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IEQ and the Impact On Building Occupants

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Research into indoor environmental quality (IEQ) and its effects on health, comfort and performance of occupants is becoming increasingly essential. Facility managers are interested in IEQ's close relationship to energy use. Employers hope to enhance employee comfort and productivity, reduce absenteeism and health-care costs, and reduce risk of litigation. The rising interest in this field has placed additional pressure on the research community for 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. A primary goal 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 *ASHRAE Journal*. More information about the objectives of the IHP project, including an online bibliography, can be found at www.IHPCentral.org.

This article precedes those summary articles, which will appear in future issues of *ASHRAE Journal*. This article summarizes the methodology used to select the papers, briefly summarizes the message of each paper and discusses the practical implications for architects and engineers.

Methodology

The IHP steering committee developed criteria for selecting the 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 14 peer reviewers, who are respected scientists and engineers with knowledge of the IHP field. The IHP technical staff nominated several papers and each peer reviewer nominated two to three papers, resulting in a pool of 26 candidate papers. All the candidate papers are listed in References.

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 Research Priorities

To gain insight into the current IEQ literature rated highly by the peer review committee, all 26 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 last row and the last column show the total number of distinct papers appearing under each row and column.

Ventilation rate/CO_2 concentrations, thermal conditions, and moisture or dampness were the IEQ factors investigated cited most often. 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.

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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/CO_2 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	

Table 1: Research trends and knowledge gaps in IHP.*

[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.

*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.

Only two papers from the pool estimated economic gains from improvements in health and productivity. Inclusion of both emphasizes 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 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. 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.

Commentary on the Five Final 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 (Heschong 1999), two (Milton et al. 2000; Seppanen et al. 1999) addressed 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. It 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 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 finding of this study was a ~20% larger increase in test scores in classes with more daylighting. If replicated in future studies, this 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 considering 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 absences, and improve perceived air quality. The papers provide considerable evidence of benefits from increasing office ventilation rates above those specified in ANSI/ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*.

HVAC maintenance deficiencies and HVAC contamination have been suspected risk factors for health symptoms, but related scientific research has been 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 subsequent issues of *ASHRAE Journal*. While more research is clearly needed, the message to architects and engineers is to pay attention to IEQ, in particular to ensuring minimum ventilation rates, because many studies have found that ventilation rates influence health, satisfaction with indoor air quality or absences.

Future Research

In the last 20 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, a critical need exists 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 multidisciplinary, involving building engineers, physical scientists, health scientists, economists, etc. In addition, research is needed on how to best stimulate building professionals to use available scientific knowledge to create healthy building environments.

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