth of mold. A British longitudinal study revealed an increase in *Alternaria* spore levels since 1992 [28]; however, this rise could be explained by an increase in cereal production in the region.

Results of an experimental study showed that rising CO₂ levels magnify the allergenicity of *Aspergillus fumigatus*, one of the most important molds in indoor and outdoor air. *Aspergilli* grown at today's CO₂ levels (around 392 ppm) are 8.5 times more allergenic compared with *Aspergilli* grown at pre-industrial CO₂ concentrations of 280 ppm. Doubling this level to 560 ppm would cause allergenicity to increase again by 3.5-fold.

Elevated carbon dioxide levels also affect the growth and allergenicity of *Alternaria alternata*. Since timothy grass (*Phleum pratense*) leaves represent a growth substrate for *Alternaria alternata* and *Cladosporium phlei*, grass was grown at four CO₂ concentrations (300, 400, 500, and 600 µmol/mol) for experimental purposes and the spore abundance of both fungi, their size (microscopy), as well as the allergen content (ELISA) of *Alternaria alternata*, were measured. *Alternaria alternata* produced almost three times more spores at CO₂ concentrations of 500 and 600 µmol/mol, while the allergen count per plant was only doubled compared with lower concentrations. Overall, elevated CO₂ concentrations result in increased production of *Alternaria* spores with a slightly lower allergen content [29].

The effects of temperature rises on the growth of fungi and their spore production were investigated

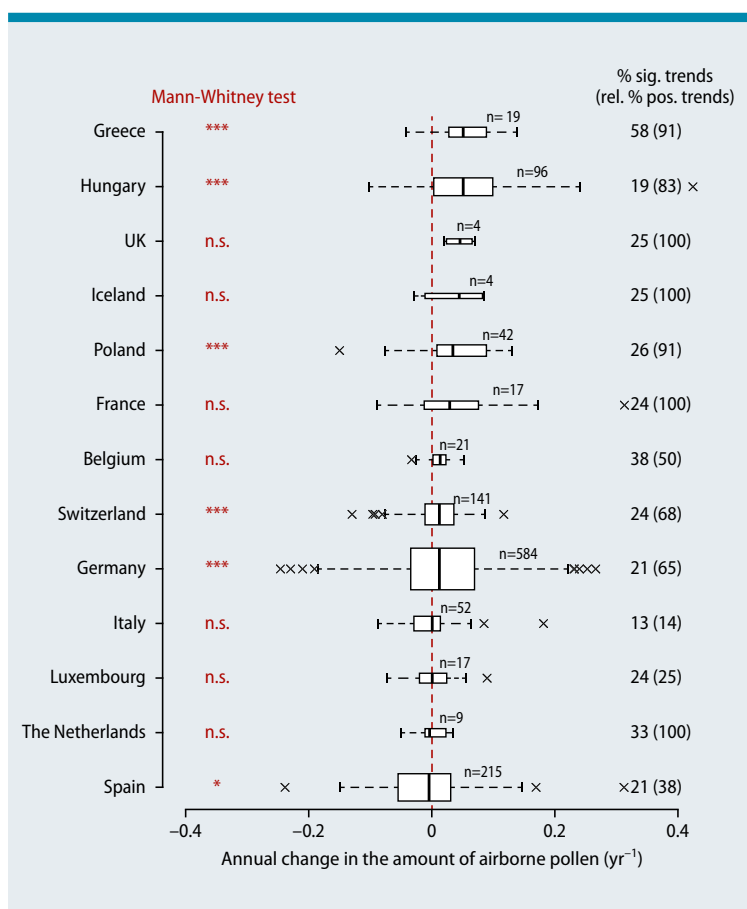


Fig. 4: Changes in annual pollen counts in 13 European countries. The data show significant changes in mean values (Mann-Whitney test) for six countries (from [17]).

in six highly allergenic fungal species (*Alternaria alternata*, *Aspergillus niger*, *Botrytis cinerea*, *Cladosporium cladosporioides*, *Cladosporium oxysporum*, and *Epicoccum purpurascens*). Under experimental conditions, they were exposed to the average temperatures and nutrient conditions in the 1980s, 1990s and 2000s, in the UK, as well as those specified by the IPCC in their climate change scenario up to 2100. Mycelium growth and spore production were observed.

All six species grew faster at higher temperatures, in particular the temperatures prognosed for 2100. Most fungi produced more spores at higher nutrient availability, yet few spores at higher temperatures. *Cladosporium* was the only exception, producing more spores at higher temperatures [30].

It can be generally assumed that, as a result of rising temperatures and CO₂ levels in the atmosphere, fungi will exhibit a significant growth spurt and faster mycelium growth, yet relatively lower spore production. In summary, this will increase allergenic

exposure arising from fungi, thereby amplifying its effect on respiratory tract allergies.

Climate change and indoor allergens (particularly house dust mites)

Although epidemiology and experimental studies have yielded only little information on this subject, one can conclude the following:

- Climate change has an indirect effect on indoor air.
- The colder the temperatures in winter, the more indoor spaces are heated and thus dryer, thereby reducing the chances for mite population growth. Warmer winters, on the other hand, induce the opposite effect: The warmer the temperature, the less heating is used and the greater the air humidity, resulting in potentially higher mite growth. It has been shown in Germany that cold winters are associated with a reduction in mite numbers in bedrooms [31]. In this context, a further study revealed that significant temperature fluctuations from summer to winter are associated with a lower frequency of asthma [32]. Warmer winters in Germany would result in an increased humidity in homes and workplaces, and thus a greater incidence of house dust mite-related allergic rhinitis and asthma – and vice versa in the case of cooler winters!

Boundaries of knowledge

Any discussion on this topic must point out the boundaries of knowledge that currently exist, including the following:

- Since the intensity and characteristics of climate changes are subject to regional differences, it is difficult to make generalized conclusions, not least in terms of possible effects on allergic diseases.
- Measurable epidemiological changes can only be quantified after decades; climate studies require time series of at least 30 years.
- There are significant gaps in our knowledge on airborne allergen-induced asthma exacerbations (e.g., lack of knowledge on the clinically relevant threshold values for pollen or mold allergens), added to which the threshold values in the affected population or in individuals depends on a multitude of variables.
- The problem created by the combination of different pollutants (e.g., pollen with particulate matter or ozone pollution) and its effect on the respiratory tract remains unclear.

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Conflict of interests

Prof. Dr. Karl-Christian Bergmann is chairman of the German Pollen Information Service (Stiftung Pollen-informationsdienst, PID) and states that there are no conflicts of interest.

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