RESEARCH NEEDED TO ADDRESS THE IMPACTS OF CLIMATE CHANGE ON INDOOR AIR QUALITY

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Introduction

Awareness of the many connections between climate change and indoor air quality (IAQ) is relatively new. However, anthropogenic climate change will have many impacts on IAQ and how indoor air is managed (e.g., Girman et al., 2008; Levin, 2008).

Buildings exist to shelter people from the effects of weather and climate and, in this manner, create indoor environments. It follows then, that changes in climate may necessitate changes in the way that we manage indoor environments in new and existing commercial and public buildings and residential housings, including the indoor air quality of those environments. In particular, the challenge will be to manage indoor air in face of generally warmer outdoor air temperatures without increasing our carbon footprint, thereby exacerbating climate change.

This paper lists some of the research needed to address likely impacts of climate change on indoor quality. The paper is organized around likely impacts of climate change and their connections to the indoor environment. The research needs listed are not comprehensive. Instead, they are intended to prompt discussion within the research community and with policy makers so that critical research needs are developed and addressed.

It should be noted that this paper accepts the consensus of the world's scientific community that the warming of the earth's temperature over the last several decades has been largely caused by anthropogenic greenhouse gas emissions (IPCC, 2007).

Heat Waves

Higher air temperatures will have many consequences for the indoor environment. It will lead to heat waves, increased use of air conditioning and higher ozone concentrations. While there have been fewer cold- and heat-related deaths in the past 30 years in the USA, it is believed that this is due to increased use of residential central heating and air conditioning. Nonetheless, despite this overall trend, in 1995, a heat wave in Chicago killed more than 700 people in a matter of days (Kaiser et al., 2007). In 2006, a North American heat wave killed approximately 160 in California. Populations thought to be at risk in heat waves include children less than five years old, the elderly, people with chronic diseases, socially isolated individuals and low income individuals and the California deaths largely confirmed this. The California Department of Health Services (Trent, 2007) examined the heat wave effects in some detail by focusing on 140 deaths from classic heat stroke during the heat wave. They found that these deaths were mostly among the elderly and occurred indoors. In only one case was air conditioning used prior to death. Ninety percent of the heat stroke deaths occurred in areas where more than 50% of the residents live below the Federal Poverty threshold. However, colder climates are not exempt from heat waves. According to a report from the Earth Policy Institute (Larson, 2006), more than 52,000 Europeans died from heat in the summer of 2003.

Many regions of the world will increase their use of air conditioning because of climate change, especially in residences. These regions include many parts of Europe, Canada and the northern regions of the USA. However, the infrastructure to support this increase is relatively weak in some areas. This will create an increased need for education of the designers of buildings, the designers and fabricators of air conditioning systems and an opportunity for education on IAQ issues as well.

However, increases in the use of air conditioning will increase energy uses and, consequently, the carbon footprint. Therefore, there is a need to use air conditioning as effectively and efficiently as possible and to explore alternatives to the use of traditional air conditioning.

- What alternative cooling strategies can be used, e.g., improved siting of buildings, pre-cooling ventilation air in earth tunnels, regional use of evaporative air cooling, nighttime cooling and storage?
- What strategies for cooling buildings are best employed in which regions?
- What are costs of different cooling strategies?
- For some strategies, e.g., use of evaporative air cooling, outdoor air ventilation is increased. What are the implications for ozone exposure with such use?
- What alternative design strategies for buildings can be used to make them more energy efficient, e.g., avoiding heat gain to minimize external thermal load, reflective roofs, overhangs, awnings, and sunscreen shades?
- How can air-conditioned public buildings, movie theaters, schools or shopping malls be designed for successful use as cooling shelters?

Ozone

Higher tropospheric temperatures caused by climate change will increase ozone production, with the potential to degrade IAQ. The linkage of elevated ozone to poor IAQ is well established (Weschler, 2006). Ozone not only causes direct health effects but also indirect effects, due to reactions that produce irritants in the form of oxygenated volatile organic compounds and particulate matter. Elevated ozone could lead to greater adoption of ozone scrubbing in mechanical ventilation systems. Currently, this technology is not widely used; therefore, this adoption could actually improve IAQ. However, there are many unanswered questions to the use of ozone scrubbers for indoor environments.

- How well do ozone scrubbers work?
- How can ozone scrubbers be most effectively incorporated into heating, ventilating and air-conditioning (HVAC) systems? For commercial building systems? For existing residential systems that do not bring outdoor air into the home mechanically? For new homes with advanced designs that mechanically bring outdoor air into the home through the HVAC system?
- What is their capacity?
- What is their cost (both first cost and operating cost)?
- Do they create any harmful byproducts?
- What chemicals found indoors are most problematic, in terms of reacting with ozone? What products and materials used indoors emit these chemicals?

Wildfires

Increased plant growth is another possible consequence of climate change. In addition, some regions will experience drought conditions. These can combine to increase the potential for wildfires due to the larger amount of dry biomass. Smaller snowpacks in mountain areas could exacerbate this potential when smaller than normal run-off extends the fire season. Since wildfires produce massive amounts of particulate matter over extensive areas, public health officials in regions prone to wildfires will have to develop and disseminate information on how to mitigate this pollution. This information could contain guidance on how to shelter homes and workplaces from the pollution by better filtration on mechanical ventilation systems or the use of stand-alone air cleaners employing filtration.

- Can portable air cleaners be used successfully to remove contaminants produced by wildfires from the indoor air of residences and temporary shelter locations, e.g., schools and community buildings?
- Should HVAC systems in residences and temporary shelters located in areas prone to wildfires be permanently modified with in-duct air cleaners so that they can remove contaminants from wildfires? If so, how best to modify them?

- o Should such air cleaners also remove gaseous contaminants or is the removal of particulate matter sufficient, considering the duration of wildfires and likely exposures?
- o How well do such air cleaners work for wildfire contaminants?
- o What is their capacity? Is it sufficient for the volumes of polluted air they would have to clean? Is it sufficient for the duration of exposures to pollutants from wildfires?
- o What are first costs? What are operating costs?

Allergens

Elevated carbon dioxide concentrations and higher temperatures can promote growth and earlier flowering of some plant species, greatly extending the pollen season. Since pollen is an important trigger (and possible cause) of asthma, some researchers hypothesize that climate change could be an important factor in the increase in asthma incidence (Beggs and Bambrick, 2005). If this proves to be true, using the indoor environment as means to mitigate pollen exposure becomes more important. However, this will necessitate a better understanding of how to prevent pollen from entering buildings and how to best remove it, if it does enter a building.

- o What factors determine exposure to pollen indoors?
- o How can pollen exposure indoors be controlled? For example, do walk-off mats help? What is the best way to clean pollen from indoor surfaces?
- o How well do air cleaners work to reduce exposures from pollen? How should they be used in a control strategy?

Water/Moisture Intrusion

Due to climate change, more extreme precipitation events are expected, with attendant flooding. Hurricane Katrina provided a powerful example of the impact of a tropical storm on IAQ, with the aftermath of widespread mold contamination of buildings caused by flooding (Solomon et al., 2006). This mold contamination was exacerbated by electric power outages that hampered efforts to pump out water, and to use dehumidifiers and air conditioners to assist in drying. In addition, the use of portable generators by an uninformed population to deal with power outages led to carbon monoxide poisonings (CDC, 2005).

However, while Katrina provides a powerful example of effects from extreme precipitation events originating in the tropics and impacting coastal areas, higher latitudes are not exempt from such events. In 2005, thousands of people in Central and Eastern Europe were evacuated from their homes due to flooding (BBC News, 2005).

But flooding need not occur for precipitation events to cause problems in indoor environments. Water intrusion is already a problem in many buildings and climate change may exacerbate this problem. For example, the U.S EPA's BASE study of 100 randomly selected U.S. office buildings found that 45% of the buildings had current water leaks with 34% occurring in occupied spaces (Girman et al., 2002). Other studies have associated moisture with increased health effects (IOM, 2004; Mudarri and Fisk, 2007).

- Why do building envelopes fail to prevent water intrusion? To what degrees do poor construction, poor design, and poor material choice contribute?

- How can water intrusion be identified more quickly so that problems can be addressed earlier?

- How can we identify and develop more moisture-resistant building materials?

- How can we prevent foundation cracks due to soil's expansion and contracting resulting from more frequent dry and wet weather events?

Disease Vectors

Some tropical diseases transmitted by mosquitoes may increase with climate change, e.g., dengue fever and malaria, although the extent to which this may occur is controversial. Several factors can cause this: more favorable microclimates caused by increased plant foliage; extended plant growing seasons; and increased availability of water. One paper suggests that the global population at risk of Dengue Fever would be about 5-6 billion with climate change, compared to 3-5 billion without it (Hales et al., 2002). Possible increases in malaria due to climate changes are more controversial (Rogers and Randolph, 2000), with some models suggesting large increases and others suggesting much less dramatic increases (Sutherst, 2004). If climate change causes the spread of diseases currently considered tropical diseases into what are now more temperate climates, the use of pesticides could increase, which could degrade IAQ. Alternatively, the concern about vectors (both rodents and insects) could be used to promote wider use of integrated pest management. In addition, the indoor environment can function as a partial sanctuary from many vector-borne diseases.

- How likely are the spread of malaria, Dengue Fever and West Nile disease to the USA.?

- What are current exposures to pesticides and what factors determine exposures? How might these exposures change in response to climate change? In residences? In the workplace? In schools?

- How can pesticide intrusion to indoor environments be controlled? How well do walk-off mats work? How could they best be used? Are there other methods for controlling pesticide exposure indoors?

- How can alternatives to pesticide use, e.g., integrated pest management, be best promoted? Are there demonstrations that should be conducted to provide examples to the public and building managers?

Energy Efficiency

Inevitably, as we attempt to reduce our carbon footprint, the energy use of buildings will attract more scrutiny. The energy use of buildings is a large and attractive target for reductions since buildings in the U.S. represent approximately 45 % of the greenhouse gas emissions (Levin, 2008). In the 1970's, one of the responses to the energy crises was to reduce ventilation rates in buildings, with little consideration of the consequences of doing so. The result was a large increase in buildings with indoor air quality problems and increased exposure of the public to indoor air pollutants. Research is needed to provide energy efficient solutions to heating and cooling buildings without degrading indoor air quality.

- What energy-efficient technologies are neutral toward IAQ or actually improve it?

- Can ventilation rates be reduced without increasing risk if emissions from products and materials used indoors are also reduced?

- Is the development of advanced air cleaner technology needed to remove indoor air pollutants as an alternative to dilution with outdoor air?

- Can ventilation strategies be optimized for health and energy use (e.g., economizer cycles that increase ventilation rates to provide "free cooling" when outdoor conditions permit, heat recovery ventilation systems, etc.)?

- Can programs already in existence for reducing product and material emissions be more broadly adopted, e.g., the Finnish M-1 Label (Finnish Classification of Indoor Climate 2008) or California's 1350 program (Cal. Section 01350)?

- Are demonstrations of existing ventilation strategies or product and material emissions reduction strategies needed to provide convincing proof to policy makers, the public and building designers, builders, managers and owners?

- How can information about ventilation and product emissions be most effectively presented to building code officials, the insurance industry and leaders of the green building movement?

- Do buildings designed and constructed to be green use less energy than more typical buildings? Is their IAQ better than more typical buildings?

- Should the heating and cooling functions of HVAC systems be separate from the ventilation function?

- Does individual (personal) control of HVAC systems lead to less energy use?

- Can significant energy savings be achieved by employing a personal cooling system vs. a space cooling system?

- If occupants have individual temperature control of their workspace, how do we prevent "thermostat wars", i.e., co-location of individuals desiring widely different thermal comfort parameters?

Summary

Awareness of the many connections between climate change and indoor air quality is relatively new. However, indoor environments deserve special consideration because indoor environments are where people will be sheltered from many of the impacts of climate change. Because of this, there is a great need to improve our knowledge of how to manage indoor environments to mitigate these impacts in a way that doesn't compromise energy efficiency and doesn't increase our carbon footprint. In some cases, knowledge gaps can be filled through demonstration projects. These demonstration projects can take advantage of situations where some knowledge exists about technologies with the potential to provide solutions but where insufficient knowledge exists to permit effective application of these technologies.

This report lists many research needs necessary to allow us to accomplish the goal of mitigating the impacts of climate change without degrading energy efficiency and without increasing our carbon footprint. This list of research needs is not comprehensive but is intended to prompt discussion within the research community and with policy makers so that critical research needs are developed and addressed.

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