IAQ: Indoor Environmental Quality - Current Concerns

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March 2007

Buildings are increasingly designed or required to be “sustainable” or “green” in recent years giving the quality of the indoor environment new importance. The indoor environment is central to public health because we spend so much time there. Concentrations of most pollutants are higher indoors, often as much as ten or more times higher than in outdoor air. A person is generally 1000 times more likely to inhale a chemical molecule if it is emitted indoors rather than outdoors. The potential importance of the indoor environment is further enhanced by the fact that pollutants emitted indoors have greater source strengths than outdoors on the basis of area. But efforts to address indoor pollutants and provide healthful and productive indoor environments often conflict with efforts to protect the larger environment from the adverse effects of our building technologies (Levin, 2006). A “healthy building” adversely affects neither the occupants nor the larger environment (Levin, 1981;1995)

It has been said that indoor air quality and the related factors that comprise the indoor environment to which humans are exposed emerged as a distinct field in the 1970s, first in Europe and later in North America and parts of the Pacific Rim.

The founders of this new domain, emerging from their backgrounds in the historical study of outdoor air pollution, indoor thermal climate, and occupational; respiratory, or immunology branches of medicine recognized that focusing primarily on the ambient environment was becoming less relevant as people spent more of their time indoors in buildings increasingly cut off from the outdoor environment. They shifted their attention to the most obvious “microenvironment,” indoors, where people often experience their greatest exposures.

The emergence of sick building syndrome along with recognition of the hazards posed by asbestos, radon, formaldehyde, and Legionella pneumophila among others along with increasing emphasis on energy conservation gave new meaning to efforts to study and understand the impacts of buildings on their occupants’ health, well-being, and productivity. The shift from historically-prevalent interior building finishes such as plaster, wood, and concrete to the use of products made from new chemicals and plastics along with the reduced ventilation created what would now be regarded as extremely high concentrations of many chemicals of concern. Today, architects, engineers, and designers throughout the world know what a volatile organic compound (VOC) is and many have made concerted efforts to reduce occupant exposures to these and scores of other common indoor pollutants.

More recently, concerns about moisture and mold along with new emphasis on fine and ultra-fine particles have created awareness of the complexity of the indoor environment and of the many factors that can affect occupants’ perceptions of the environment and the impacts of the environment on occupant health. Furthermore, perception of the environment and occupant's own comfort have become important foci for researchers and building operators alike (Cain, 2002). Perceptions strongly color the human experience, and the indoor environment is no exception. Many researchers have tried to separate the impact of office workers attitudes toward their employer, supervisor, or office space from the impacts of the physical environment on worker health and productivity.

Efforts to control human exposure to hazardous substances in water, food, and outdoor air have all had their scientific progress enhanced by increasingly sensitive instruments to characterize the constituents of the environment, and many of the advances have been applied indoors as well. The deeper scientists delve into the chemical, physical, and biological composition of the air indoors and the deposition of pollutants on surfaces, the more complex the processes appear. Much of what goes on is highly dependent on the exchange of air with the outdoors as well as on the indoor "climate" – the characteristics of the indoor environment most relevant to humans (Weschler, 2002; 2004).

Recent findings and challenges in indoor environment science and design

The quality of indoor air is usually defined by the characterization of the pollutants in it – that is, the degree to which it is polluted. This points to the gap in our knowledge of what truly good indoor air quality might be. Much of what we know is inferred from human responses to indoor air, but many pollutants – e.g., radon and carbon monoxide – are odorless, invisible constituents of the air that can kill. Until the last two or three decades, virtually all of the concern about indoor air has been focused on its aesthetic properties – odor and, in relevant situations, smoke. Building codes attempt to protect us from combustion products originating from our common appliances or from burning building materials during fires. But there is very little other protection in the codes or any other laws or regulations to protect building occupants directly from harmful air quality. The surge in bans on smoking indoors are hopeful sign that where serious health harm is likely, regulators can act. It remains to be seen whether they will be able to protect people from polluting behaviors and harmful exposures in the privacy of their own homes or from more subtle hazards.

While IAQ is a relatively new concern for most scientists and engineers, the thermal conditions for human occupancy have long received considerable attention from all quarters. The green or sustainable building movement must grapple with the control of the quality of the air and thermal conditions while also minimizing unnecessary use of fossil energy and the attendant atmospheric emissions. Not the least of these emissions is carbon dioxide (CO_2) whose impact on the atmosphere is closely associated with the global average temperature. Since the greenhouse gas impact of CO_2 on the atmosphere is from 5 to 200 years, it is not easy to quickly reverse the impacts of today's emissions nor to mitigate those of the recent past. It is not particularly important where on the planet the emissions originate because atmospheric mixing results in a global impact (Nazaroff and Levin, 2006). As attention to greenhouse gas emissions increases and limitations are imposed either through regulation or economics, the use of fossil fuels in buildings and electricity from fossil-fuel fired electric plants will be curtailed presenting unprecedented challenges to designers and building owners alike. As the pricing of fossil-fuels increases due to diminishing supplies and increasing extraction and processing costs, further constraints on designers use of electric energy and combusiton processes to provide thermal comfort, ventilation, and illumination as well as many other building services will become even more challenging.

IEQ vs. "green" buildings

So-called “green” designers struggle with the trade-offs between improving IAQ and thermal conditions while attempting to minimize the impacts of fossil energy consumption on global climate (Levin, 2006). Those who wish to ventilate naturally (passively) run into the problem of controlling the entry of outdoor air pollutants through windows or doors where no filters or other air cleaning devices can be applied. To make matters worse, indoor air scientists have now shown that bringing ozone or other common outdoor pollutants in through building ventilation, natural or mechanical, results in chemical reactions with many “green” building materials and cleaning products producing new chemicals that are far more toxic than those from which they are formed. Many of these green products are intended to reduce occupant exposures to traditional toxic solvents and cleaning chemicals but actually result in exposures to ultra-fine particles, toxins, carcinogens, and acidic aerosols that are far worse. For example, building products such as linoleum (containing linseed oil, often considered a “green” material because of its “natural” ingredients), or cleaning products (based on green solvents and cleaning products such as pine or citrus oils) react with ozone to form such toxic chemical products (Nazaroff and Weschler, 2004).

The Health Factor

Recently published scientific evidence suggests that ozone indoors is not only a threat due to its interactions with chemicals commonly found indoors but also because higher outdoor ozone levels have been associated with significantly increased rates of premature death (Bell, 2006). The effects appear to occur down to concentrations far below the national ambient air quality standards (NAAQS) at levels commonly found in indoor air and even in cities previously considered healthy in terms of ambient air ozone concentrations. Further evidence is available that indoor ozone exposures contribute a significant fraction (25% to 60%) of human exposure to ozone and that the effects are not only in terms of increased mortality but also increased morbidity (Weschler, 2006).

Similarly, scientific findings regarding particulate matter less than 2.5 micrometers in diameter ($PM_{2.5}$) concentrations at levels perviously considered very low suggest an increased level of particle filtration is necessary to protect building occupants from respiratory and cardiovascular health hazards (Dominici et al, 2006). Of major significance is the finding that the effects are not the same in all parts of the U.S. In fact, the effects in the eastern U.S. are far greater than those in the west, suggesting that where you are matters.

Challenges to the Building Community

The new knowledge gained by the indoor environmental scientists brings both enhanced understanding and substantial challenges to the larger building community. Existing knowledge is relatively underutilized or ignored, and resolution of some of the most difficult conflicts often reflects outdated and oversimplified technical solutions. If the same level of concern for human life safety that has informed structural design in modern buildings is to be applied to the health and well-being of occupants, a considerably deeper involvement with the indoor environmental issues will be required.

An appropriate opportunity for more active involvement in indoor environmental research and application will come with the next triennial international “Indoor Air ‘xx” conference to be held in Copenhagen, , in 2008. Information on the conference is available at www.indoorair2008.org. Proceedings from past conferences can be obtained through ISIAQ, the International Society for Indoor Air Quality and Climate, at www.isiaq.org. The “sustainable” built environment community needs to embrace this topic within its own deliberations. The current attention to the topic is substantial and growing, but the depth of understanding and the adequacy of its treatment are still overly simplistic and unsophisticated in the various building environmental guidance documents, rating systems, and design tools employed by the vast majority of “sustainable building” designers.

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