



# Climate Effect, Globalization, and Ethics in Allergy

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## Abstract

The prevalence of allergic diseases is increasing rapidly and has already reached an epidemic level. Two major drivers of this development are climate change and

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globalization, which both induce an increase in allergens. Concomitant climate change fosters the spreading of the latter on a global scale. The increase in allergens not only aggravates the symptoms and the degree of suffering for patients who already are allergic, but also gives rise to new cases of allergies. The distribution of allergies in society follows a steep socioeconomic gradient worldwide. According to well-established theories of justice such a distribution of the allergy burden is unfair. This fact adds a major ethical dimension and challenge to the allergy epidemic. This chapter draws on the key points of policies for allergy prevention and treatment. It shows how related programs and measures can be conceptualized and prioritized according to the principles of distributional justice.

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**Keywords**

Climate change · Distributional justice · Ethics · Globalization · Policy · Pollen allergy

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## **1 Motivation**

The World Health Organization (WHO) rates the so-called noncommunicable diseases (short NCDs) as the biggest global medical challenge. These chronic diseases such as cancer, cardiovascular diseases, diabetes, respiratory and allergic diseases are globally the main cause for the loss of quality of life and premature death (GBD 2017). Especially allergies are on the rise and have already reached a prevalence rate which is epidemic (EAACI 2014). NCDs typically develop from the interaction of environmental risk factors and an individual's genetic and metabolic endowment. Climate change and globalization are two major risk factors for the spread of allergies. This chapter demonstrates how both climate change and globalization induce an increase in numbers of allergens and foster their distribution on a global scale. The symptoms of allergic patients are aggravated and there are many new incidents.

According to recent studies, the prevalence of allergic diseases is connected to socioeconomic factors, both across and within countries. Especially socially and economically weak parts of the population suffer from allergic diseases (Behrmann 2010). According to theories of justice, like the Rawlsian theory (Rawls 2003), this spread of allergies within the population is unfair. Therefore the handling of the allergy epidemic is connected to major ethical considerations and challenges. This chapter shows how key points of allergy mitigation policies, related programs, and measures can be conceptualized and prioritized according to the principles of distributional justice and such be handled in a more humane way.

## **2 Climate Change and Globalization as Major Drivers of the Allergy Prevalence**

### **2.1 Prevalence Facts and Socioeconomic Impact**

The twentieth century is characterized by enormous achievements in enhancing population health, especially with respect to life expectancy and infant mortality. However, recently this trend seems to have started to stagnate or even partly decline. Since the beginning of the twenty-first century, there is an increasing prevalence of NCDs (Behrmann 2010). Particularly, allergic diseases constitute a serious and large-scale health problem worldwide. Both in developed and in low to middle income countries, the rise in allergic sensitivities towards ordinary environmental substances has reached an epidemic level during the last decades (EAACI 2014). On a global scale, 10–40% of the population is affected (Pawankar et al. 2013). Allergies cover a broad range of severe to mild disorders such as life-threatening anaphylaxis, food allergies, asthma, rhinitis, conjunctivitis, angioedema, urticaria, eczema, eosinophilic disorders, and drug and insect allergies (Pawankar 2014). Globally 300 million people suffer from asthma and about 200–250 million people suffer from food allergies. One tenth of the population suffers from drug allergies and 400 million from rhinitis (Pawankar et al. 2013). In Europe allergies are the most common NCD. There are 150 million European allergy sufferers and according to the current prediction half of the entire EU population will be affected by 2025 (EAACI 2016).

Alongside the substantial individual suffering due to the life-threatening or chronic course of the allergic condition and the impairment of the quality of life, allergies induce a high socioeconomic burden. On the one hand, they impose huge direct costs on health care systems, for instance in terms of pharmaceutical expenses, hospitalization, and other forms of treatment (Weiss et al. 2004). On the other hand, indirect costs due to the diminished productive capacity of allergy sufferers in school, studies, and work cause a considerable financial burden for societies (Zuberbier et al. 2014). Figure 1 gives an overview of these direct and indirect costs for selected countries.

### **2.2 General Classification of Risk Factors**

The increasing prevalence of allergies together with the related suffering and costs urgently calls for efforts to identify the underlying causes, mechanisms, and risk factors in order to conceptualize and implement counter-measures in terms of prevention and therapy. The World Allergy Organization (Pawankar et al. 2013) provides a comprehensive overview of the state of research with respect to potential risk factors for allergic diseases which can be classified as follows:

The causes which lead to the development of allergies are complex – for an overview see Fig. 2. Allergies evolve through the interaction of risk factors rooted in the individual's genetic predisposition and environmental influences. In this context,

| Country     | Year costs calculated | Population (2010) | Disease           | Direct costs*     | Indirect costs**       | Total costs estimated |
|-------------|-----------------------|-------------------|-------------------|-------------------|------------------------|-----------------------|
| Australia   | 2007                  | 23 million        | All allergies     | A\$ 1.1 billion   | A\$ 8.3 billion        | A\$ 9.4 billion       |
| Finland     | 2005                  | 5.3 million       | All allergies     | €468 million      | €51.7 million          | €519.7 million        |
| South Korea | 2005                  | 50 million        | Asthma            | -                 | -                      | US\$ 1.78 billion     |
|             |                       |                   | Allergic rhinitis | -                 | -                      | US\$ 266 million      |
| Israel      | 2010                  | 7.5 million       | Asthma            | -                 | -                      | US\$ 250 million      |
| Mexico      | 2007                  | 103 million       | Asthma            | -                 | -                      | US\$ 35 million       |
| USA         | 2007                  | 310.2 million     | Asthma            | US\$ 14.7 billion | US\$ 5 billion         | US\$ 19.7 billion     |
|             | 2005                  |                   | Allergic rhinitis | US\$ 11.2 billion | Up to US\$ 9.7 billion | Up to \$20.9 billion  |

**Fig. 1** The Economic Burden of Allergy (World Allergy Organization 2011). \* Expenditure on medications and health care provision. \*\* Cost to society from loss of work, social support, loss of taxation income, home modifications, lower productivity at work, etc.

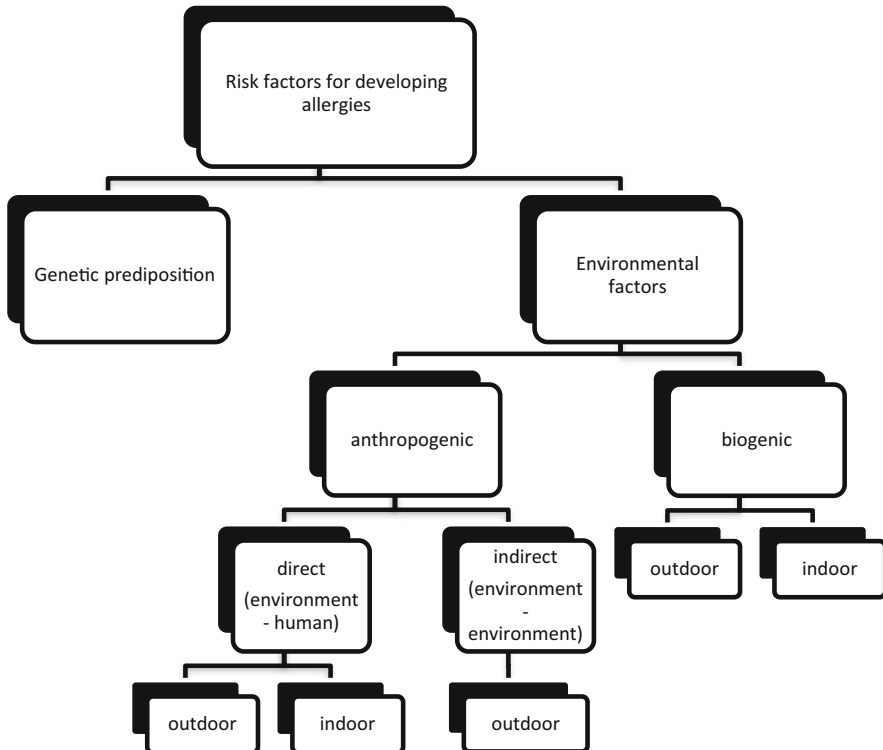


**Fig. 2** Classification of risk factors for the development of allergies (Heuson and Traidl-Hoffmann 2018)

environmental influences need to be considered comprehensively as the unity of all exogenous factors humans are exposed to (Ring et al. 2012). Therefore, anthropogenic factors, of both physical and chemical nature (such as pollution), and biogenic factors (such as pollen or microbes), most notably in combination with specific lifestyles (including nutrition) and living environments, affect human health (Traidl-Hoffmann 2017).

### **2.2.1 Genetic Predisposition**

Recent studies have shown that the functionality of the epithelial barrier of the skin, the respiratory tract, and the intestine plays a crucial role in an individual's susceptibility to allergies. This functionality may be seriously harmed by genetic mutations. For instance, the Filaggrin-null mutation is rated as the most frequent genetic disposition associated with atopic eczema. The instance of such mutations implies a considerably larger probability for allergenic environmental factors to cause a sensitization. Furthermore, the skin's natural protective film is impaired due to the lack of Filaggrin. Resulting changes in the microbial equilibrium cause further irritations of the skin barrier (Irvine et al. 2011).

### **2.2.2 Direct Anthropogenic Environmental Factors**

Anthropogenic factors exert a direct influence on human health and this is also the case when it comes to the development of allergic diseases (environmental–human interaction) (D'Amato et al. 2016a). Figure 3 provides an overview of the most common factors, which are given by various forms of outdoor and indoor pollution.

Globally, the main sources of outdoor pollution are fuel combustion, emissions from vehicles, construction and agricultural operations, power plants and industries, primarily refineries. Primary pollutants such as CO, CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and PAHs are directly emitted into the atmosphere, whereas O<sub>3</sub>, a secondary pollutant, results from the reaction between UV radiation/sunlight, hydrocarbons, and NO<sub>2</sub>. PM can either be emitted directly (primary PM) or be formed in the atmosphere from gaseous precursors, mainly SO<sub>2</sub>, NO<sub>x</sub>, ammonia, and non-methane VOCs (secondary PM) (Pawankar et al. 2013). These pollutants (either separately or mutually) cause or exacerbate the symptoms of major allergic diseases like asthma, allergic rhinitis, and respiratory allergy (EAACI 2014).

The sources of the leading risk factors for indoor pollution are environmental tobacco smoke (ETS), biomass (wood/coal) fuel, cleaning and washing products, and mold/dampness caused by humidity from cooking and heating on open fires or with inefficient stoves and poorly ventilated rooms. The emitted pollutants (see Fig. 3) can cause or aggravate allergic diseases and symptoms such as asthma, bronchial hyper-responsiveness, cough, irritations of nose, mouth and throat and may finally induce atopic sensitization (Weisse et al. 2012).

The basic mechanism of action of these direct anthropogenic risk factors can be described as follows. Environmental substances seem to achieve this via an interaction with the aryl hydrocarbon receptor, which responds to keratinocyte stimuli from the environment and mediates allergic symptoms such as atopic dermatitis (Hidaka et al. 2017).

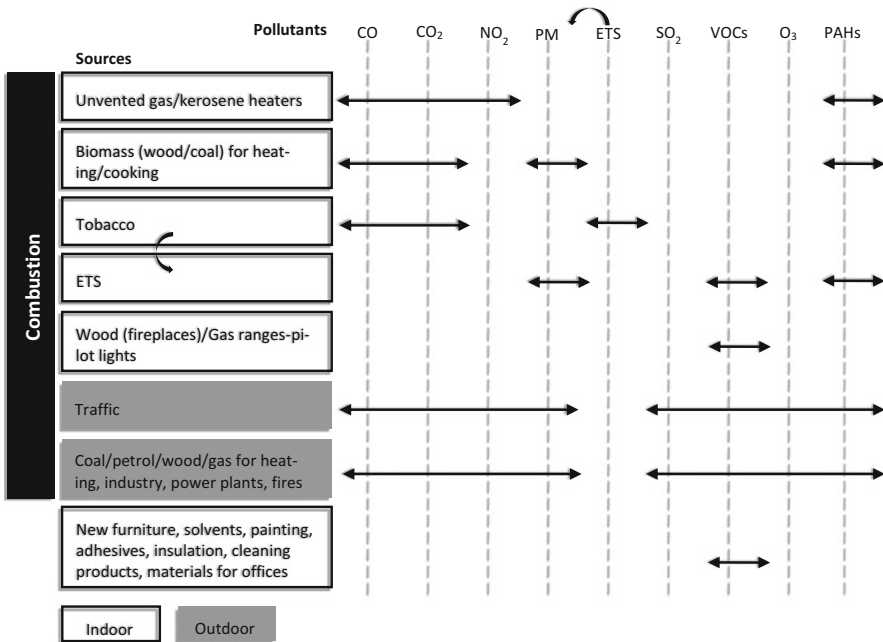


**Fig. 3** Common anthropogenic direct risk factors and relative outdoor/indoor sources (Maio et al. 2013). Reused with permission from the World Allergy Organization. *CO* Carbon monoxide, *CO<sub>2</sub>* Carbon dioxide, *NO<sub>2</sub>* Nitrogen dioxide, *PM* Particulate matter, *ETS* Environmental tobacco smoke, *SO<sub>2</sub>* Sulfur dioxide, *VOCs* Volatile organic compounds, *O<sub>3</sub>* Ozone (secondary pollutant), *PAHs* Polycyclic aromatic hydrocarbons

### 2.2.3 Indirect Anthropogenic Environmental Factors

Additionally, the influence of anthropogenic environmental factors on the susceptibility to allergies can occur indirectly. Such environmental–environmental interactions appear to be a missing link in the comprehensive understanding of allergic diseases. This interaction is characterized by the influence of certain environmental factors amongst each other. It has been demonstrated both in vitro and in clinical studies that birch pollen from areas with a higher ozone load have a significantly increased allergenicity than those from areas with a comparatively lower concentration of ozone (Beck et al. 2013).

### 2.2.4 Biogenic Environmental Risk Factors

Biogenic factors, i.e. factors of organic origin, are usually involved in the development of allergic diseases. Figure 4 provides an overview of the major biogenic environmental risk factors.

In terms of inhaled biogenic allergens, it is important to distinguish between outdoor and indoor allergens. The majority of outdoor allergens arise seasonally such as pollen from grasses, trees, and weeds (Adkinson 2008). Typically, there is a positive correlation between the exposure to pollen and the severity of symptoms

| Category            |                                                    |              | Primary site of exposure | Prevalence of exposure | Dispersal                   | Sensitization                                                     |
|---------------------|----------------------------------------------------|--------------|--------------------------|------------------------|-----------------------------|-------------------------------------------------------------------|
| Inhaled             |                                                    |              |                          |                        |                             |                                                                   |
| Outdoors            | Pollen                                             |              | Nose, eyes               | +++                    | Windborne                   | Up to 30% worldwide                                               |
|                     | Mold spores                                        |              | Nose, eyes               | +++                    | Windborne                   | Up to 10% worldwide                                               |
|                     | Algae                                              |              | Nose, eyes               | +                      | Windborne                   | Rare                                                              |
| Indoors             | Acarids                                            | Dust mite    | Nose, lungs              | +++                    | Transient after disturbance | Temperate zones                                                   |
|                     |                                                    | Storage mite | Nose, lungs              | +                      |                             | Farming                                                           |
|                     | Insects                                            | Cockroach    | Nose, lungs              | ++                     |                             | Widespread                                                        |
|                     |                                                    | Other        | Nose, lungs              | +                      |                             | Locally common                                                    |
|                     | Mammals                                            | Cats         | Nose, lungs              | ++                     | Airborne for many hours     | Common                                                            |
|                     |                                                    | Dogs         | Nose, lungs              | ++                     |                             | Common                                                            |
|                     |                                                    | Other        | Nose, lungs              | +                      |                             | Dependent upon exposure                                           |
|                     | Non-inhaled                                        |              |                          |                        |                             |                                                                   |
| Food                | Peanuts, tree nuts, wheat, soy, egg, chicken, etc. |              | Oral and/or skin         | +++                    | N/A                         | Sensitization variable; up to 4%; not clearly related to exposure |
| Bites, stings, etc. | Hymenoptera                                        |              | Skin/circulation         | +                      | N/A                         |                                                                   |
|                     | Ticks                                              |              | Skin                     | +                      | N/A                         | Locally important                                                 |

**Fig. 4** Major biogenic risk factors for allergic diseases (Pawankar et al. 2013)

(Gilles et al. 2011). Other significant causes of sensitization are mold allergens and fungal spores (Chew et al. 2000). Exposure to outdoor allergens is dependent on the concentration of aeroallergens, the time spent outdoors, and the capability to seal off indoor areas from outdoor allergens (Pawankar et al. 2013).

Major sources of indoor allergens include dust mite droppings, animal dander, cockroach droppings, and molds. With respect to asthma there also is a dose-response relationship between exposure to the above-mentioned allergens and sensitization (Platts-Mills et al. 1997).

Non-inhaled biogenic allergens mainly arise from food sources or insect bites and stings. In case of food allergies, the symptoms are primarily oral, gastrointestinal, or urticarial. Food allergens often occur regionally (Connett et al. 2012) and they can significantly contribute to the development of atopic dermatitis (Han et al. 2009). Insect venom is a potent allergen and repeated exposure bears the risk of both an IgE response and subsequent anaphylactic responses (Pawankar et al. 2013).

In conclusion, to a large extent the root causes leading to the epidemic increase in allergic diseases are still unknown (Ring et al. 2012). In the past, the genetic predisposition was seen as the only responsible factor for the development of allergic diseases. Yet the vast increase in the prevalence of allergies suggests that allergies are also an environmental disease (Traidl-Hoffmann 2017). Obviously, anthropogenic climate change and globalization (Castelain 2011) are two recent trends with enormous impact on our environment and on related (health-)conditions. The increase in both areas strongly overlaps with the spread of the allergic epidemic and hence we need to consider and analyze anthropogenic climate change and globalization themselves as risk factors for the development of allergies. Taking climate change and globalization into account would aid the understanding of the

sources of the allergic epidemic and is an essential prerequisite for creating effective counter-measures and strategies in terms of prevention and therapy. The following two sections demonstrate how climate change (Sect. 2.3) and globalization (Sect. 2.4) cross-sectionally influence the above-mentioned environmental risk factors for developing allergic diseases.

## 2.3 Anthropogenic Climate Change

### 2.3.1 Background

The climate system is subject to natural external factors and complex internal processes. Nevertheless, according to the current state of research, it is very likely that anthropogenic greenhouse gas (GHG) emissions are the main cause of global warming which has occurred since the middle of the twentieth century (IPCC 2014). Besides the well-known adverse ecological effects of climate change, the rise in temperature poses increased risks to human health, especially with respect to allergic diseases (see Sect. 2.3.2).

### 2.3.2 Impacts on Allergies

Climate change increases the prevalence of allergic diseases in a both direct and indirect manner (see Fig. 5). The largest effect is noticeable in pollen allergies and associated problems of respiratory health (Pawankar et al. 2013).

#### Direct Impacts

The major direct impact of climate change on allergic diseases is given by the increased occurrence of heat waves (Demain 2018). These prolonged periods of abnormally hot weather induce heat stress which, especially in combination with air pollution, promotes inflammation and lowers the airway hyper-reactivity threshold due to fluid loss and disrupted pulmonary perfusion. Consequently, during a heat

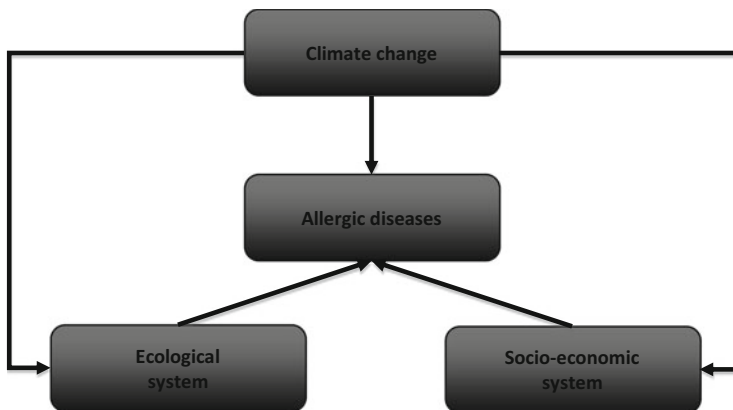


**Fig. 5** Direct and indirect impacts of climate change with respect to allergic diseases

wave patients with chronic respiratory diseases, including asthma and related allergies, bear a higher mortality risk of 1.8–8.2% compared to average summer temperatures (Witt et al. 2015). According to recent projections, more intense heat waves in the future will induce further aggravation of respiratory allergies which will culminate in an increase in mortality (Costello et al. 2009).

### **Indirect Impacts (Ecological System)**

The majority of the negative effects of climate change on allergic diseases are passed on via ecological pathways and most notably affect the respiratory system and respiratory related allergies (Beggs 2016). The major factors of climate change which impact on the development and worsening of allergies are the increasing global average temperature, sea level rise, extreme weather events, and with that changing crop production.

#### **Increasing Global Average Temperature**

##### **Longer Pollen Season and Increased Pollen Concentration**

The rise in global average temperature causes the expansion of vegetation periods. This prolongs the pollen season and increases the allergenic biomass. Consequently, allergy sufferers are exposed to higher pollen concentrations for longer periods of time and the level of suffering increases accordingly. Due to higher pollen exposure levels, the risk for previously healthy people to (re-)develop allergies increases as well. Empirical evidence has shown that there is a correlation between a rise in temperature and the total pollen concentration in Europe. This is especially noticeable for the allergenic birch and grass pollen (Smith et al. 2014). Particularly striking is the proportional increase in birch pollen concentrations in urban microclimates and hence one can assume that the ambient air pollution in terms of NO<sub>x</sub>, CO<sub>2</sub>, and VOCs can raise the pollen concentration in the environment (Ziello et al. 2012). This hypothesis is also consistent with experiments in climatic chambers (Zhao et al. 2017). However, recent studies show that the pollen concentrations in urban areas are subject to strong local and temporal variations, which necessitates tighter pollen monitoring networks within cities or even personal pollen exposure measurements (Werchan et al. 2017).

##### **Rising Prevalence of Allergic Diseases Due to New Types of Pollen**

Climate change promotes the growth of invasive plant species (so-called neophytes), which are mainly spread by anthropogenic processes. A prime example is given by ragweed which is originally endemic to the American continent and whose pollen is rated as a strong allergenic trigger. The smooth phenotype of ragweed seeds enhances the rapid spreading of the plant by wind. Anthropogenic activities, such as interregional trade in agricultural products, have further enabled the introduction and spread of ragweed in Europe (Rogers et al. 2006). The establishment of ragweed in new regions is further promoted by climate change, because longer periods of heat create new vegetation niches for non-native plants (Sikoparija et al. 2017). It is beyond dispute that the occurrence of ragweed causes new sensitizations and allergies (Burbach et al. 2009). In addition, other neophytes such as the Canadian goldenrod or the late goldenrod are suspected to cause pollen allergies. However,

because these plants are characterized by insect pollination rather than distribution of pollen by wind, their allergic potential is limited primarily to cut flowers indoors (BfN 2018).

#### Increasing Aggressiveness and Allergenicity of Pollen

Additionally, besides registering an increase in pollen due to anthropogenic climate change recent scientific studies have provided evidence for the fact that growing environmental pollution may enhance the allergenic potential of allergy-causing plants. Exposure experiments have shown that traffic-related pollutants strengthen the release of allergenic particles from pollen (Motta et al. 2006). But not only quantitative changes take place. Results from field and in vitro studies show a qualitative change in allergens too. NO<sub>2</sub> exposure leads to nitrosylation of the birch allergen (Zhao et al. 2016). Moreover, an exposition to particles induces nitration of allergenic proteins and moreover formation of new allergens (Zhao et al. 2017). The effect of environmental pollutants on allergenicity is by no means limited to pollen, but can also affect other airborne allergen carriers, such as mold fungi (Lang-Yona et al. 2016).

Furthermore, recent climate chamber experiments showed increased pollen allergenicity as a result of ozone pollution and this was especially striking for the ragweed pollen (Zhao et al. 2016). Yet also in field studies birch pollen from areas of high ozone pollution has a higher allergenicity than pollen from trees that thrive in areas with lower ozone levels (Beck et al. 2013). It is important to note that climate change fuels this pollutant-induced increase in allergenicity, as there is a positive correlation between temperature rise and ozone concentration. Finally, recent studies show that carbon dioxide in combination with drought stress promotes the allergenicity of ragweed pollen (Zhao et al. 2017). It is critical to note that not every pollutant necessarily increases the allergen content of pollen, especially under in vitro conditions (Rogerieux et al. 2007). This insight is strengthened by a field study, which was unable to prove a correlation between NO<sub>2</sub> and allergen content (Beck et al. 2013). However, it is now known that the allergenicity of pollen is determined not only by its allergen content but also by a variety of low-molecular-weight mediators (Gilles-Stein et al. 2016). These mediators are released from pollen in higher concentrations when they grow in an urban environment and under high NO<sub>2</sub> concentration (Beck et al. 2013). Even if not all effects of climate change lead to augmented pollen allergenicity, overall there is a clear trend.

#### Sea Level Rise

Since the beginning of the twentieth century, the global mean sea level has risen by approximately 0.2 m and a rise of approximately 0.08 m has occurred since 1993. According to current projections, it is very likely that by the end of the twenty-first century the sea level will have risen by one additional meter (Church et al. 2013). A higher sea level increases the indoor moisture in populated coastal areas. In the aftermath of Hurricane Katrina (New Orleans, USA) high fungal concentrations – both indoor and outdoor – were recorded (Barbeau et al. 2010). Wet housing conditions, especially when combined with increased temperatures and CO<sub>2</sub> levels, will encourage fungal growth and mold contamination which would have serious

adverse effects in terms of respiratory allergies (Katelaris and Beggs 2018). Allergic sensitization to fungi is an important risk factor for allergic asthma and fungal exposure has been linked to asthma exacerbations and hospital presentations involving a rise in asthma mortality (Tham et al. 2014). In addition to allergic rhinitis and asthma, fungal exposure has been associated with afflictions such as allergic broncho-pulmonary aspergillosis, hypersensitivity pneumonitis, allergic fungal sinusitis, and atopic dermatitis (Katelaris and Beggs 2018).

This sea level rise induced boost of respiratory allergies is aggravated by the fact that there has been a strong population growth in lower coastal areas over the past decades, implying that more and more people are exposed to damp housing conditions (Demain 2018). According to a meta-analysis of 33 epidemiologic studies, adverse respiratory health outcomes in occupants rise by 20–50% because of wet living conditions and related mold exposure (Fisk et al. 2007).

### Extreme Weather Events

There is increasing evidence for severe asthma attacks during thunderstorms in high pollen seasons in various geographical zones, most notably in Europe and Australia (Lin et al. 2009). During the first 30 min of a thunderstorm the heavy rainfall ruptures pollen grains thus releasing respirable allergenic particles (USGCRP 2016). Furthermore, cold downdrafts transport these aeroallergens to the ground level where they spread due to strong electric fields caused by the thunderstorm and hence promote bronchial hyper-responsiveness (D'Amato et al. 2012). Consequently, pollen allergy sufferers who are exposed to the first phase of a thunderstorm are faced with high allergen levels and are at risk of severe asthmatic shocks and exacerbations of allergic symptoms (D'Amato et al. 2016b).

### Food Allergies

Food allergies are on the rise. In industrialized countries, 4–8% of children and 3–4% of adults are affected (Burks 2015). Recent studies point out that IgE-mediated allergies to common food types result not only from sensitization through the gastrointestinal tract, but also from sensitization to homologous pollen allergens through the respiratory tract. The food allergies then arise due to the cross-reactivity with certain airborne allergens (Popescu 2015). For instance, the prevalence of plant food allergy in Europe is significantly influenced by sensitization to specific proteins in birch pollen, while in the Mediterranean area sensitization mainly occurs through profilins and non-specific lipid transfer proteins (Burney et al. 2014). This indicates that (re-)distribution of allergenic plants due to climate change will also probably induce altered patterns of food allergies (Katelaris and Beggs 2018). Additionally, recent experimental studies suggest that the allergenicity of some plant-based foods is enhanced at higher levels of CO<sub>2</sub> (Ziska et al. 2016). As a final comment aeroallergens have been shown to presumably play an important role in inducing pediatric eosinophilic esophagitis (Fahey et al. 2017).

## Indirect Impacts (Socio-Economic System)

On top of the pathway of the ecological system, climate change transmits detrimental effects with respect to health and allergies via a socio-economic system (Haines and Ebi 2019). One major impact is that climate change impairs the food supply provided by the agricultural sector.

Altered climatic and environmental conditions diminish the yield of vegetables and legumes, which play a crucial role in sustaining health and preventing (non-communicable) diseases (Scheelbeek et al. 2018). This scarcity especially hits poor countries and parts of the population with lower incomes, which out of necessity consume cheaper and thus less healthy sources of food (Kinney 2008). Moreover, increasing CO<sub>2</sub> concentrations are suspected to be involved in lowering the nutritional quality (of proteins, B vitamins, and micronutrients) of major crops, such as rice or wheat. (Myers et al. 2014). The associated adverse effects on the general state of health foster the development and severity of allergic diseases.

Climate change also accelerates the impoverishment of poor countries due to the abovementioned production losses in the agricultural sector and damages caused by flooding or extreme weather events. As a result, fewer resources are available for investments in the public health system, implying an insufficient supply of measures for preventing and treating allergic diseases (Tanner and Horn-Phathanothai 2014). Finally, impoverishment causes migration and conflicts, both of which undermine a stable and resilient health condition of the people affected (Abel et al. 2019).

## 2.4 Globalization

### 2.4.1 Background

Globalization in simple terms refers to the rising flow of goods, people, services, labor, technology, and capital worldwide and the associated increase in interconnectedness of the various parts of the world. Major drivers of these accelerated exchanges are the creation and development of new information and communication technologies and of new means of transportation. Hence globalization is primarily an economic process of interaction and integration, accompanied by social, political, and cultural aspects (Guttal 2007). For obvious reasons and as explained below, globalization and associated changes have a major impact on human health, see Fig. 6.

### Demographic Changes

Population growth plays an often neglected but crucial role in global change, especially with respect to its inherent contribution to the increase in GHG emissions and climate change. According to recent UN projections the world population is expected to rise to 9.3 billion by 2050. Therefore there is an urgent need for efficient climate change mitigation and adaptation strategies. These must include components to deal with related health problems (United Nations 2019). Besides climate change, population growth exerts massive pressure on regional environments. These pressures include soil exhaustion, water depletion, and the loss of various wild

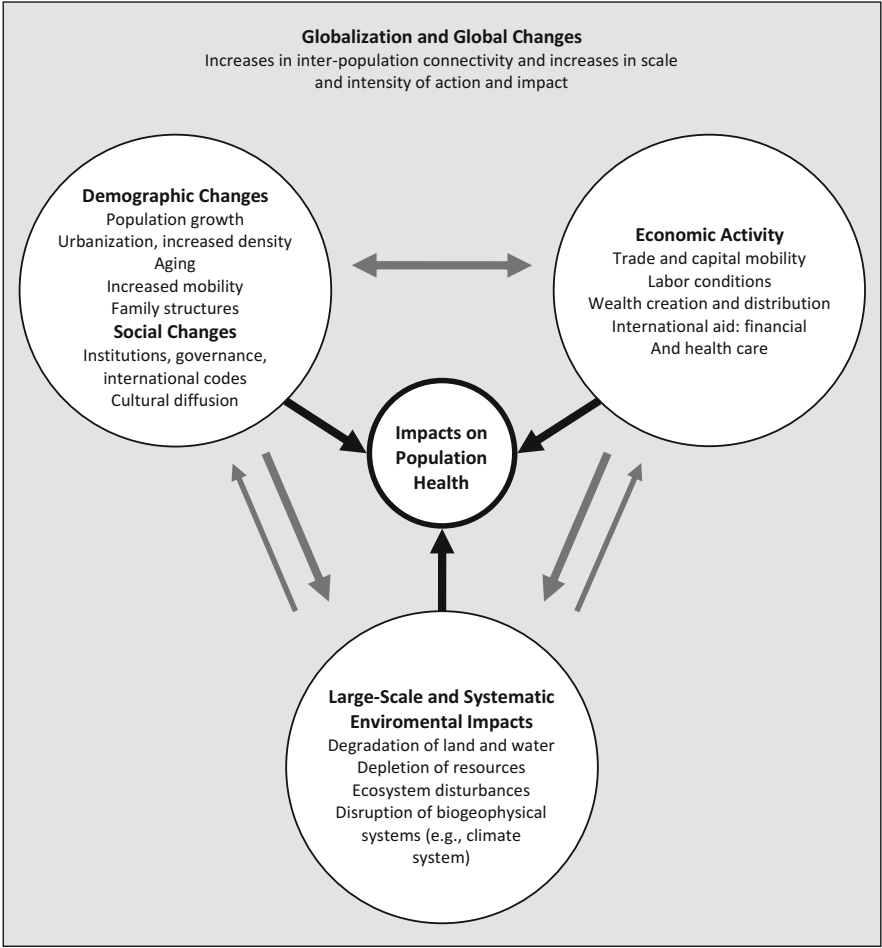


**Fig. 6** Impacts of Globalization and associated changes on human health (McMichael 2013)

animal and plant food species. They harm the ecosystem and thus foster poverty and a decrease in human health.

### Social Changes and Economic Activity

The social and economic dimension of globalization affects human health in various direct ways, such as the increased prevalence of both (new) infectious diseases and NCDs, rising resistances to antimicrobial agents, workplace-related health risks due to the deregulation of international labor markets or expansion of tobacco marketing (Labonté et al. 2011). Indirect health impacts are given by increasing inequalities in wealth, education, autonomy, and social inclusion (Marmot et al. 2008). Some aspects of globalization also benefit human health. For instance, the increased

availability of information, progress in international vaccination programs and systems to address infectious diseases as well as a greater capacity for long-distance responses to disasters. A prime example in this respect is given by the COVID-19 pandemic which has hit the EU in February 2020. Nevertheless, a sustainable improvement of conditions for human health requires linking environmental and sociocultural conditions and basic human biologic and psychological needs.

## **Environmental and Ecologic Changes**

Primary prevention of health problems associated with global environmental and ecologic changes, such as degradation of land and water or depletion of natural resources, requires coordinated international policies and supplementary local policies and actions. This is for the reason that these problems, as in case of climate change, are rooted in individual actions on the local or regional level (e.g., GHG-emissions caused by economic activities of single agents), but then accumulate to adverse health impacts on a global scale (e.g., health problems related to global warming) (McMichael 2013).

### **2.4.2 Impact on Allergies**

Globalization brings (potential) allergy sufferers increasingly into contact with products, food, plants, and animals from other cultures or countries (Castelain 2011). Allergic contact dermatitis, airborne allergies, animal dander, and food allergies are on the increase due to the global change and increased interconnectedness.

#### **Allergic Contact Dermatitis**

This type of allergy is mainly caused by toxic or allergenic substances that are processed in internationally traded commodities. For instance, 2006 marked the beginning of an epidemic with several hundred people suffering from eczema throughout Europe. All of these patients had purchased armchairs imported from China whose stuffing contained dimethyl fumarate (DMF). In China, DMF commonly serves as a cheap antifungal agent – despite its harmful effects on health and the environment. Due to its volatility, it causes acute contact dermatitis accompanied by biological signs of rhabdomyolysis (Lammintausta et al. 2010).

Another trigger of contact dermatitis can be nickel. Allergic sensitization may be caused by repeated skin contact with objects releasing nickel in critical quantities, such as fashion jewelry, belt buckles, or cell phones (Livideanu et al. 2007). Even though the EU has banned products whose release exceeds a critical nickel-threshold, imported nickel-containing commodities from overseas countries can reach the European market due to insufficient controls and thus constitute a serious source of allergic contact dermatitis (Thyssen et al. 2009).

Besides commercial products, specific types of plants may trigger allergic contact dermatitis. For instance, some plants from the anacardiaceae family (such as the cashew nut tree) contain “urushiol.” This highly allergenic substance can cause severe acute dermatitis by single contact. Relevant plants are common in the American wilderness, especially in the USA and Canada. However, globalization

bears the risk that these plants may invade Europe through contaminated cargo containing earth or vegetables or through illegal importation (Sasseville 2009).

### **Airborne Allergies**

Plants causing airborne contact dermatitis may spread around the world as a result of two internationally interlinked economic activities. A famous example is given by *Parthenium hysterophorus* (“white grass”), a highly allergenic plant that cross-reacts with other asteraceae plants. Originating in Mexico, it made its way to the USA, Africa, Australia, and India via trade flows of contaminated cereals. Primarily in India, white grass has developed into a major trigger of contact allergy (Mahajan et al. 2004). Counter-measures to prevent the spread of toxic or harmful botanicals may cause additional allergic emergencies. For instance, many countries impose regulations prescribing shipped freight containers to be decontaminated with pesticides or other potentially deleterious gases. These fumigants have not only been detected in the air of shipping containers, but can also settle down and contaminate the transported commodities. With a half-life of up to several months, the contaminating substances persevere for a considerable amount of time. As a result, both dock workers and consumers are at risk to develop associated skin allergies or respiratory irritations (Castelain 2011).

Plants disseminating aeroallergens may themselves also spread around the globe due to processes of globalization. The prime example is ragweed, which was presumably transported from North America, its original habitat, to France in a load of animal feed. Due to the ragweed seeds’ capability of sticking to tires, to the increase in traffic and the changing climatic conditions, it has been possible for ragweed to spread across Europe (Laaidi et al. 2003).

Finally, the increase of people travelling themselves can lead to the exposure to aeroallergens due to the different flowering seasons at the destination of travel.

### **(Domestic) Animals**

One of the negative side effects of globalization consists in the expansion of the ruthless trade in exotic animals as pets. Amongst others, chinchillas (endemic to the Andes Mountains) presumably trigger asthma and rhinitis; gerbils (Mongolia) and jerboas (North America) may induce anaphylaxis by their bites (Curin and Hilger 2017). These animals need to be considered as dangerous and venomous. They are not adapted to our climate and are often abandoned by their overburdened or annoyed owners.

### **Food**

Clearly, globalization has boosted the availability and consumption of (previously) exotic food, i.e. vegetables and fruits, including those with the most allergy-sensitizing impact, such as peanuts, kiwis, avocados, bananas, or celery (Castelain 2011). But also various kinds of seafood, industrial food, spices, and herbs are nowadays widespread around the globe.

Globalization has led to a severe rise in allergies to cashews, Brazil nuts, sesame, and seafood. Labelling requirements that ensure that warnings against potential

allergens are declared on the products are often insufficient. Because the traceability of processed raw materials, especially from developing countries, is very difficult, cross-contamination is a likely consequence (Taylor and Baumert 2010).

A new emerging serious threat not to be underestimated is the spread of genetically modified (GM) foods, which often contain proteins that were previously not present in human food. Typical GM foods such as soybeans or crops spread from the USA act as potential sources of allergic reactions that impair human health (Bawa and Anilakumar 2013).

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### **3 The Ethical Dimension of Allergic Diseases**

#### **3.1 Fundamental Ethical Implications of the Allergic Epidemic**

As described above, allergies need to be ranked as severe chronic illnesses that cause various morbidities including irritable disorders such as dermatitis as well as disabling conditions associated with a high mortality risk, such as asthma and anaphylaxis. These medical conditions considerably reduce the patients' quality of life (Michaud et al. 2006). In combination with the epidemic-like prevalence, allergies constitute a major ethical issue on a global scale. This especially becomes obvious against the background of the human right to health which is defined in the constitution of the WHO as: "The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being" (World Health Organization 1948). As can be seen impressively from the currently ongoing COVID-19-pandemic, maintaining and adhering to the human right to health is in no way an automatism, it rather requires insistent and globally concerted political action.

On the one hand, this right constitutes an urgent and immediate moral obligation of the international community to implement and intensify health strategies that pointedly address allergic diseases in terms of therapy. On the other hand, a major pillar of such strategies is prevention, i.e. the mitigation of the above-mentioned risk factors, especially climate change and globalization. In this respect, restoring and sustaining a health-promoting environment is of vital importance. For obvious reasons, an intact environment is an essential prerequisite for implementing human rights – be it in terms of health, food and water supply or even self-determination. This connection was recognized for the first time in the UN Convention on the Rights of the Child (UN General Assembly 1989). Specifically, this convention emphasizes the need to address environmental issues in child disease control. The scientific evidence for the adverse health effects of environmental pollution and climate change underpins the urgent call for ethically motivated action to fight the allergic epidemic.

## 3.2 Matters of Distributional Justice

Besides this basic moral obligation, allergic diseases involve crucial matters of distributional justice that need to be addressed by ethically motivated corrective action and related health programs. Clearly, the allergic epidemic is boosted by recently emerging and reinforcing risk factors rooted in the anthropogenic influence on the natural environment as well as in processes associated with globalization (Traidl-Hoffmann 2017). However, the question of vulnerability to allergic diseases crucially depends on social determinants.

Allergic sensitization indeed occurs in all social classes and ethnic groups, but the distribution of the pathology follows uneven patterns. Specifically, there is a strong negative correlation between the socioeconomic status and morbidity from allergic diseases (Almqvist et al. 2005). For instance, hospitalizations for asthma mainly occur in low and middle socioeconomic classes, and asthma morbidity primarily affects ethnic minorities (Foggs 2005). This socioeconomic gradient in terms of allergy suffering apparently does not depend on universally granted access to public health services, as has been shown in a respective study for Canada (Behrmann 2010). Raised morbidity rates among lower classes are tied to factors of social deprivation. For instance, poverty stricken children in urban livelihoods are frequently exposed to cockroaches, rodents, mold, and dust due to inadequate housing standards (Breyse et al. 2004). Additionally, ethnic minorities or financially weak parts of the population are forced into neighborhoods with low housing costs which typically feature increased levels of environmental pollution and thus involve a higher risk for developing allergies. These groups also have to frequently cope with cheap (and potentially bioengineered) groceries and limited diets which may trigger food (and other) allergies. To sum up, certain populations such as children, ethnic minorities, and members of lower socioeconomic classes are particularly vulnerable to allergy and asthma morbidity.

However, this socioeconomic gradient in terms of developing allergies does not only apply for different classes of population, but also for countries or world regions as a whole. In this sense, allergic diseases and asthma are increasing particularly in low and middle income countries, due to specific poverty-related risk factors (Pawankar 2014). People in these countries frequently use solid fuel such as wood, cow dung, or crop residues, which is burned in simple stoves or open fire in order to generate domestic energy (Pawankar et al. 2013). Moreover, in middle income countries people have reached a sufficient level of wealth to consume tobacco products. Taken together, estimates suggest that indoor pollution is five times higher in poor countries compared to industrialized ones (World Health Organization 2007). To aggravate the situation, developing countries typically set lower priorities on environmental protection compared to economic growth. Therefore, there are higher levels of outdoor pollution in developing countries, which enhances the prevalence of allergic diseases (Pawankar et al. 2013). Additionally, these countries are especially vulnerable to the impacts of climate change, inducing an additional boost to related allergy risk factors (Heuson and Traidl-Hoffmann 2018).

Obviously, this socioeconomic gradient in terms of allergy prevalence across population groups and countries constitutes a serious injustice, since factors beyond the control of an individual such as being a member of an ethnic minority, population class or country cause an increased risk of allergy and asthma morbidity. Consequently, distributional justice necessarily needs to serve as guiding principle for the setting of goals within global strategies and programs to mitigate the allergic epidemic.

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## 4 Policy Implications and Conclusion

The ethical dimension of the allergic epidemic depicted above has two major policy implications. First, the severity and extent of this epidemic requires a comprehensive and globally concerted strategy and program in order to sustainably tackle allergies and thus adhere to the human right to health proclaimed by the WHO (EAACI 2016). Second, seeing that the prevalence of allergies follows a steep socioeconomic gradient both in terms of population groups and countries, the stated strategies and programs need to be conceptualized and prioritized according to the principle of distributional justice.

### 4.1 Globally Concerted Strategy and Program to Sustainably Tackle Allergies

A comprehensive answer to the allergic epidemic must include a broad range of policy measures (EAACI 2014). Since the severity of allergic diseases is frequently underrated, the initial task would be to raise the awareness of allergic diseases and their priority both in the general public and among policy makers. Subsequently, national policies and interventions in terms of treating and alleviating the burden of allergic diseases need to be developed and interlinked between countries and world regions. This includes the promotion of capacity building and the improvement of health care delivery with respect to accessibility and affordability to treatment. Naturally, an essential prerequisite is to support research on increasing the tolerance, on early intervention, prevention and control of allergic diseases. However, the most promising and efficient strategy to tackle the allergic epidemic requires prevention and with that addressing its roots and the abovementioned risk factors – most notably climate change and globalization.

In terms of climate change mitigation, a mix of environmental policy instruments is the most promising approach. The central pillar of this mix is provided by tradable emission licenses that guarantee both the ecologically effective and economically efficient reduction of GHGs (Heuson 2010). The GHG emissions trading market addresses the majority of climate-related air pollutants. However, it should be expanded to include previously not covered emission sources and sectors. Furthermore, the quota of licenses should be significantly reduced compared to the status quo. Currently, the legally permitted emissions are far too high – not only in terms of

climate change mitigation and allergy prevention, but also with respect to the license market's economic efficiency. In addition to this, other allergy-relevant air pollutants that are not directly related to GHG emissions can and should be regulated in an efficient manner through emission taxes. However, if the priority is to meet a certain emission threshold – for example due to serious health impairments of the respective pollutant – quantitative regulatory instruments, in particular emission quotas are preferable. Suasoric approaches merely play a complementary role due to their vague ecological effectiveness. Examples are promoting information campaigns on the acceptance of “harsher” environmental interventions or on environmentally friendly behavior at the individual level.

Despite its benefits on the economic and cultural level, globalization comes with severe risks and drawbacks in terms of allergies. As world trade gathers momentum the complexities also increase more and more. For this reason, allergens contained in food, animals, plants, commodities, and packaging are distributed all over the world, thus exposing people with new and more allergens. In principle, product standards, regulations on processing methods or imports should be sufficient to address these concerns. However, relevant legislation often falls short of the required standard unless it is unilaterally issued by states or confederations, as can be seen in case of the EU. This is due to the dramatic increase in the volume of imports, which is associated with many new allergen-sources and ways of circumventing EU law. Additionally, online trade and counterfeiting similarly undermine respective unilateral legislations (Castelain 2011). For this reason, a sustainable strategy to mitigate the increasing prevalence of allergies induced by globalization necessarily requires international efforts to conceptualize, issue, and finally enforce uniform trade- and product-related legislation. However, seeing that such legislation can never cope with the rapid development of globalization and associated trade flows completely, the strategy needs to involve continuously updated campaigns of information to consumers.

## **4.2 Conceptualizing and Prioritizing Allergy Programs According to the Principle of Distributional Justice**

Theories of social justice serve as useful approach to tackle socially unequal and thus unjust distributions of diseases such as the allergic epidemic (Behrmann 2010). In particular, the most influential theory of justice – especially with respect to health policy – is given by John Rawls's “justice as fairness” (Daniels 2008). This theory places the focus on the premise of equality of opportunity, claiming that people should possess equal liberties and potentials to pursue their goals of life (Rawls 2003). This principle emphasizes the responsibility for social institutions to implement policies that guarantee equal opportunity to all members of society. In this sense, allergy-related policies ought to reduce allergy morbidity amongst the whole range of allergy sufferers in equal manner, independent of their social or ethnical background. Commercial interests or similar influences as for example asserted by

lobbying of particular interest groups must not distort this equal treatment of allergic patients.

The second major principle of the Rawlsian theory refers to the moral imperative for social institutions to take precautions against discrimination. Along these lines, health policies ought to fight against the stigmatization of parts of the population suffering from a specific disease. This includes framing health policy measures in a way that patients do not accidentally get discriminated. For instance, this applies to the support of socially weak individuals with respect to the prevention or treatment of allergies that emanate from poor housing conditions.

In conclusion, these principles justify the pooling of health benefit resources towards especially underprivileged allergy patients. Moreover, the Rawlsian theory can be used to develop schemes and algorithms to prioritize and choose among competing allergy policies in terms of prevention and treatment (Behrmann 2010).

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