Implications

VOL. 03 ISSUE 2 www.informedesign.umn.edu

A Newsletter by InformeDesign. A Web site for design and human behavior research.

IN THIS ISSUE

Residential Indoor Air Quality: Implications for Design Professionals

Introduction

There is much discussion in conferences as well as the popular and scientific literature about indoor air quality (IAQ) including preventative strategies that may be reasonable in the design, construction, remodeling, and operation of buildings.

Research in these areas has been heavily weighted on questions involving commercial and institutional buildings including healthcare facilities and schools. In cases of healthcare facilities, especially hospitals, this attention is quite appropriate since patients may be immune-compromised or otherwise highly vulnerable to serious health complications—including death, from indoor air pollutants (IAP).

This attention is also appropriate in schools because occupants increasingly include those with asthma and allergies. Combined with conditions from IAP, illness and discomfort that adversely affects learning can be the result in those indoor environments (see an excellent review by Mendell and Heath, 2005). Also, recently there has been excellent work (Federspiel, et al, 2004) regarding commercial buildings the economic impact of IAP on worker productivity.

However, because people spend a majority of their time **in their homes**, it is important that design professionals consider the scientific base of knowledge about IAP exposures in residential indoor environments. This knowledge is especially important when designers are influencing the indoor environments of some of the most vulnerable in the population including infants, elderly, and those with allergies, asthma, and suppressed immune systems.

This article summarizes a critical review of recent published scientific literature examining IAQ in residences. The goal of this review is to identify adverse health effects caused by poor IAQ, identify causal associations between indoor pollutants and health effects, and describe techniques to reduce these pollutant concentrations. This article grows out of a review completed for the US Environmental Protection Agency's (EPA) Radiation and Indoor Environments National Laboratory by the University of Minnesota (Angell, et al, 2005a and 2005b).

Health Effects of Indoor Air Pollutants in Residences

An understanding of air pollution inside buildings is fundamentally an appreciation of health and comfort effects. The *raison d'ètre* of this understanding is the concern that airborne contaminants cause adverse health effects in those who occupy buildings with polluted indoor air. Health effects that could be affected by IAP include the following (Berglund, et al, 1992):

Respiratory diseases lead the list of health effects, since the respiratory system is the organ group most directly affected by air pollution. Important respiratory health effects include acute and chronic changes in pulmonary function, increased incidence and prevalence of respiratory symptoms, sensitization of airways to allergens, and increased spread of respiratory infections. Principal IAP agents included combustion products, environmental tobacco smoke (ETS), biological agents (e.g., mold, bacteria), and formaldehyde (HCHO). Susceptible groups to respiratory diseases include children, elderly persons with impaired lung function, patients suffering from Chronic Obstructive Pulmonary Disease (COPD), unborn children whose mothers smoke, and immune-compromised individuals.

Allergies and other diseases of the immune system have become better understood in recent years. Allergic asthma and extrinsic allergic alveolitis (hypersensitivity pneumonitis) are the two leading diseases caused by allergens in the indoor air. Principal agents include house dust mites, pets, insects, and molds. These are linked to allergic asthma and rhino conjunctivitis. Allergens and other immune system diseases are a risk to everyone. Approximately 10-12% of the population responds easily to allergen exposure and develops allergic asthma. This number appears to be increasing. The Institute of Medicine review, *Clearing the Air*, represents a careful review of our current understanding of asthma as of 2000.

Lung cancer is the major form of cancer that has been linked to IAP. Principal agents include radon and ETS. Radon in homes causes about 21,000 lung cancer deaths each year in the US. Other known human carcinogens found in the indoor air include asbestos and HCHO. Susceptible groups to cancer include current smokers whose lungs have been damaged by the effects of tobacco smoke. Smokers' risk increases synergistically when exposed to radon or asbestos in the indoor air.

Skin and mucous membrane effects include primary and secondary irritation caused by direct stimulation of sensory cells by environmental exposures and secondary irritation following changes in the skin, mucous membranes, or other tissues. Principal agents of irritation include HCHO, volatile organic compounds (VOC), ETS, and nitrogen dioxide (NO_2).

Sensory and central nervous system responses are often collected together and referred to as sick building syndrome (SBS) symptoms and perceived air quality. The class includes perception of the physical environment (draft and odor) and body perceptions such as eye irritation and dry skin. However, the effects are broader than that. Principal agents of sensory and central nervous system effects include VOCs, HCHO, and pesticides. Large differences are seen in sensitivity among different individuals. Aging tends to decrease sensitivity. Children and fetuses are particularly sensitive because of

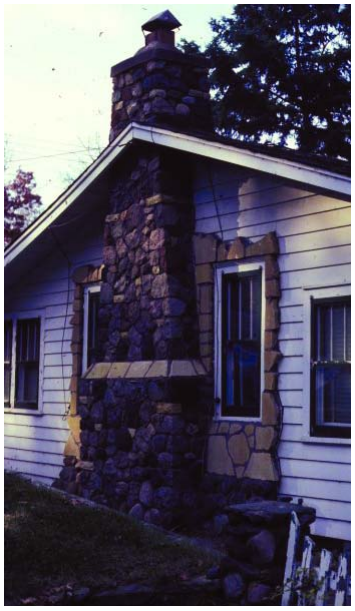
potential lifetime exposure and the sensitivity of the brain during initial development.

Cardiovascular Diseases (CVD) are associated with IAP. Principal agents include ETS and carbon dioxide (CO). ETS is suspected because of the strong association between smoking and CVD. CO exposure decreases oxygen carried to organs. Jones (1999) notes that moderate concentrations of CO can produce adverse reactions in ischemic (tissue anemia) heart disease patients.

Reproductive effects and liver and other organ systemic effects are two other areas that could be affected by IAP, although few studies have attempted to link these effects with IAP.

Design Decisions Impacting on Indoor Air Pollutants in Residences

There are many decisions in the design process that may impact on IAP in residences and thus, impact on the health of occupants including the following examples:



"Vent-free" fireplaces may expose occupants to unhealthy concentrations of carbon monoxide (CO), nitrogen dioxide (NO_2), and particles. To put it simply, "people should not live in chimneys" and unvented combustion devices should not be used indoors.

Kitchen ranges—both gas and electric, lacking exhaust fans that vent to the exterior may expose occupants to unhealthy concentrations of particles. If the range and oven are gas-fired and not vented to the outdoors, CO and NO_2 concentrations may also be unhealthy. Exhaust hoods that discharge indoors serve no useful function. Therefore, all kitchen ranges should be vented to the outdoors.

Furnaces and boilers that vent without powered fans are susceptible to backdrafting unhealthy CO, NO_2, particles, and water vapor indoors—especially when make-up air is not provided to major exhaust devices (including down-draft range exhausts). In a recent study of homes in winter, 20% of gas water heaters and 10% of gas furnaces backdrafted when all exhaust fans were turned on (Bohac, 2002). These represent staggering rates of failures. When designers specify and contractors install exhaust devices, make-up air needs to be provided especially in more air-tight houses.

Attached garages may be sources of pesticide, VOC, and CO exposures in homes. For example, in a study of 50 houses with multiple CO alarms, 80% of the events were triggered by CO leaking from the garage into the house following vehicle start-up (Wilber and Klossner, 1996). If unattached garages are not an option, it is important to consider isolating attached garages by sealing the common wall with the house and exhaust venting the garage.

Finishing below-grade spaces and other areas susceptible to water intrusion invites mold and bacterial contamination that can adversely affect those with asthma and allergies as well as cause skin and eye irritation and trigger SBS reactions. Be very careful when finishing spaces that have any symptoms or other history of water intrusion. In addition, when considering finishing space in basements, in slabs-on-grade, or above crawlspaces, recommend radon testing both before and after finishing.

Implications

Build-out of occupied spaces needs to be done in a manner to protect occupants from exposure to construction-related pollutants including VOCs from materials and finishes, as well as particles and mold spores from demolition and other activities. Commonly, isolating the workspace by barriers and exhaust ventilation controls construction pollutants.

Use of carpet is quite controversial. Clearly, when carpet is vulnerable to water intrusion or when carpet cannot or will not be maintained according to industry standards, there is risk of adverse health reactions including asthma and allergic reactions, skin and eye irritation, and trigger SBS reactions. It is important that designers consider the question, "How often will carpet maintained to industry standards?"

Use of building products and finishes or furnishings containing HCHO or that release VOCs may adversely affect those with asthma and allergies as well as cause skin and eye irritation and trigger SBS reactions, especially in the months following construction. Where possible, avoid products containing HCHO and finishes that produce VOCs.

References

—Adler, S. (1995). Refugee stress and folk belief: Hmong sudden deaths. *Social Science & Medicine, 40*(12), 1623-1629.

—Angell, W., Grimsrud, D., Lee, H., & Braganza, E. (2005a, forthcoming). "Residential indoor air quality, ventilation, and building-related health effects: Critical review of scientific literature," *Proceedings of the 9th International Conference on Indoor Air and Climate*. Beijing, China: International Society of Indoor Air Quality and Climate.

—Angell, W., Grimsrud, D., Lee, H., & Braganza, E. (2005b, forthcoming). "Critical review of the scientific literature on residential indoor air quality." *Proceedings of the Air and Waste Management Association Annual Conference*. Minneapolis, MN: AWMA.

—Berglund, B., Brunekreef, B., Knoppel, H., Lindvall, M., Mohave, L., & Skov, P. (1992). "Effects of indoor air pollution on human health." *Indoor Air 2*(1), 2-25.

—Bohac, D. (2002). "Results from house appliance safety and depressurization tests conducted on single family houses undergoing sound insulation." *Proceedings of the 9th International Conference on Indoor Air Quality and Climate - Indoor Air '02* (III, pp. 594-599). Monterey, CA.

—Federspiel, C., Fisk, W., Price, P., Liu, G., Faulkner, D., Dibartolomeo, D., Sullivan, D., & Lahiff, M. (2004). "Worker performance and ventilation in a call center: Analyses of work performance data for registered nurses." *Indoor Air 14*(s8), 41-50.

—Institute of Medicine Committee on the Assessment of Asthma and Indoor Air. (2000). *Clearing the Air: Asthma and Indoor Air Exposures*. Washington, DC, National Academy Press.

—Jones, A. (1999). "Indoor air quality and health." *Atmospheric Environment 33*(28), 4535-4564.

—Mendell, M., & Heath, G. (2005). "Do indoor pollutants and thermal conditions in schools influence student performance?" *Indoor Air 15*(1), 27-52.

—Wilber, M., & Klossner, S. (1997). "A study of undiagnosed carbon monoxide complaints." *Proceedings of ASHRAE Annual IAQ Conference: ISIAQ Fifth International Conference on Healthy Buildings: Global Issues and Regional Solutions* (Vol. 3, pp. 179-183). Washington, DC.

Additional Web Site Sources:

Indoor Air Quality (IAQ):
—www.epa.gov/iaq
—www.dehs.umn.edu/iaq
Radon:
—www.cce.umn.edu/radon

About the Author:

William J. Angell is professor and Director of the Indoor Air Quality Project at the University of Minnesota. He has also served as a visiting scientist at the US Environmental Protection Agency's (EPA) Radiation and Indoor Environments National Laboratory and Lawrence Berkeley National Laboratory's Indoor Environments Program. Angell has testified before Congress, chaired external, peer-reviewed panels for EPA's Office of Research and Development, and served as a lead expert witness for the US Department of Justice. He has received EPA's Outstanding Leadership Award. Angell received his M.S. from Iowa State University.

Related Research Summaries

InformeDesign has many Research Summaries about residential indoor air quality, and related, pertinent topics. This knowledge will be valuable to you as you consider your next design solution and worth sharing with your clients and collaborators.

"Mold in Flooded Homes: A Long-Term Problem" —*Journal of Environmental Health*

"Improving Indoor Air Quality in Homes" —*Journal of Exposure Analysis and Environmental Epidemiology*

"Indoor Air Pollutants Cause Eye Irritation" —*Indoor Air*

"Ventilation's Impact on Indoor Air Quality" —*Indoor Air*

"Indoor Air Quality and Carpet: More Information Needed"—*Housing and Society*

"Residential Air Change Rates and Indoor Air Quality"—*Journal of Exposure Analysis and Environmental Epidemiology*

"Residential Air Quality and Fungi"—*Journal of Exposure Analysis and Environmental Epidemiology*

"Sources of VOCs in New Homes"—*Indoor Air*

Photos Courtesy of:

Dave Hansen, Ag Experiment Station, University of Minnesota (baby, p. 2)

Caren Martin, University of Minnesota (remainder)

InformeDesign®
Where Research Informs Design

The Mission

The Mission of InformeDesign is to facilitate interior designers' use of current, research-based information as a decision-making tool in the design process, thereby integrating research and practice.

Created by:
University of Minnesota

Sponsored by:
ASID