Building-related health effects: What do we know?

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Hospital buildings provide space for healthcare, employment, residence, shelter, and comfort. Building design, construction, operations, and maintenance influence the indoor environment and the health and well being of staff, patients, visitors and other occupants. Design and construction decisions also have impacts on the environment and public health regionally and even globally. Materials extraction, product manufacturing, transportation, use, recycling, and disposal influence air and water quality, land use, and can contribute to ozone depletion and climate change. The health of workers in the supply, production, and disposal/recycling chain, as well in building construction, operations, and maintenance, is also affected.

This paper primarily addresses the influence of buildings on the health of occupants. It briefly touches on more far-reaching concerns, including the appropriateness of certain healthcare-related activities.

The indoor environment:

Building-related comfort and health are directly related to indoor environmental quality, which is determined by combinations of temperature, temperature gradients, humidity, light, noise, odors, chemical pollutants, personal health, job or activity requirements in the building, and psychosocial factors. That is, buildings are complex dynamic systems of multiple interacting factors that determine the state of the system at any given time.

Microenvironments within buildings may be highly relevant determinants of health impacts among occupants. Spatial heterogeneity among a mixture of relevant variables makes it difficult to study and understand causal health-related relationships. (Spengler, 2000)

Much work on building-related health focuses on combinations of temperature, humidity, ventilation, and indoor air pollution. Air pollutants include volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), microbial VOCs (MVOCs), particulates, nitrogen oxides, ozone, carbon dioxide, and biological agents such as bacteria, viruses, and fungal spores. Many air pollutants are generated indoors while others infiltrate from the outdoors. These factors interact in multiple combinations that vary over time and place, even within the same room or building, making it difficult to understand the extent to which each contributes to health outcomes.

For example, assessments of exposure to indoor air pollutants which assume homogeneous concentrations in a room will miss important concentration gradients around point sources of emissions. Concentrations may vary by several-fold, depending on proximity to an emitting source. (Furtaw, 1996)

Building design, operations, and maintenance must be considered collectively. Design and construction choices will influence operations and maintenance in ways that make building related complaints more or less likely.

Many studies that attempt to examine building related illness are limited by their design (e.g. cross sectional surveys are common and are limited by several kinds of bias), lack of quantitative exposure information, subjectivity in outcome measures, and uncertainty about what potentially causal factors should be measured. Further, because of interactions among multiple building related factors, commonly used statistical techniques do not lend themselves to the analysis. Models based on principal component analysis or structural equation modeling show some promise, but will need further work before being generally applicable. (Pommer, 2004)

<u>Building-related illness, building-related symptoms, sick-building syndrome, and multiple chemical sensitivity:</u>

Sharp distinctions between health and comfort are not readily apparent and may not be appropriate. Building related illnesses include specific diseases like, for example, Legionnaire’s disease, which can be traced to a single source or cause.

Building-related symptoms include:

- mucous membrane symptoms (blocked or stuffy nose, dryness of the throat, rhinitis, sneezing, dry eyes.

- Headache, confusion, difficulty thinking and concentrating, fatigue

- Cough, wheeze, asthma, frequent respiratory infections

- Allergic reactions; dry skin

The term "sick building syndrome" (SBS) is used to describe situations in which building occupants experience acute health and comfort symptoms that appear to be linked to time spent in a building, but often no specific cause can be identified. Complaints may be localized in a particular zone or widespread throughout the building. SBS is sufficiently common and has been sufficiently described to have attained robust stature in medical and architectural disciplines.

To further complicate analyses, some people seem to be particularly sensitive to a wide variety of environmental contaminants at relatively low concentrations. In some of these people, a diagnosis of multiple chemical sensitivity (MCS) suggests that it is virtually impossible to separate assessments of the quality of the indoor environment from the unique vulnerability of some building occupants. The pathophysiology of MCS is uncertain and controversial, although an increasingly robust scientific database supports the importance of this phenomenon. (National Research Council). It is, therefore, difficult to draw a distinct line between a building with an unhealthy indoor environment and one in which a subset of building occupants appear to have heightened sensitivity to often poorly defined but ordinary environmental contaminant levels.

Building-determinants of indoor environmental quality, comfort, and health:

Building material emissions and reactivity:

Building operating conditions and products used in building design and operation create an environment in which complex emissions and chemical reactions can occur. Direct emissions from building materials (primary emissions) are generally highest soon after manufacture and construction and diminish thereafter. Secondary emissions are caused by the actions of other substances or activities on the material. For example, moisture, alkali in concrete, ozone from electronic equipment, or cleaning materials can influence emissions from building materials. Secondary emissions may be a chronic problem. (Sundell, 1999)

Cooler surfaces on a wall can increase local relative humidity facilitating emissions from wall covering material. Humidity or dampness in concrete floor construction facilitates alkaline degradation of di-ethyl-hexyl phthalate (DEHP), a plasticizer used in polyvinylchloride (PVC) floor covering as well as other PVC products.

Ozone that gains entrance from the outdoors or that is emitted from photocopiers or laser printers can react with unsaturated double bonds in various polymers to create aldehydes and ketones. These secondary emissions may be highly reactive, and irritate skin and mucous membranes of building occupants. (Wolkoff, 1997; Wechsler, 2000)

Nitrogen oxides from outdoors or generated from photocopiers or laser printers can also react with a variety of VOCs to form irritant compounds, including aldehydes. (Wolkoff, 1997). Highly reactive free radicals are also formed by reactions of NO2 and ozone with unsaturated compounds. Many of these compounds are not easily measured, yet they may be highly relevant in terms of health effects.

Indoor pollutants associated with building operations and maintenance:

Building design decisions can also influence which products are used in routine building operations and maintenance, influencing indoor environmental quality. Some cleaning products contain respiratory tract sensitizers or irritants. Even cleaning products promoted as “greener” sometimes contain citrus or pine-based materials which can themselves, or in reaction with oxidants such as ozone, contribute to indoor air pollution.

Occupants of buildings cleaned more often that once weekly tend to report fewer building related symptoms. (Skyberg, 2003)

Building and landscape design can influence the likelihood of indoor pest problems. Routine use of integrated pest management strategies can reduce indoor and outdoor pesticide use, thereby contributing to improved indoor environmental quality.

Ventilation:

High or low ventilation rates can have a significant impact on symptoms. Limited evidence suggests that ventilation rate increases up to 10 L/s person may be effective in reducing symptom prevalence and occupant dissatisfaction with air quality and higher ventilation rates are not effective. (Spengler, 2000) But because of complex relationships among ventilation rates, contaminant levels, and building-related health complaints or satisfaction with air quality, the use of ventilation as a mitigation measure for air quality problems should be tempered with an understanding of its limits.

Dampness and humidity:

Building dampness can facilitate mold growth, particularly on surfaces with organic material that can serve as a nutrient source. MVOCs can also be emitted from HVAC systems. Fung and Hughson reviewed all English language studies (n=28) on indoor mold exposure and human health effects published from 1966 to 2002. They concluded that excessive moisture promotes mold growth and is associated with increased prevalence of symptoms due to irritation, allergy, and infection. However, methods for assessing exposure and health effects are not well standardized.

Surface materials:

Several studies show a correlation between certain materials on interior building surfaces and risks of asthma, wheezing, or allergy. Materials that may be causally related to these symptoms include PVC flooring and wall coverings, new linoleum, synthetic carpeting, and particle board. (Jaakkola, 2004) Increased risk of childhood risk of bronchial obstruction, wheezing and allergic symptoms is reported associated with PVC plastic and plasticizer-containing surfaces. (Jaakkola, 1999; Oie, 1999; Bornehag, 2004; Tuomainen, 2004; Norback, 2000)

Particulate air pollution:

Particulate indoor air pollution is of variable size and composition. Particulates may contribute to building-related symptoms in occupants, but the relative contributions of particle size, particle mass, and particle composition are uncertain. (Christensson, 2002) High-speed floor polishing can contribute significantly to airborne particulates, depending on the equipment used and the nature of the surface material. (Bjorseth, 2002; Roshanaei, 1996)

Health impacts beyond the building:

It is also important to acknowledge that hospital design, construction, and operating decisions can have far-reaching public environmental health impacts from water and energy consumption, materials transportation, and occupational health concerns throughout the materials supply chain.

Releases of environmental pollutants from materials extraction, manufacturing, and disposal practices can have regional and even global consequences for public environmental health. Building designers have an opportunity to influence worker and public environmental health through informed materials selection and attention to worker and social justice concerns.

In addition, it is essential to begin to address explicitly the long term public and environmental health impacts of healthcare activities themselves. Those activities are rarely subject to the same scrutiny to which we subject the building infrastructure.

In the United States, health care related expenses comprise about 15% of the GNP. This amount is growing annually and much of the growth can be attributed to the development of new technologies, each with its own implications for public environmental health.

Resource extraction, materials manufacture, and disposal are responsible for most human impacts on the natural world. The scale of health care activities and life-cycle impacts of related materials flows contribute substantially to environmental degradation. High-tech equipment, pharmaceuticals, transportation, and water and electricity consumption in health care have major environmental impacts. Despite the commitment of most countries to growth, material throughput must be drastically scaled back in order to achieve sustainability. The health care system must do its share.

Pierce and Jameton have made a strong argument for health care’s particular ethical responsibility. (Pierce & Jameton, 2004). Marginal improvements in materials policies may help, but a fundamental re-examination of the scope of clinical services is also required. This may inevitably lead to concerns about rationing, but rationing, according to Pierce and Jameton, should not be thought of as less than optimal care but rather as sustainable optimal care, if the health care industry is going to meet its ecological responsibilities.

Conclusions:

Buildings are complex dynamic systems comprised of multiple materials assembled and operated in ways that create an indoor environment with considerable heterogeneity in space and time. Building-related illnesses result from multiple factors that are often difficult to quantify and that interact in complex ways. Considerable additional research is necessary in order to advance the understanding of building-related health effects. Statistical techniques used in the analysis of complex dynamic systems may be helpful and should be further explored.

Although it is difficult to establish clear cut evidence-based guidelines for all aspects of building design, construction, and operation, several themes emerge from the published literature. Low-emitting materials should be selected. Materials that might support mold growth should be reduced. Building design, construction, and operations should ensure that moisture does not accumulate. Material selection should be influenced by cleaning requirements and the extent to which cleaning may contribute to VOC and particulate concentrations. Low emission materials, along with appropriate ventilation, temperature and humidity control, will contribute to improved indoor air quality.

Individual, community, and ecological health are interpenetrating. They are influenced by building design, construction, and operating decisions and should be routinely assessed during planning stages. Along with attention to direct and indirect impacts of building design, construction, and operating decisions, a fundamental re-examination of the scope of clinical services is also required, if the health care industry is going to meet its ecological responsibilities.

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