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Climate Change Effects on Respiratory Health: Implications for Nursing

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Abstract

Purpose: Greenhouse gases are driving climate change. This article explores the adverse health effects of climate change on a particularly vulnerable population: children and adults with respiratory conditions.

Approach: This review provides a general overview of the effects of increasing temperatures, extreme weather, desertification, and flooding on asthma, chronic obstructive lung disease, and respiratory infections. We offer suggestions for future research to better understand climate change hazards, policies to support prevention and mitigation efforts targeting climate change, and clinical actions to reduce individual risk.

Findings and Conclusions: Climate change produces a number of changes to the natural and built environments that may potentially increase respiratory disease prevalence, morbidity, and mortality. Nurses might consider focusing their research efforts on reducing the effects of greenhouse gases and in directing policy to mitigate the harmful effects of climate change. Nurses can also continue to direct educational and clinical actions to reduce risks for all populations, but most importantly, for our most vulnerable groups.

Clinical Relevance: While advancements have been made in understanding the impact of climate change on respiratory health, nurses can play an important role in reducing the deleterious effects of climate change. This will require a multipronged approach of research, policy, and clinical action.

Nurses, the largest global health workforce group (World Health Organization, 2016b), are critically important to efforts aimed at increasing patient and public awareness of the effects of climate change on human health, anticipating threats to individual health, assessing communities' environmental health vulnerabilities, and lessening the health effects of climate change (Canadian Nursing Association, 2008). Nurses can accomplish these aims through research, practice, and policy that strengthens community resilience, narrows health inequities, and facilitates positive adaptation in the face of climate stressors (Anderko, Davies-Cole, & Strunk, 2014; Goodman, 2015).

Unfortunately, the health threats inherent in climate risk exposures are poorly understood by many nurses (Adlong & Dietsch, 2015), who often see climate change actions as incongruent with their daily work (Anåker, Nilsson, Holmner, & Elf, 2015). Further, education curricula focused on climate change are scant (Barna, Goodman, & Mortimer, 2012; Goodman, 2015; Richardson, Grose, Doman, & Kelsey, 2014; Richardson et al., 2016). To address these gaps, deans from schools of nursing, medicine, and public health have created a global partnership committed to training their students to effectively address the health impacts of climate change (The White House, 2015), supporting the integration of content across science and clinical course work (pediatrics, maternal health, geriatrics, chronic diseases). The purpose of this review of the literature, therefore, is to provide an overview of climate change effects on

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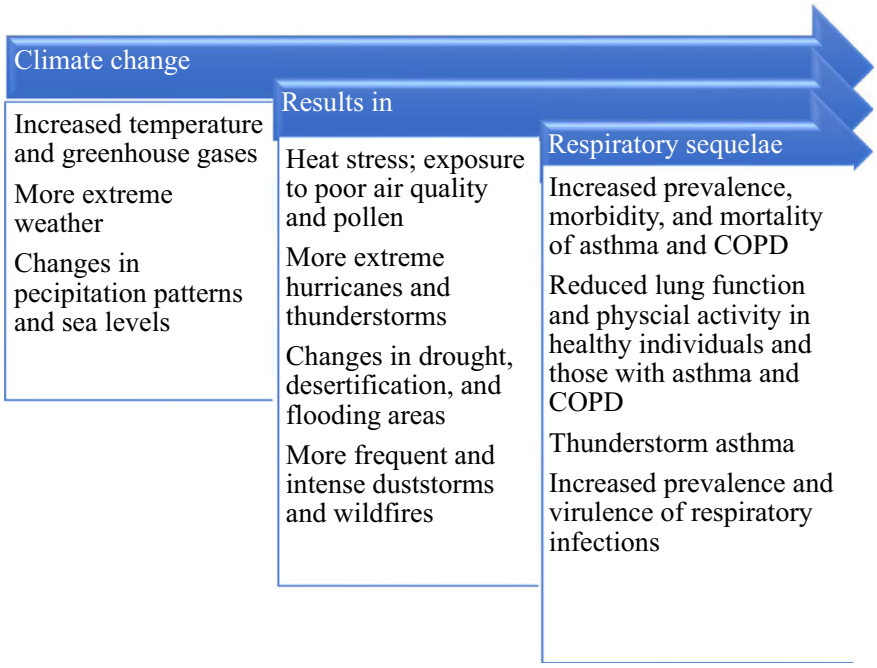

Figure 1. Effects of climate change and its respiratory consequences. COPD = chronic obstructive pulmonary disease.

human respiratory health, highlighting the role of nurses in shaping research priorities, practice standards, and policies to minimize these risks.

We first review the climate change events that will impact respiratory health. Next, we examine the dangers of climate impact on specific respiratory disease populations (e.g., chronic obstructive pulmonary disease [COPD], adult and pediatric asthma), identify reasons why respiratory infectious diseases will increase with climate change, and explore the threats to human health if these risks are not lessened (**Figure 1**). We conclude with the policy, research, and practice changes that will be needed for nurses to meet the challenges to population health posed by climate change.

The Impact of Climate Change on Factors Associated With Respiratory Health

Carbon dioxide (CO_2) and black carbon (BC) are the leading greenhouse gases implicated in global warming. These gases are the end-products of fossil fuels burned in order to power industrial processes, and air, marine, rail, and road transportation. Together with greenhouse gases formed from agricultural burning (deforestation), wildfires, and volcanic eruptions, CO_2 and BC cause increases in average temperature, more extreme weather, changes in precipitation patterns, and rising sea levels (Engelthaler et al., 1999; National Academics of Sciences Engineering and Medicine, 2016). Changing weather patterns mean that days are hotter than average seasonal temperatures in the summer, which increases ground-level ozone (O_3) and the levels of outdoor air pollutants such as fine particulate matter (PM) and CO_2. In turn, higher CO_2 levels increase the volume of allergenic plant growth, the speed of growth, and the amount of pollen produced and released while also extending the plants' range and the length of the pollen-producing season (D'Amato et al., 2007; D'Amato, Cecchi, D'Amato, & Annesi-Maesano, 2014; Engelthaler et al., 1999). Additionally, PM and O_3 have been shown to have an inflammatory effect on the airways, allowing easier airway penetration of aeroallergens that produce respiratory effects (D'Amato et al., 2014).

Climate change is expected to drive more extreme weather events, which have the potential to increase respiratory-related morbidity and mortality. For example, severe weather, such as thunderstorms and hurricanes, is expected to increase in frequency and intensity (Crimmins et al., 2016). The rainwater from these storms is thought to hydrate and rupture pollen grains, releasing inhalable aeroallergens that, under typical conditions, would be too large to be respirable. When this occurs in high pollen seasons such as in late spring and summer, asthma epidemics can occur (D'Amato et al., 2007; D'Amato et al., 2014), as was recently the case in Australia when eight persons with asthma died and 10,000 required hospital treatment after a severe thunderstorm was implicated in the release of dangerous

levels of ryegrass pollen (Innis, 2016). Acute respiratory infections also increase following hurricanes (Centers for Disease Control and Prevention, 1999).

Further, more severe and more frequent wildfires and dust storms can be anticipated due to increased drought and desertification resulting from climate change. These wildfires and dust storms have the potential to transport high concentrations of PM thousands of miles from their source (De Sario, Katsouyanni, & Michelozzi, 2013). Dust storms also have the potential to carry bacteria, fungi, and influenza across vast distances, posing a serious health risk to those with a compromised respiratory status (Wu, Lu, Zhou, Chen, & Xu, 2016; Xu et al., 2012). Changing precipitation patterns and rising sea levels will cause more flooding, which has been linked to spikes in both indoor and outdoor levels of microbes and mold (D'Amato et al., 2014; Institute of Medicine, 2011; Takaro, Knowlton, & Balmes, 2013).

Climate changes may also influence the survival, reproduction, or distribution of allergens/pathogens (bacterial, viral, and fungal), vectors, hosts, and disease transmission (Institute of Medicine, 2011; Wu et al., 2016). For example, warmer and longer seasons will extend the range and activity of stinging insects, and as a result, more cases of anaphylaxis can be projected (D'Amato, 2002; Institute of Medicine, 2011). El Niños, recurring patterns of warm water that influence global climate patterns, will be more common and more powerful in coming years; hantavirus pulmonary syndrome is more prevalent when El Niños occur (Hjelle & Glass, 2000). These types of climate pattern changes, along with more extreme weather events, will likely affect vectors and host immune responses too, leading to higher incidence and virulence of respiratory infections, including zoonotic and waterborne bacterial respiratory infections.

Taken together, the effects of climate change on the built and natural environments will contribute significantly to increases in the prevalence of pulmonary, allergic, and infectious respiratory diseases and their associated morbidity and mortality.

Climate Change and Respiratory-Related Diseases and Infections

Chronic Obstructive Pulmonary Disease

Although respiratory disorders are prevalent worldwide and contribute significantly to global morbidity and mortality, climate change is creating a rise of health-related respiratory diseases. According to the World Health Organization, over 235 million people suffer from asthma (World Health Organization, 2013), and 65 million people are living with COPD (World Health Organization, 2016a). Three million people die from COPD each year, and the World Health Organization predicts COPD will be the third leading cause of death by 2030 (World Health Organization, 2016a), with climate change–driven heat stress, outdoor and indoor air pollution, and respiratory infections identified as major contributing factors. Increasing levels of ground-level O_3 (Cheuvront & Haymes, 2001), hotter than average seasonal temperatures in the summer and temperature extremes have all been implicated as contributing to premature death in those with respiratory conditions (Crimmins et al., 2016). In fact, many of the 70,000 who died in a 2003 European heat wave had co-existing respiratory conditions (Robine et al., 2008).

Asthma

In particular, asthma is strongly influenced by changing environmental factors. Increasing temperatures and altered rainfall patterns, along with the changing frequency and severity of extreme weather patterns, which include extreme heat, floods, and storms, can increase the number of people affected with asthma (McIver et al., 2015). Moreover, there has been an increased prevalence in allergic respiratory disease and asthma over the past decades (D'Amato, Vitale, Lanza, Molino, & D'Amato, 2016) as a direct result of changes in the production and dispersion of pollen (D'Amato et al., 2015; D'Amato et al., 2016). In addition, long-term continuous exposure to high levels of O_3 may reduce lung function in adults (and children) and contribute to the increasing prevalence of both asthma and COPD (McConnell et al., 2002).

Asthma in older adults. Older adults have anatomical and physiological changes that put them at increased risk for experiencing adverse sequelae due to climate change (Sharma & Goodwin, 2006). Structurally, chest wall changes impair respiratory compliance, increasing the workload of breathing. Additionally, there is a decrease in respiratory muscle strength, impairing and weakening their cough reflex making them less able to clear irritants due to climate change. Overall, older adults have decreased lung function with aging.

Asthma in children. Asthma is a significant pediatric health concern. Its prevalence, highest during childhood (Sears et al., 2003), has been increasing over the past six decades, with the estimated overall worldwide prevalence of current asthma being 11.7% among children 6 to 7 years old and 14.1% among those 13 to 14 years old (Mallol et al., 2013). Children are especially vulnerable to the negative effects of climate change due to the fact that children are physiologically different from

adults, and that children are exposed to a greater amount of pollutants and allergens than adults.

The respiratory and immune systems of children are still developing and, as such, differ significantly from those of adults, with the consequences of exposure to toxins having more harmful results. Lung development is an ongoing process, with most of the development occurring postnatally, and not being complete until 18 to 20 years of age (Dietert et al., 2000); the developing lung is very susceptible to damage when exposed to environmental pollutants (Miller & Marty, 2010). In addition, children have smaller lungs and airway passages, and when inflammation occurs because of exposure to inhaled agents, inflammation can significantly block airflow. This is in contrast to adults, in whom the larger airways may allow for air to be distributed throughout the lung, bypassing inflamed areas. Additionally, children's immature immune systems (Dietert et al., 2000) make them more vulnerable to respiratory infections because children cannot fight the negative effects when exposed to toxins.

Another factor contributing to the increased vulnerability of children to climate change is their greater exposure to pollutants and allergens. One reason for this is that children breathe more rapidly than adults (Bunyavanich, Landrigan, McMichael, & Epstein, 2003), inhaling a higher volume of air per kilogram of body weight (Tzivian, 2011). Additionally, their relatively more narrow airways leads to more tissue exposure per volume inhaled, which in turn results in more inflammation (Bunyavanich et al., 2003). Children are also exposed to more pollutants and allergens because children play outdoors more and have higher rates of mouth breathing with exercise. As such, children are exposed to a greater amount of polluted air and allergens, which enters directly into their lungs with mouth breathing, bypassing potential filtration that takes place in the nasal passages, increasing parenchymal damage (Bunyavanich et al., 2003). Moreover, relative to adults, children play closer to the ground, where particulate matters are found in higher concentrations (Kenagy, Lin, Wu, & Heal, 2016).

Infectious Respiratory Diseases

It is expected that climate change will increase infectious respiratory diseases. For example, hantavirus pulmonary syndrome caused by exposure to deer mice urine and feces (Khasnis & Nettleman, 2005) is more prevalent when El Niños occur (Hjelle & Glass, 2000). As of January 2016, there have been 690 cases of hantavirus pulmonary syndrome in the United States, with a mortality rate of 36% (Centers for Disease Control and Prevention, 1999). There are no effective treatments to date. Variable rainfall associated with El Niños has been hypothesized to affect the production of the pine nuts on which deer mice feed (Douglass, Calisher, & Bradley, 2005) or to increase the likelihood that deer mice seek shelter in homes (Engelthaler et al., 1999), increasing deer mice populations and human contact, which in turn increases the risk for disease transmission. Increases in humidity and temperatures will also support the transmission and survival of influenza virus (Wu et al., 2016).

Respiratory-related mortality is also higher in sand dust storms (Stanley & Farrant, 2015) and in heat waves due to more occurrences of infectious respiratory diseases (Kan, 2011). Climate change and extreme weather events will likely lead to higher incidence and virulence of waterborne bacterial respiratory infections, like Legionella (Yoder et al., 2008), and respiratory fungal infections like aspergillosis; an outbreak of aspergillosis struck survivors of the 2011 tsunami in Japan (Mirsaeidi et al., 2016).

Morbidity Associated With Respiratory Disease and Respiratory Infection

Seventy-five percent of CO_2 emissions are directly related to fossil fuel burning and agricultural burning (deforestation; D'Amato et al., 2016). Air pollution and high pollen counts affect health, especially for those with chronic respiratory diseases like COPD and allergic asthma. Inhaling O_3 causes epithelial damage, with a subsequent inflammatory response that affects the upper and lower airways (D'Amato et al., 2016). When air pollution exceeds safe levels, emergency department visits increase and patients with asthma experience more symptoms (D'Amato et al., 2011). As O_3 levels increase, lung function is reduced, airways become more hyperreactive, and the risk for asthma and COPD exacerbations increases (D'Amato, 2002). Long-term continuous exposure to high levels of O_3 impairs respiratory function and exacerbates airway inflammation not only in patients with asthma, but also in healthy individuals. Increased temperatures are associated with more emergency room visits and hospitalizations for pneumonias, asthma, and COPD (Ostro, Rauch, Green, Malig, & Basu, 2010), and heat waves contribute to increased morbidity from infectious respiratory diseases (Kan, 2011).

Physical activity is important in both healthy individuals and individuals with chronic illnesses; over 3 million deaths are attributed to insufficient physical activity annually (World Health Organization, 2016c). In healthy individuals, increased temperatures and changes in air quality can significantly limit physical activity performance (Cheuvront & Haymes, 2001). Increased heat

stress associated with climate change can also negatively affect lung function and exercise capacity in patients with COPD (Jehn et al., 2013). In a cross-sectional analysis of 10,898 adults in the National Health and Nutrition Examination Survey, individuals with respiratory conditions reported changing their activities due to poor air quality (Wells, Dearborn, & Jackson, 2012). Increases in air pollution are associated with greater symptom burden (e.g., cough) and a limitation in walking for those with asthma and COPD (Alahmari et al., 2015). As mentioned previously, indoor air quality is also negatively affected by climate change; indoor aerobic exercise may increase the inhalation of indoor air pollutants (Ramos et al., 2015).

Anticipating, Responding to, and Lessening the Impact of Climate Change: The Role of Nurses

The potential exists for respiratory disease epidemics and respiratory infection pandemics to overwhelm healthcare systems and bankrupt global and human resources. In these scenarios, vulnerable patient groups will suffer the most. Combating the deleterious effects of climate change on respiratory health will require a multipronged approach. While it will take generations to reduce the health effects of greenhouse gases, there are immediate opportunities for nurses to lead research, practice, and policy initiatives aimed at lessening these effects. In fact, national nursing organizations (American Association of Colleges of Nursing, 2011) and international nursing organizations (International Council of Nurses, 2012) mandate such actions. The only risk is if nurses choose not to act. **Table 1** identifies research, practice, and policy strategies that nurses can undertake to reduce the harmful health effects of climate change, detailed in the following three sections.

Table 1. Nursing Strategies to Reduce the Harmful Effects of Climate Change

Priority areas for	
Nursing research	Develop programs of research focused on enhancing understanding of • the health impacts of climate change • the efficacy and effectiveness of risk reduction interventions • vulnerable populations (those with respiratory or mental health conditions, reduced mobility or cognitive function, the poor, children, those who reside or work in prone-risk areas) • social factors that foster adaptation or alter risk • decision support and integrated assessment tools
Nursing practice	Provide evidence-based information to help patients develop adaptive strategies focused on modifying exposure to excessive temperatures, extreme events or poor air quality • Daily monitoring of heat, air quality and pollen counts • Identification of alternative locations and types of physical activity during periods of excessive heat, pollution, or pollen counts • Identification of best times and locations (inside/outside) for exercise • Securing appropriate shelter during extreme weather events • Use of personal cooling garments and devices Support disaster preparedness and response efforts Integrate effects of climate change in clinical coursework (pediatrics, maternal health, geriatrics, chronic diseases, etc.)
Nursing policy	Promote public health initiatives (e.g., public transportation, improved air quality standards, mitigation programs focused on water-borne, airborne, or vector-borne illnesses) Participate in urban planning efforts to increase safe, accessible, walkable green spaces Develop relationships with local governments or planning commissions to improve the built environment Promote efforts to reduce healthcare systems' carbon footprint (e.g., waste management, green buildings, energy and purchasing, safer chemical use) Support national and international efforts to capture and store (underground sequestration) CO_2 and energy

Setting a Climate Change Research Agenda

Nurse scientists must contribute to the growing body of bench-to-bedside scientific evidence that documents the health impacts of climate change and evaluates the efficacy and effectiveness of interventions focused on reducing exposure or on reducing the health effects of unavoidable exposure. While more research is needed on understanding the driving forces behind climate change, efforts must also be focused on understanding vulnerability. To that end, data are needed on factors that may modify the effects of climate change (e.g., sex, age, socioeconomic status; Xu et al., 2012) so that we may better understand the potentially differential impact on subpopulations (Bunyavanich et al., 2003). Similarly, examining existing social factors that may foster adaptation, or alter risk, to climate change (e.g., participation in sports) is needed (Xu et al., 2012). Decision support and integrated assessments will be needed if tailored adaptation and prevention strategies are to be designed and tested (Corell et al., 2014).

Nursing Practice in the Era of Climate Change

There is a need for nurses to help their patients develop adaptive strategies, which focus on modifying the

built environment to respond to the negative impact of climate change that has already occurred (Sheffield & Landrigan, 2011). For example, nurses may want to be involved in actions to minimize exposure to smoke from fuels (Institute of Medicine, 2011). Nurses can assess patients' risk by evaluating their overall health, including respiratory function. Nurses may want to consider assessing the environment where patients live and work (or go to school, for pediatric patients), including air quality by noting the proximity to emissions from cars (living close to highways) or factories and their mass transit accessibility. Teaching families how to assess allergen exposure and palliative measures are also important steps nurses can take.

Patient education may focus on changing physical activity patterns of asthma and COPD patients in response to temperature extremes (Jehn et al., 2013) or poor air quality indices (Wells et al., 2012). Nurses could assess a patient's usual physical activity patterns and develop personalized interventions. Educating patients on where to exercise (indoors versus outdoors; Wen, Balluz, & Mokdad, 2009) and when to exercise (e.g., early morning when temperatures, pollutants, and pollen levels are lower) requires that patients understand what exposures pose a risk and where important data on temperature, air quality, and pollen counts can be found. In Australia, patients responded to extreme heat by employing personal cooling techniques in addition to engaging in physical activity during the morning hours (Banwell, Dixon, Bambrick, Edwards, & Kjellström, 2012). This strategy can also be used during periods of extreme cold; for example, performing activities when temperatures are warmer in the afternoon hours or exercising indoors (Carey, Aase, & Pliego, 2010).

Climate Change Policy

From a policy perspective, nurses might become involved in efforts to promote public transportation or increase urban tree canopy or may want to be involved in urban planning efforts to increase economic development and reduce economic disparities (Xu et al., 2012). Other policies around providing green, open spaces that are accessible to residents in conjunction with efforts to improve air quality may foster recreational walking that can promote physical activity and well-being in individuals with respiratory illnesses (Chaix et al., 2014). Community-level interventions might also target the features of the built environment that conspire against control of respiratory disease (Keddem et al., 2015), such as ventilation and weatherization of homes in which vulnerable populations reside (Institute of Medicine, 2011). Lastly, nurses may want to consider becoming involved in efforts within their healthcare system to reduce the agencies' carbon footprint (Muñoz, 2012; Stanley & Farrant, 2015; Wormer et al., 2013). For example, nurses could encourage their healthcare system to make operating rooms green by using reusable gel pads, powering down operating room lights and equipment when not in use, and using alcohol-based waterless scrub; decrease hospital waste by segregating nonhazardous waste (e.g., paper, metal, glass) from infectious waste; use recyclable products and reusable cups and dishware in break rooms; and have monitors and computers go into sleep mode automatically when not in use.

Conclusions

Climate change produces a number of changes to the natural and built environments that lead to potential increases in the severity and prevalence of respiratory diseases, and children appear to be most vulnerable. While advancements have been made in understanding the impact of climate change on respiratory health, additional work is needed to help prevent and reduce the deleterious effects of climate change. Nurses can play an important role in reducing this negative effect of climate change with a range of actions, including developing, implementing, and evaluating strategies to directly reduce greenhouse gases, being involved in policy work, and considering the impact of climate change in their clinical assessment of patients and tailoring treatment and education based on these assessments.

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Clinical Resources

- American Academy of Nursing's Expert Panel on Environmental & Public, Healthhttp://www.aannet.org/expert-panels/ep-environmental-and-public-health
- Natural Resources Defense Council, https://www.nrdc.org/
- Health Care Without Harm's Nurses Climate Change Toolkit, https://noharm-uscanada.org/content/us-canada/nurses-climate-change-toolkit

- Canadian Nurses Association, https://www.cna-aiic.ca/~/media/cna/page-content/pdf-en/climate_change_2008_e.pdf?la = en
- Campaign for Action, http://campaignforaction.org/climate-change-health-nursing/
- Alliance of Nurses for Healthy Environments, http://envirn.org/
- American Nurses Association's Principles of Environmental Health for Nursing Practice with Implementation Strategies, http://www.nursingworld.org/MainMenuCategories/WorkplaceSafety/Healthy-Nurse/ANAsPrinciplesofEnvironmentalHealthforNursingPractice.pd

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