The Public Health Perspective on Hazard Reductions in Indoor Environments

by

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ABSTRACT

In the effort to define and develop the "Next Generation Building", a holistic approach is needed to design and develop structures that are not only capable of withstanding natural disasters and other major hazards, but can also provide an indoor environment in which the occupant is protected from injury, disease, and harmful environmental exposures. This paper describes key factors that are important in understanding the relationship between the indoor environment and human safety and health.

KEYWORDS: public health, indoor environment, safety, prevention, research

1.0 INTRODUCTION

People spend over 85% of their day indoors, and sensitive and susceptible populations spend even more time indoors[1,2]. There is compelling evidence demonstrating the relationship between the indoor environment and the health and well-being of the occupants. There has also been growing interest on the impact of the indoor environment on health at the Centers for Disease Control and Prevention (CDC) and the Office of the US Surgeon General. As part of the CDC Goals Initiative and an effort to develop a Surgeon General's *Call to Action* document on a healthy indoor environment, both agencies aim to link the importance of a healthy indoor environment with respect to factors such as prevention and eliminating health disparities. They also aim to inform the American people of the science, evidence, and data to improve their understanding of, and appreciation for, a healthy indoor environment.

The improvement of indoor environments in the "Next Generation Building" also works in concert with the Healthy Homes and Healthy Communities agenda outlined in *Healthy People 2010*, which serves as a prevention framework the US[3]. The document highlights national health objectives designed to identify the most significant preventable threats to health and to establish national goals to reduce these threats. There are specific national objectives that aim to improve office indoor air quality and to reduce exposures to indoor pollutants including allergens and radon.

The dialogue to improve the understanding of the indoor environment on human health, however, should not be confined to those in public health. It is important for all building professionals to recognize the complex linkages surrounding integrated building research, design, and human health.

2.0 HEALTHY BUILDINGS

A healthy building, from a public health perspective, can be defined as one that is sited, designed, built, maintained, and renovated to support the health of its occupants. Additionally, the sustainability of the building, in the context of potential impacts resulting from climate change, is

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an important consideration. There are numerous indoor impacts and hazards that can affect people's health; three key features will be highlighted: (1) safety factors, (2) building design, and (3) environmental factors.

2.1 Safety factors

The main goal with respect to building safety factors is to prevent unintentional injuries. It is estimated that 8000 deaths[4] and 12 million nonfatal injuries occur in US housing annually[5]. Injury from fires, hypothermia and hyperthermia illness, and falls are commonly reported. It is estimated, for example, that among the nearly 400,000 US residential fires in 2005 in which the fire departments responded, 3,030 deaths resulted; the most accurate predictor of death was the absence of a smoke alarm[6,7]. Similarly, hyperthermia and hypothermia are highly preventable with the proper cooling and heating in indoor environments. Falls are also extremely preventable if buildings meet code standards. These examples of preventable unintentional injuries are intrinsically tied to building design and public awareness.

Safety factors and considerations can also include the ability of new building materials to perform and confer protection during hazard events. With the increasing demand to integrate sustainable and other new materials into construction practices, it is important to consider their safety and durability, as well as their ability to protect the occupants.

2.2 Building design

There are three critical areas of public health with respect to building design: accessibility, ventilation, and dampness. Accessibility is directly impacted by affordability, community design, building code standards, and overall building design. It is estimated that 5.5 million people with a disability face barriers to participation in buildings because of design or absence of sidewalks[8]. Building accessibility needs to work in concert with community design and can be achieved by emphasizing the interactions between the building structure and occupant behaviors.

Ventilation is an important building characteristic as it directly affects an occupant's sense of comfort, perceived air quality, and health[9]. If not designed, installed, maintained or operated properly, ventilation can have harmful effects on the indoor environment. Some pollutant levels measured indoors are 2–10 times greater than those measured outdoors[10,11]. Recent research on building ventilation and filtration suggest that reduced infiltration of outdoor particulate matter indoors can improve health and economic gain[12]. It is also estimated that tens of thousands of premature deaths in the developed world can be reduced annually through the use of improved mechanical ventilation systems with proper supply air filtering in buildings[13].

Dampness is known to influence conditions for mold growth, which is a risk factor for health effects, especially respiratory disease[14]. In extreme hazard events, such as Hurricanes Katrina and Rita in 2005, an extraordinary growth of mold and presence of endotoxin and glucans were observed at levels associated with health effects[15]. Building materials that reduce or minimize the water-holding capacity of buildings and inadequate ventilation have been cited to strongly influence indoor dampness. Adapting and integrating sensor technology, such as those used to monitor the structural wellness of buildings, to monitor moisture in the walls and ventilation systems can be helpful as an early detection system to prevent health effects commonly associated with indoor dampness. Use of materials that can effectively minimize or retard mold growth can also be helpful in reducing exposures and potential effects, especially during hazard events.

2.3 Environmental exposures

Occupant protection from indoor environmental exposures often fall under two categories: chemical and biologic exposures. These exposures are ubiquitous and individuals can become exposed through inhalation, ingestion, and dermal contact. Some common health symptoms often associated with these exposures include allergy-like symptoms, headaches, shortness of breath, and disease[16]. A main concern regarding these particular indoor environmental exposures is that the dose impacting health is still not clearly understood. The synergistic or additive effects of chemical mixtures and toxicity of microorganisms also need to be studied further.

2.3.1 Outdoor and indoor chemical exposures

Chemical exposures from the outdoor environment commonly enter the building through the HVAC systems or leaks in the building envelope. Outdoor pollutants including traffic emissions and biomass burning (e.g., wildfires), which constitute numerous pollutants including particulate matter, volatile organic compounds, and soot, have been shown to impact health[17,18]. A recent study in California observed that homes near heavy traffic can affect lung development in children[19]. While proximity to heavy traffic is difficult to avoid with the increasing growth of our communities, changes in siting requirements or measures to minimize outdoor air indoors may assist in reducing exposures.

Ozone is another ambient pollutant that can infiltrate into the indoor environment, but the amount of ozone that infiltrates into the indoors or other micro-environments (e.g., vehicles) is affected by factors such as the frequency in which windows are opened and the use of air conditioning. Daily inhalation intake of indoor ozone may range from 25%–60% total ozone intake[20]. Short-term exposures to ozone have been associated with an increase in daily mortality as well as cardiovascular and respiratory hospitalizations[21,22]. There is also data that suggests that excess morbidity and mortality from ozone is still occurring at and below the current US national standard[23,24]. Building design and ventilation, therefore, can play a role in reducing exposures indoors.

Sources of ozone can also be found indoors such as from laser printers and photocopiers[25]. Other common indoor sources that can also impact an occupant’s exposure include products that emit irritants such as building materials and cleaning agents. Lead-based paint, pesticides, and combustion sources such as carbon monoxide, biomass burning from indoor cooking, and environmental tobacco smoke are also indoor sources that are known to elicit health effects.

Building materials can also emit chemicals. Formaldehyde, for example, is commonly emitted by pressed wood products and cleaners. It is known to cause cancer with chronic exposures[26]. These exposures can also impact the respiratory system, especially among the growing population with chemical sensitivities. Developing materials that produce little to no emissions will therefore be critical in reducing potential exposures and minimizing health effects.

2.3.2 Outdoor and indoor biologic exposures

Biologic exposures in indoor environments, including exposures to allergens, viruses, bacteria, and fungi, are also of concern as they are known to cause various health symptoms and effects. Allergens, for example, include pet dander, cockroach antigen, and pollen. It is well understood that allergens can exacerbate asthma symptoms after repeated exposures[27]. Viruses and bacteria are also of concern and these sources are primarily from building occupants. Efforts have been made to reduce transmission of exposures in the indoor environment. Fungi are also known to serve as allergens, toxins, and infectious agents[28].

An occupant's exposure to biologic and chemical sources can therefore be impacted by many factors. These factors include emission rates of specific sources and building system characteristics such as the efficiency of the HVAC system. Temperature and humidity also play an important role in one's sense of comfort as well as in promoting mold growth. Physical factors, such as furniture placement, human activities, and behaviors can also greatly influence exposures and need to be considered when designing a healthy building.

In the design process, tools such as Geographical Information Systems (GIS) can be extremely helpful in constructing the physical environment within a building. GIS can overlay biological and physical processes, as well as simulate ecosystems to predict the effects of hazards and exposures on health-related outcomes such as physical comfort and security. More specifically, GIS may assist in depicting a representation of exposures that may affect the respiratory health and safety of building occupants. For example, GIS can be used to predict indoor air quality using different ventilation systems and various air cleaning materials, chemicals, or devices. At another level, GIS applications can provide information on emissions-producing structures, highways, and landfills and their releases within a specified perimeter of a particular building over a specified time period.

3.0 RESEARCH GAPS

While there has been considerable progress in studying the relationship between specific outdoor air pollutants and health as well as exposures in occupational settings, gaps still exist in understanding the relationship between indoor environments and health. More specifically, gaps remain in characterizing dose-response relationships for exposures in indoor environments. Target levels for indoor pollution levels for occupancy need to be more clearly defined. In turn, collaborative efforts to identify methods to reduce the risk through actions such as material substitution, encapsulation, or dilution through ventilation can then be achieved.

This process is extremely complex; considerations such as behavioral and social factors as well as individual susceptibilities need to be made. Populations who are most at risk for disease and disability from indoor hazards also need to be better addressed.

With the changing environment, there is also an urgency to evaluate the potential impacts of climate change (i.e., increasing temperatures, increasing pollen production, rising sea levels, and increasing number of severe storms) not only on the building structure, but also on the indoor environment and human health. The increased awareness of global climate change has led to a growing movement in the development of green buildings and the use of more sustainable materials. While there is encouragement to use products that emit zero to low levels of emissions, a need still remains to improve our understanding of new material properties with respect to performance, durability, and potential acute and chronic health impacts. Additionally, the impact of climate change on potential energy shortages and increasing prices can also affect the provision of ventilation, thermal control, and humidity control by mechanical systems as these features may become less reliable or less available[29].

As we find new methods to reduce energy use, it will be important to evaluate the potential impact of low energy buildings and indoor air quality on health. Sustainable design will continue to be incorporated in building practices. Accordingly, we believe that it would be important and informative to quantify the amount of gain in health as buildings improve as well as study the effect of the indoor environment over the lifetime of an individual. From this, we can learn how to create healthier environments and issues such as health and productivity can be better evaluated.

4.0 NEXT STEPS

CDC can play a key role in filling some of the gaps in understanding the relationship between the indoor environment and human health through surveillance, inter-disciplinary training and health communication; however, additional support from other building professionals including engineers, developers, and architects will also be important. For the “Next Generation Building”, we are faced with the challenge to not only produce a healthy and high quality indoor environment, but an environment that can work in concert with fire, seismic, and wind safety.

There is groundwork for collaborative work to design the “Next Generation Building” through the following efforts:

- Developing sensor technology to monitor the indoor environment
- Using GIS for modeling exposures indoors which can assist in building design
- Developing and improving materials that can not only withstand outdoor environmental hazards, but can also prevent the growth or generation of indoor environmental hazards
- Creating low energy and sustainable buildings that provide a comfortable and healthy environment for its occupants.

As we continue to develop our understanding of indoor environments and its impact on human health, we find it key to foster an inter-disciplinary partnership at the international, federal, state and local level.

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