Climate Change and Our Environment: The Effect on Respiratory and Allergic Disease

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Climate change is a constant and ongoing process. It is postulated that human activities have reached a point at which we are producing global climate change. It provides suggestions to help the allergist/environmental physician integrate recommendations about improvements in outdoor and indoor air quality and the likely response to predicted alterations in the earth's environment into his or her patient's treatment plan. It incorporates references retrieved from Pub Med searches for topics, including: climate change, global warming, global climate change, green house gasses, air pollution, particulates, black carbon, soot and sea level, as well as references contributed by the individual authors. Many changes that affect respiratory disease are anticipated. Examples of responses to climate change include energy reduction retrofits in homes that could potentially affect exposure to allergens and irritants, more hot sunny days that increase ozone-related difficulties, and rises in sea level or altered rainfall patterns that increase exposure to damp indoor environments. Climate changes can also affect ecosystems, manifested as the appearance of stinging and biting arthropods in new areas. Higher ambient carbon dioxide concentrations, warmer temperatures, and changes in floristic zones could potentially increase exposure to ragweed and other outdoor allergens, whereas green practices such as composting can increase allergen and irritant exposure. Finally, increased energy costs may result in urban crowding and human source pollution, leading to changes in patterns of infectious respiratory illnesses. Improved governmental controls on airborne pollutants could lead to cleaner air and reduced respiratory diseases but will meet strong opposition because of their effect on business productivity. The allergy community must therefore adapt, as physician and research scientists always have, by anticipating the needs of patients and by adopting practices and research methods to meet changing environmental conditions. **(J Allergy Clin Immunol: In Practice 2013;1:137-41)**

Key words: *Allergy; Climate change; Workgroup report*

Even before the early ancestors of modern humans began walking on 2 legs, climate change was a constant and ongoing process. During an earlier warm era, trees and plants now common in areas of the United States were found near the North Pole.[1] Only 18,000 years ago most of the North American Continent was covered in ice.[2] From historical records a recent cooling period known as the little ice age occurred from the 15th to the 19th century. This cooling caused a decline in human existence because of massive crop failures and hypothermia-related disease.[3] The subsequent warming trend that began in the 19th century has been good for humans; however, for the first time in history our activities may be affecting the environment in ways that are contributing to global climate change.

In this report our assumption is that the climate is changing, and we examine anticipated effects relevant to allergists. Discussion of the extent and cause of climate change is beyond the scope of this report.

Climate change has received much attention in the past several years and it was reviewed extensively in the *Journal of Allergy and Clinical Immunology* in 2008.[4] The purpose of this report is to compile information on allergic disease as it relates to indoor and outdoor pollutant exposure and to critically examine both the known and proposed effect climate change will have on allergic disease. It is difficult to predict how societies will adjust behavior in response to predicted climatic changes. If some experts' predictions are correct, climate change has the potential to affect all aspects of allergen exposure, including both indoor and outdoor allergens as well as communicable diseases

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Abbreviations used
EPA- Environmental Protection Agency
GHG- Greenhouse gas

(eg, influenza) that are related to allergies and asthma. It has already been documented that climate warming and higher carbon dioxide will produce longer pollen seasons.[5-11] In addition, more hot sunny summer days will generate ozone, which probably means more symptoms for those at risk for asthma and breathing difficulties.[12] As sea level rises and rainfall patterns change, mold allergies will increase.[13] With warming conditions stinging and biting arthropods may be seen in new areas.[14] Other effects could happen, which may be difficult to predict. In northern climates, infectious respiratory illnesses peak in colder winter months, and pneumonia deaths parallel this change.[15] In contrast, the flu season in the southern hemisphere corresponds with the winter colder months, which is the northern hemisphere summer.[16] The effect of warming on these trends is speculative. Whether there would be a net gain or loss in respiratory health from small changes in temperature is difficult to predict. The allergist/environmental physician's approach to global climate change should be integrated and anticipatory as much as possible rather than solely reactionary.

INDOOR ASPECTS OF HUMAN RESPONSES TO CLIMATE CHANGE

Building technology and customary building practices are strongly influenced by local conditions. If given a picture of a house, most people can identify the area of the world where the house is located.[17,18] Even in the US, regional climate-driven variation is seen in construction. For example, construction in Florida is dominated by concrete because builders expect termites, and buildings are subject to mold damage due to warmth and humidity. The response to climate change is expected to produce efforts for better energy efficiency and tighter housing. Most existing housing is built to be occupied 50 years into the future. Current housing contributes about one-fourth of the total greenhouse gas (GHG) production. A typical Midwest US house produces more than 10 tons of carbon dioxide a year from heating and cooling.[19] To meet carbon dioxide reduction goals, experts at the Swiss Institute of Technology expect this will need to be cut by 80% in the next 50 years.[20] As a result of this, housing is expected to undergo energy reduction retrofits that involve superinsulation strategies and reduced exchange of indoor/outdoor air. The respiratory effect on the home's inhabitants is unclear; however, it will likely result in increased illness.

The Environmental Protection Agency (EPA) has ranked indoor air pollution among the top 5 environmental risks to public health.[21] Tighter homes often result in higher indoor humidity and reduced indoor air quality. The rate of outdoor air exchange in a building directly relates to energy costs. The upper end of the range for air exchange is energy expensive. However, if air exchange is reduced, pollutants produced indoors become more concentrated. Air pollutants that accumulate indoors include volatile organic compounds, radon gas, water vapor, smoke particulates, and protein allergens. All of these materials can cause respiratory problems in susceptible persons if sufficiently concentrated. Moisture and water accumulation can also lead to dust mite and mold growth that has particular significance for the practicing allergist.[22,23] Therefore, energy conservation benefits should be designed to prevent accumulations of moisture and indoor mold colonization.[22]

OUTDOOR ASPECTS OF HUMAN RESPONSES TO CLIMATE CHANGE

Another aspect of climate change is a predicted rise in sea level. Although variability in these forecasts is widespread, recent estimates indicate that the sea level has risen 1.8 mm per year for the past century and between 2.8 and 3.1 mm per year over the past decade,[24] Expectations that governments will be able to do anything to reverse rising sea levels are low.[25] Over the past 50 years population growth has occurred in low-lying coastal areas and along ocean fronts. The potential exists for an increase in water exposure because of flooding for an estimated 3.3 billion people worldwide who live in close proximity to costal regions. Damp buildings have been clearly associated with respiratory disease,[23] and a rise in sea level would expose a large percentage of the US population who live in costal and riparian cities to additional wet housing conditions.

Allergic disease is traditionally affected by outdoor allergens. Evidence is good that higher ambient carbon dioxide concentrations and warmer temperatures will result in increased pollen production, particularly in zones of elevated temperature, or "urban heat islands" created by large cities,[26] although construction and paving reduces the area available for pollen-producing plant growth. Higher levels of outdoor allergens can lead to higher personal exposures and more pollen infiltration into housing.

As noted in a recent review, "carbon dioxide, the most important GHG, and nitrous oxide and halocarbons, the other long-lived GHGs, have little direct effect on health."[27] Since 1870, corresponding with the industrial revolution, our atmospheric carbon dioxide level has risen from 280 ppm to the current level of more than 400 ppm in cities and 387 ppm in more rural environments.[28] Predicted carbon dioxide levels in 50 years are more than 600 ppm. Until recently indoor carbon dioxide levels were supposed to be below 1000 ppm, but in response to rising outdoor levels the recommended level has been changed to 700 ppm above ambient levels.[29] Levels more than 1000 ppm often occur in crowded spaces such as classrooms and auditoriums, and the resultant drowsiness induced in the room's occupants is noticeable.[30,31]

AIR POLLUTANTS

Ozone is a pollutant gas with direct effect on the human respiratory system. Ozone concentration in the lower atmosphere has increased since preindustrial times. Although by some measures air quality in the US has improved over recent decades, ozone remains a problem that is related to increasing emissions of methane, carbon monoxide, and nitrogen oxides produced chiefly by transportation-related activities. Numerous studies have linked increased respiratory-related emergency department visits and increased hospital admissions to elevated levels of outdoor ozone.[12] Ground-level ozone is measured in parts per billion (ppb). A moderately high annual mean maximum ozone concentration of 60 ppb is typically seen in large cities of the developed world.[12] This is of great concern, because young children with asthma can begin having symptoms at approximately 60 ppb,[12] and healthy young adults experience significant decrements in lung function and increased inflammation in the airways when experimentally exposed to ozone at 60 ppb.[32] In most US cities, warnings are issued when monitors for ozone reach or exceed 125 ppb, averaged over 1 hour. The EPA color codes ozone pollution levels. An orange warning is issued if 1-hour ozone levels are between 125 and 164 ppb, a red warning between 165 and 204 ppb, and a purple warning between 205 and 404 ppb. Efforts by the EPA to control airborne volatile organic carbon and particle pollution have reduced ground level ozone in the US for the past 20 years,[33] yet currently most large cities in the US have 10 to 20 orange days a year and 1 to 2 red days a year. Estimates are that by 2030 a much larger area of the globe will experience a background of 60 ppb and that by 2060 most populated areas will have typical ozone concentrations of at least 60 ppb.[12] Despite successful programs aimed at reducing ozone in the US, ozone is expected to increase worldwide over the next 50 years.[12] However, if large cities around the world are successful in reducing vehicle-based emissions as has been the case for eastern population hubs in the US, urban concentrations of ozone may decrease or rise less rapidly.[34]

An example of climate change in an area of increasing asthma is the Southwest US. Increasing swings between El Nino (wet winter) conditions and La Nina (dry winter) conditions along with higher year-round temperatures have altered historic forest fire patterns.[35] Heavy undergrowth production in wet years coupled with the death of large numbers of pines during drought conditions in dry years have increased frequency and intensity of forest fires. In addition, at least partially because of warmer temperatures, several species of bark beetles have devastated trees from Alaska to southern Arizona, leaving dead trees ready to burn. Current beetle infestations are the worst in recorded history,[36] and the increased fire risk is dramatic. The resulting smoke along with other pollutant activities brought by increasing human habitation have turned this once haven for those with respiratory difficulties into a community with increasing respiratory symptoms.[37] In recent years, the American Lung Association has given Maricopa County, Arizona, low grades for air quality. More than 390,000 Arizona adults (12%) were told by a health care professional they currently have asthma. In addition, approximately 59% of the adults with asthma reported having an episode or attack within the past year.[38] Arizona remains a state with a good quality of life; it has just developed the same air pollution and pollen issues of other states with large cities. Even clean, Rocky Mountain air is not exempt from climate change. Winter pollution season (October 31 through March 31) in the 7-county Denver metro area brings air quality action days.[39] Issuance of air quality action days mandates restricted burning by residents and asks for voluntary reduction in driving.

Responses to environmental change may cause many behavioral changes. "Green" practices create concerns for persons with allergies. Composting facilities may cause increased respiratory diseases through the increased fungal burden they put into the air.[11] Biomass and biodiesel may produce as many problems for persons with asthma as coal and oil.[11,12,40] Burning wood produces harmful chemicals, including carbon dioxide, carbon monoxide, unburned hydrocarbons, and formaldehyde. In addition, tiny particles coated with these same harmful chemicals (particulate matter) are created by wood burning.[41] Inhaling these particles contributes to cardiovascular problems, asthma, emphysema, and bronchitis.[41] Particle pollution from household energy is increasingly recognized as an important contributor to climate change. One of the most promising initiatives in this arena is the public-private international Partnership for Clean Indoor Air (www.PCIAonline.org). It provides resources and expertise to reduce smoke exposure from cooking and heating practices in households around the world. Biomass fuels such as dung, agricultural waste, and wood and the fossil fuel coal are the primary home energy sources for 50% of households worldwide.[41] The pollution burden from the use of biomass fuels is complex and includes significant black carbon (soot) and GHG emissions. Black carbon is linked to millions of premature deaths annually.[42] This invisible airborne particulate matter absorbs heat from the sun and accounts for 10% to 45% of global warming.[41]

GENERAL ASPECTS

Climate change is expected to alter the distribution of many species of plants and animals. Arthropods are expected to be especially affected. These include *Hymenoptera* (wasps and bees), *Diptera* (mosquitoes and biting flies), and *Acarina* (ticks and mites). All of these arthropods are temperature sensitive and many of them are vectors of disease. Allergic disease problems related to climate change are already evident in Alaska, which has recently seen a significant increase in the number of people seeking care for stings.[14] In addition to new presentations, with a warming climate insect populations may have dramatic shifts from extinction to overpopulation as they outpace traditional predation and other natural population suppressors. The allergist/immunologist will play an important role in recognizing these changing patterns.

Warmer temperatures in many parts of the planet have altered growing seasons and geographic ranges of plant species. Recent reviews indicate long-term records of flowering phenology have shown shifts over time that are consistent with climate change.[4,7-9] In northern Europe trends in airborne birch pollen levels studied over 20 to 33 years indicated start date for pollen release was significantly earlier in cities from Denmark, England, Belgium, Switzerland, Austria, and the Netherlands.[7,8] In addition, significant increases in the cumulative season birch pollen totals were registered from locations in Denmark, England, Switzerland, and the Netherlands.[5,43] Other European species, including *Alnus, Corylus, Quercus, Fagus, Platanus, Urtica, Ulmus, Juniperus*, and *Salix*, reported either earlier seasons, increased cumulative seasonal totals. or both.[43] In North America sampling reported significant increases in cumulative seasonal totals of *Juniperus, Quercus*, *Carya*, and *Betula* pollen from 1987 through 2000.[44] Changes in plant distribution have taken place at high elevations where warmer temperatures permit the growth of trees above the former tree line.[5,44] Upward migration of plant species has been documented in New Zealand, Bulgaria, Sweden, Switzerland, Spain, Alaska, and California.[5,8] A northward shift of the US floristic and plant hardiness zones has occurred from 1990 to 2006.[4]

The fertilizing effects of increased carbon dioxide on plants have been extensively studied in greenhouse, growth chamber, and whole ecosystem field experiments.[45,46] Ragweed flowers earlier and produces more pollen in urban locations where carbon dioxide concentrations and temperatures are higher.[45] Experiments indicate that when carbon dioxide levels double, individual ragweed plant pollen production increases 30% to

90%.[9,11,45,46] The same effect can be seen on other allergenic species,[9,47] including poison ivy.[47] In summary, although this increase may be beneficial for food plant production, the practicing allergist can expect to see patients affected from the effect of increasing amounts of pollen and longer pollen seasons over the coming decades.

In northern climates, infectious respiratory illnesses peak in winter months, and pneumonia deaths parallel that change.[15] The effect of warming on these trends is speculative, but warmer winters may produce less influenza.[16] Changes in patterns of respiratory health from change in climate are difficult to predict. However, if governmental policies result in lower transportation-related particulate emissions, then most of the spectrum of respiratory-related diseases will see improvement. Everything from asthma to chronic obstructive pulmonary disease is believed to be affected in a negative way by increased air pollution. If, however, we revert to coal-powered trains and electric cars charged by coal-fired power plants, there is the potential for parts of the planet to have the conditions that abounded in US cities 80 years ago. Technology has enhanced our ability to increase our energy use and quality of life while improving urban air quality. If transportation costs increase, we may see an end to the urban sprawl. The effect on the allergist might be a more crowded urban environment and a subsequent increase in communicable respiratory disease. In developing countries this could further exacerbate urban crowding and human source pollution.

CONCLUSION

As Rachael Carson so aptly stated in *Silent Spring*, "This is an era of specialists, each of whom sees his own problem and is unaware of or intolerant of the larger frame into which it fits."[48] For the allergy community, we should consider the larger frame and be concerned with anticipating the needs of patients and adapting practices to meet those needs. We will need to adapt, as physicians and researchers always have, to changes in the pattern and presentation of disease that may result from climate change.

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