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Queries

Editorial

Q1	Cain, W.S. (2002) Publisher and city of publication?
Q2	Levin, H. (1995) Publisher and city of publication?
Q3	Levin, H. (2006) 1. Publisher and city of publication? 2. All editors' names and initials?
Q4	Nazaroff, W.W. and Levin, H. (2006): 1. Publisher and city of publication? 2. All editors' names and initials?
Q5	Weschler, C.J. (2002) Publisher and city of publication?

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Editorial

Indoor Environmental Quality (IAQ)

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 the public spends 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 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 (IAQ) 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 Japan. The papers in the present issue of *Building Research & Information* are expanded from selected presentations at last year's edition of the triennial conference 'Indoor Air 2005', the 10th International Conference on Indoor Air Quality and Climate held in Beijing, China, in September 2005. These papers have undergone the journal's rigorous double-blind refereeing process and, as a consequence, have been substantially altered. This special issue of the journal includes eight papers that provide a hint of the broad range and diversity of topics and approaches now populating the field. The papers were selected for their potential relevance to readers, but they only provide a glimpse of the very wide range of recent scientific work on the indoor environment and its impacts on building occupants. They help focus some of the current issues both being addressed and not yet receiving sufficient attention.

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 a 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 mould along with new emphasis on fine and ultra-fine particles have created an 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).

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

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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).

The first paper in this issue, by Van Dijken *et al.*, 'Indoor environment and pupils' health in primary schools', uses measurements of environmental parameters and an investigation of occupants' health in Dutch schools to detect associations that can help determine how to decrease the health harmful impacts of the school environment. Such studies are not uncommon in Northern Europe, yet far too few are funded and there remains a lack of adequate knowledge to guide us with scientific certainty toward improved designs and operating procedures. Furthermore, the investigators found from the analysis of questionnaires completed by the parents of the children whose schools were investigated that the home environment plays such an important role that improving the school environment alone is not sufficient.

In another paper on schools, 'Continuous measurements of air quality parameters in schools', Grimsrud *et al.* found that even in motivated school districts, school indoor air-quality parameters can be well below accepted norms. They concluded that measurements can be useful in detecting problems and providing information for school authorities to improve the environment, even in schools presumably with well-designed and maintained indoor environments.

Persily *et al.* analysed the ventilation data from a study of 100 US office buildings between 1994 and 1998 in their paper entitled 'Survey of ventilation rates in office buildings'. They found that many buildings' ventilation system designs were below the minima prescribed by code, while the vast majority of buildings were actually operating well above their intended ventilation based on outdoor air per person. Their paper looks critically at the common methods for measuring ventilation and presents important insights into the shortcomings of the methods for determining building ventilation rates.

Moschandreas *et al.*, in a paper following up on earlier work, present their efforts to develop a model that can be useful in the investigation of building environmental problems or occupant complaints in offices. Their paper, entitled 'Validation of the Indoor Environmental Quality (IEQ) conceptual model', examines the results of different consultants' efforts to assess the relationship between building environmental parameters and occupant responses. They conclude that the tool have developed can be used proactively in building management to address occupant health and comfort problems.

A pair of papers by Roulet and various collaborators present analyses of results from the multinational European Commission-funded Health Optimisation Protocol for Energy-efficient Building (HOPE) project on energy and health in 164 buildings in nine European countries including 96 apartment buildings and 64 office buildings. In the first paper, entitled 'Perceived health and comfort in relation to energy use and building characteristics', the investigators examine the relationships between perceived environmental quality and occupant symptoms as well as the energy-use characteristics of the building. They conclude that the better buildings were not necessarily more energy intensive and that perceptions of indoor environmental quality were predictive of symptom prevalence rates. In a second paper based on the same study, entitled 'Multicriteria analysis of health, comfort and energy efficiency in buildings', Roulet *et al.* propose a method to perform a 'global evaluation' of a building's impact on its occupants based on its indoor environmental characteristics. By sorting the buildings in the HOPE study into three bins by quality of various indoor environmental factors, the authors are able to show that buildings in the best category are not necessarily more energy intensive than those in the worst category. As man faces the challenge of meeting indoor environmental quality goals without increasing greenhouse gas emissions, such information will be increasingly valued as guidance for designers and operators.

Givoni *et al.* analyse data from four separate, previously published studies in Thailand, Singapore and Indonesia in their paper entitled 'Thermal sensation responses in hot, humid climates: effects of humidity'. The paper questions the traditional wisdom regarding the role of humidity on thermal comfort in the climates investigated. It provides suggestive evidence that the dominant models of thermal comfort may not be universally applicable, thus raising questions worthy of further investigation. In their paper, entitled 'Predicting thermal comfort in Shanghai's non-air-conditioned buildings', Ji *et al.* investigate the application of traditional thermal comfort models and the new adaptive thermal comfort model. They find that in the buildings studied, people tolerated conditions outside the 'comfort envelope' described in the major international standards, thus lending more credibility to the adaptive model of thermal comfort for non-air-conditioned buildings.

Recent 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 the knowledge about what truly good indoor air quality might be. Much of what is known is inferred from human responses to indoor air, but many pollutants, e.g. radon and carbon monoxide, are odourless, 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: odour and, in relevant situations, smoke. Building codes attempt to protect us from combustion products originating from 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 behaviours 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 five to 200 years, it is not easy to reverse quickly 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 from because atmospheric mixing results in a global impact (Nazaroff and Levin, 2006).

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, whether by natural or by mechanical methods, 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 Levin, 2004).

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 under-utilized 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 of the journal's readers in indoor environmental research and application will come with the next triennial international 'Indoor Air "XX"' conference to be held in Copenhagen, Denmark, in 2008. (For more information on the conference, see http://www.indoorair2008.org) Proceedings from past conferences can be obtained through the International Society for Indoor Air Quality and Climate (ISIAQ) (http://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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