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IEQ and the Impact on Building Occupants

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Introduction

Research into indoor environmental quality (IEQ) and its effects on health, comfort, and performance of occupants is becoming an increasing priority as interest in high performance buildings and organizational productivity grows. Facility managers are interested in IEQ's close relationship to energy use in facilities. Employers, by providing excellent indoor environments, hope to enhance employee comfort and productivity, reduce absenteeism and health care costs, and reduce risk of litigation. The increasing interest in this field has put additional pressure on the research community as architects, engineers, facility managers, building investors, health officials, jurists, and the public seek practical guidelines on creating a safe, healthy, and comfortable indoor environment.

Research on the relationships of IEQ to the health, comfort, and productivity of occupants has advanced considerably within the last decade. One of the primary goals of the Indoor Health and Productivity (IHP) Project is to communicate the results of this research, currently reported primarily in research publications, to building professionals. Consequently, the IHP project has worked with a peer review panel to select five key IHP papers and prepare summaries of these papers for publication in ASHRAE Journal.

This article precedes those five summary articles, which will appear in the next five issues of the journal. This article summarizes the methodology employed to select the five papers, briefly summarizes the message of each paper, and discusses the practical implications for architects and engineers.

More information about the objectives of the IHP project, results of research conducted under this project, and project sponsors and partners can be found at www.IHPCentral.org. The web site also has an online bibliography of approximately 900 papers on the topic of indoor health and productivity, drawn primarily from approximately 100 leading international journals and international conferences.

Methodology

The IHP Project has a Steering Committee representing the sponsors of the IHP project, a small technical staff (the authors of this article), and advisory committees established for specific tasks. For this task, the IHP Steering Committee developed criteria for selecting the five papers, including the following: relevance to IHP goals; originality; novelty; quality of research approach; and value of the paper to architects and engineers. The last of these criteria was considered most important. With input from the IHP technical staff, the Steering Committee also selected an international panel of fourteen peer reviewers, who are highly respected scientists and engineers with knowledge of the IHP field. The IHP technical staff nominated several papers and each peer reviewer nominated 2-3 papers resulting in a pool of twenty-six candidate papers. All the candidate papers are listed in the *References* section. Each candidate paper plus written justifications for the nominations were distributed to all peer reviewers. Each peer reviewer then selected five papers from the 26 candidate papers. To avoid any conflict of interest, peer reviewers were requested not to include their own papers in the short list. Finally, the Steering Committee, seeking a broad portfolio, selected the final five papers from the seven papers receiving the highest number of recommendations.

Identifying Current Research Priorities and Knowledge Gaps in the IHP Literature

To gain insight into the current IEQ literature rated very highly by the peer review committee, all twenty-six candidate papers submitted were classified based on the indoor environment variables being investigated (shown along the rows in Table 1) and on the associated health/productivity outcomes (shown along the columns in Table 1). The numbers in each cell of Table 1 refer to the candidate papers listed in the reference list at the end of this article. The last row and the last column show the total number of distinct papers appearing under each row and column.

Ventilation rate/CO2 concentrations, thermal conditions, and moisture or dampness were the IEQ factors investigated most often in the pool of candidate papers. Among the health/productivity outcomes, sick building syndrome symptoms were discussed in an overwhelming number of studies (18 out of 26) followed by evaluation of task performance, and occurrence of allergy/asthma symptoms. Only two papers from the pool estimated economic gains from improvements in health and productivity, and inclusion of both in the short list emphasized the importance of this topic and the need for more research on these outcomes. Although eight studies discussed enhancement of task performance from improved indoor environments, they focused on either component skills that represent a very small subset of the range of activities performed by people in work environments or on performance metrics such as standardized test scores of school students that cannot be used in many indoor environments. Very few studies have investigated the effects of indoor environmental parameters on the overall productivity of non-industrial workers. The gaps in Table 1, where the peer review committee identified no or very few top-rated papers, highlight areas of research need.

Table 1: Classification Scheme for Candidate Papers to Identify Research Trends and Knowledge Gaps in the IHP Domain. The numbers within the table refer to specific papers in the reference section. The numbers of the five selected papers are shown in bold type.

IEQ Variables	**Health/Productivity Outcomes**					
	Sick Building Syndrome Symptoms[a]	**Allergy and Asthma**	**Communicable Respiratory Illness (Short-term Sick Leave)**[b]	**Task Performance or Productivity**	**Economic Gains**	**Total Papers**
Ventilation Rate/CO2 Concentrations	(1, 12, **18**, 22, 23)	(22)	(**13**, **18**)	(23)	(**6**, **13**)	7p
HVAC System Characteristics	(12, 17, **19**)	(**19**)			(**6**)	4p
Building material and furnishings	(12)	(11[c])				2p
Volatile Organic Compounds	(10, 20, 22)	(7[c])			(**6**)	5p
Moisture/dampness	(3[c],4, 5[c], 16[c])	(3[c], 4, 5[c])	(5[c], **13**)		(**6**)	6p
Dust on surfaces	(8, 15, 17, 21)	(21)				4p
Daylighting/Lighting	(10)			(2, **9**, **14**)	(**6**)	5p
Thermal Conditions	(10, 12, 20, 25, 26)			(24, 25, 26)	(**6**)	7p
Crowding	(12)		(**13**)		(**6**)	3p
Total Papers	18p	8p	3p	8p	2p	

[a]Lower respiratory symptoms such as cough, wheeze, tight chest, and difficulty breathing are included.

[b]Examples include common cold, influenza – illnesses that may be responsible for some short-term sick leaves.

[c]These studies were conducted in home environment and were included as candidate papers because reviewers believed that the findings of the papers may have some relevance to non-industrial work environment as well.

Commentary on the short-listed papers

Of the five final papers, one estimated potential health benefits and economic gains from practical improvements in IEQ (Fisk 2000), one investigated the relationships of daylighting with students' performance in schools (Heschong 1999), two (Milton et al. 2000; Seppanen et al. 1999) addressed the relationships of ventilation rate to the health of building occupants, and the last paper reported associations between characteristics of HVAC systems and self-reported health symptoms (Sieber et. al. 1996). All of these papers were published in the last five years.

Fisk (2000) summarizes available research on the major indoor environment factors affecting human health and productivity. For the U.S., this paper estimates that health effects experienced by millions of people annually could be significantly reduced by improving IEQ, with associated annual economic benefits of tens of billions of dollars. The paper indicates that improvements in lighting and thermal conditions may lead to additional, even larger, productivity gains. The paper reviews the literature on the relationships of IEQ with communicable respiratory disease, allergies and asthma, and sick building syndrome symptoms and also briefly reviews the literature on the relationships of thermal conditions and lighting with productivity. Since the design, construction, and operation of buildings is often driven by the desire to minimize costs, the economic estimates in this paper should be of great interest to architects, engineers, facility managers, and employers.

The paper by Heschong (1999) relates a physical environmental parameter, daylighting in school classrooms, to standardized test scores of students at a time when test scores are driving school budget decisions. The findings of this study, ~ 20 percent larger increases in test scores in classes with more daylighting, if replicated in future studies, would provide a compelling case for increased daylight in classrooms.

Minimum ventilation requirements are of much interest to building engineers and operators and have been a controversial topic within ASHRAE. To date, these minimum ventilation standards have had a limited scientific underpinning. The papers by Seppanen et al. (1999) and Milton et al. (2000) help to consolidate and solidify the scientific basis for the development and refinement of ventilation standards. They are particularly useful in light of current energy shortages and the renewed interest in reducing ventilation rates in buildings to save energy. These papers indicate that higher ventilation rates will, on average, improve occupants' health, reduce absence from work, and improve perceived air quality. The papers provide considerable evidence of benefits from increasing ventilation rates above those specified in ASHRAE Standard 62-1999 for offices.

HVAC maintenance deficiencies and HVAC contamination have long been suspected risk factors for health symptoms, but the related scientific research has been quite limited. The paper by Sieber et al. (1996), based on a study of complaint buildings, is one of the few indicating the importance of HVAC cleanliness and maintenance for human health. The paper also reported that pollutant sources located near outside air intakes increased the risk of adverse health effects. The analyses controlled for the effects of age and gender on health symptoms but the study was not able to identify which HVAC cleanliness or maintenance conditions actually caused an increase in health effects.

Taken together, these five papers increase the strength of available scientific evidence that IEQ substantially affects health and productivity. Each of these studies had some limitations that will be discussed in the summary articles to be published in the subsequent issues of this journal. While more research is clearly needed, the message to architects and engineers is to pay attention to IEQ, in particular to assuring minimum ventilation rates, because numerous studies have found that ventilation rates influence health, satisfaction with indoor air quality, or absence.

Future Research

In the last twenty years, IEQ researchers have substantially advanced our understanding of links between enhanced health and productivity and improved IEQ, but many uncertainties remain about the costs and benefits of specific measures. Consequently, there is a critical need for more research to quantify the relationships of IEQ to health and productivity, define acceptable IEQ, and the best methods and costs of improving IEQ. The most effective research in this field will be highly multidisciplinary, involving building engineers, physical scientists, health scientists, economists, etc. In addition, we need research on how to best stimulate building professionals to use available scientific knowledge to create healthful building environments.

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