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ABSTRACT

Purpose

The goal of this project was to develop, based on the experience of those who investigate health complaints in buildings, practical strategies for preventing building-related symptoms in office buildings, suitable for use by those who own, lease, or manage office space.

Methodology/approach

Ideas from six experienced building investigators on primary causes and key prevention strategies were gathered and prioritized through consensus and voting in a structured, multi-day workshop.

Findings

The top ranked problems identified were, in priority order: excessive building moisture, inadequate outdoor air, dust on indoor surfaces, indoor gases and odors, inadequate thermal control, and inadequate attention by management to indoor environments. The highest priority strategies recommended for preventing building-related symptoms were: managing moisture at building exteriors, operating ventilation systems per design intent, providing at least minimum ventilation rates, and maintaining indoor temperatures at 72°F ±2°. Findings in the scientific literature were generally consistent with these recommendations.

Research limitations/implications

Findings reported here result from a subjective synthesis of empirical knowledge, not from scientific research, and have not yet been scientifically confirmed. Still, IEQ investigators showed considerable agreement on the most important causes of symptom complaints in office buildings and the key methods for preventing these problems.

Practical implications

These recommendations, generally consistent with available research findings, provide useful practical guidelines for those who own, manage or maintain office buildings.

Originality/value

The empirical knowledge of practitioners, concentrated and synthesized here, offers more guidance for choosing health-protective strategies in office buildings than current science.

Key words

indoor environmental quality, sick building syndrome, symptoms, ventilation, moisture, office buildings

Introduction

Complaints by occupants in offices and commercial buildings of health symptoms, discomfort, and odors (sometimes called "sick building syndrome" or building-related symptoms) have been documented for almost 30 years. These problems have persisted despite decades of investigation and increasing scientific research. Occurrence of these building-related symptoms has been estimated to cause important reductions in performance among the occupants working in these buildings (Mendell et al., 2002; Fisk et al., 2000).

Available scientific information is too limited to identify the specific indoor exposures (such as particular chemicals or microorganisms) that cause building-related symptoms in office buildings, much less to establish what levels of these exposures are safe. Thus, setting documented health-protective *indoor exposure standards* (that is, reference levels that should not be exceeded, and below which these adverse effects in building occupants do not occur) has not been possible in these buildings. Nor, in the absence of documented indoor exposure standards, has scientific research documented a set of *building-related practice standards* that have been shown to prevent occurrence of building-related symptoms (that is, ways of designing, operating, or maintaining buildings that prevent these health effects in occupants even without needing to measure specific contaminants). .

In the absence of exposure or practice standards scientifically demonstrated to protect health, the most effective current strategies for preventing building-related symptoms rest on *empirically based* concepts of "good building practice" rooted in the experience of building professionals. This experience has provided input for some formal consensus guidelines, such as current ventilation standards. (Although the historical basis for ventilation standards was controlled scientific studies on odor control, the more recent effort to protect health through ventilation standards was initially based only on professional experience. Recently, this effort has begun to incorporate scientific findings.)

For many aspects of indoor environmental quality (IEQ), no formal process exists for distilling professional experience into guidelines for protecting occupants. Although a variety of building professionals such as facility managers have experience of this kind, the most concentrated experience regarding successful and unsuccessful building practices and features exists among those professionals who investigate buildings with occupant health, comfort, and odor complaints. We will refer to these professionals as IEQ investigators.

The goals of the current project were to utilize the practical knowledge and experience of leading IEQ investigators to:

(a) Identify the most important environmental factors *leading to* IEQ problems and the resulting building-related symptom, discomfort, and odor complaints in office workers, and
(b) Develop a set of key recommendations for *preventing* these building-related problems and their adverse effects on health, comfort, and productivity, suitable for use by those who buy, lease, or manage office space.

The project brought together six experienced IEQ investigators with decades of combined problem-solving experience in thousands of buildings. A group process gathered and summarized their knowledge about the key environmental factors causing building-related symptoms in office buildings, and the key strategies for preventing these problems. The results

were compared to current scientific knowledge, and summarized for use in developing practical guidelines for maintaining good IEQ.

Methods

This project used a structured multi-day workshop, involving a sequence of exercises and discussion with voting, to achieve consensus among a group of leading IEQ investigators in the U.S. The workshop gathered opinions from the investigators on the following questions:

Environmental Causes

- Based on your experience as an IEQ investigator, what are the most important *environmental causes or risk factors* for building-related symptoms and discomfort complaints in U.S. office buildings?
- Why have you selected these as the most important risk factors?

Prevention Strategies

- What are your top recommended specific measures for *preventing* these health and comfort problems in office buildings (e.g., aspects of design, commissioning, operation, maintenance, or management)?
- Why do you recommend these measures?

Participating IEQ investigators considered the risk factors and prevention strategies in these categories:

- Building, initial (design, location, construction, commissioning)
- Building, ongoing (operation, maintenance, repair, replacement, housekeeping)
- Behavioral/organizational (management IEQ approach, occupant behavior)

Staff from the Indoor Environment Department at Lawrence Berkeley National Laboratory (LBNL) planned, conducted, and summarized the workshop, without contributing answers to the questions presented. After the workshop, LBNL staff, based on their familiarity with the current scientific literature, informally summarized risk factors for building-related symptoms identified in the scientific literature, compared these to risk factors identified by the IEQ investigators, and produced a summary report of the process.

IEQ investigators at the workshop included four in private practice and two federal government employees. These investigators provided and prioritized ideas during the workshop, and reviewed several draft versions of the summary report.

take in Table I

Results

During the workshop, the participating IEQ investigators developed a prioritized list of building-related problems (Table 1) that, based on their collective experience, were the most important causes of building-related symptom complaints in office buildings. They defined “importance” of causes primarily by their frequency of causing problems requiring investigation (although the original workshop concept had also included the severity of health problems caused).

For each of these problems, they then developed a set of top recommended prevention strategies, shown in Table II. They then ranked the entire list of recommended strategies by relative

importance in preventing building-related symptoms complaints. The top ranked strategies are provided in Table II.

Take in Table II

Risk factors for building-related symptoms with consistent support in the scientific literature were summarized and organized to correspond with the building-related risk factors identified by the investigators (Table III).

Take in Table III

Discussion

This project has attempted to condense and summarize valuable aspects of the empirical knowledge of IEQ investigators about the causes of building-related symptom complaints. This knowledge has not been formally summarized, although it is informally reflected in some prior guidelines for building managers (e.g., "Building Air Quality" by the U.S. EPA and NIOSH (1991). As is often the case, the empirical knowledge of practitioners offers more guidance for choosing health-protective strategies than current science, although the efficacy of empirically based strategies often has not been confirmed.

There is substantial overlap between the empirically based and scientifically based lists of problems. For each *environmental* category of investigator-identified building-related problems, at least one scientifically documented example was available (Table 3). For example, the scientific literature has demonstrated that symptoms are more common in buildings with lower ventilation rates, with higher temperatures even within the conventional comfort envelope, and with building moisture damage. No scientific documentation was available of symptoms caused directly by inadequate management attention to IEQ, although many environmental deficiencies could result from such inattention.

Because health studies of risk factors in buildings for causing symptoms generally do not estimate how *commonly* the risks occur or the relative *importance* of specific effects, such studies cannot themselves support prioritized recommendations for prevention strategies. Separate descriptive data is available on the high frequency of some building-related risks in representative U.S. office buildings, from the U.S. Environmental Protection Agency's Building Assessment Survey and Evaluation (BASE) study (Brightman et al., 2000). For instance, 85% of office buildings studied had past water damage, including roof leaks in 50%; 43% had current water damage (unpublished analyses, Author 1). Also, calculations with BASE data suggest that 23% of BASE buildings provided less than the minimum rate of outdoor air specified in current ventilation standards. During hot weather conditions, when ventilation systems would likely be providing their lowest rates of outdoor air ventilation, approximately 32% of the BASE buildings provided less ventilation than provided in current standards (unpublished analyses, Author 9).

Limitations of study

These results were produced by a small group of IEQ investigators, primarily industrial hygienists or engineers, during a two-day meeting, through consensus based on years of experience rather than through scientific research; however, this exercise has been useful in summarizing an important source of information on how inadequacies in buildings can adversely affect the health of occupants. The investigators in this project suggested prevention strategies,

although much of their primary work is in diagnosing and suggesting remediation strategies for existing problems, with few opportunities for follow-up to evaluate efficacy of the recommended solutions.

Conclusions and Implications

IEQ investigators showed considerable agreement on the most important causes of building-related symptom complaints in office buildings and the key methods for preventing these problems. These recommendations are generally consistent with available research findings, and provide useful practical guidelines for those who own, manage or maintain office buildings. Critical tasks for preventing occupant symptoms in office buildings include managing moisture at building exteriors, providing adequate ventilation, and controlling indoor thermal conditions.

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Table I. Key problems causing building-related symptom complaints, listed in descending order of estimated importance, and recommended prevention strategies for each, based on the experience of IEQ investigators

Problem Category	Top Recommended Prevention Strategies
Excessive building moisture	• Water management of building exterior • Humidity control by HVAC • Maintain water vapor management through envelope
Inadequate amount or quality of outdoor air	• Operate per design intent (effective controls) • At least minimum rates of outdoor air (per ASHRAE) at air handling unit • Scheduled maintenance of outdoor air system
Surface dust	• Management of renovations (containment and management of air pressure relationships) • Housekeeping • Surface and material selection
Gases and odors	• Locate outdoor air intakes away from sources • Management of renovations (containment and management of air pressure relationships) • Local exhaust venting for special uses/sources

Inadequate thermal control	• Meet ASHRAE 55 for temperature and relative humidity
	  o Maintain 72°F ±2°
	  o Pay attention to radiant heat exchange, proximity to window, and window type
	  o Limit air velocity to 25 ft/min maximum
	• Control of high relative humidity (e.g., <60, 70%)
	• Local control of temperature

Inadequate attention by management to preventing adverse effects of the indoor environment on occupants, versus minimizing immediate costs	• Communicate about activities that cause employee complaints, and about addressing complaints • Set up IEQ management plan (e.g., EPA/NIOSH building action plan) • Promote employee/management IEQ committees/ safety and health committees for ongoing communication

Table II. Highest priority strategies for preventing building-related symptom complaints (selected from initial priorities in Table 1), based on the experience of IEQ investigators

Problem Category	Top Recommended Prevention Strategies
Excessive Building Moisture	• Water management of building exterior
Insufficient Outdoor Air	• Operate ventilation system per design intent (requires effective controls) • Provide at least ASHRAE 62.1 minimum outdoor air ventilation rates at air handling unit
Thermal Discomfort	• Maintain indoor temperature at 72°F ±2°

Table III. Likely causes of building-related symptom complaints: priority problems identified by IEQ investigators compared to related problems identified in the scientific literature[1, 2]

Building-related problems causing symptom complaints, identified by IEQ investigators	Building-related risk factors associated with symptoms in office buildings, identified in the scientific literature
• Excessive building moisture	Moisture and microbial growth in occupied space, within building envelope, or in HVAC system Presence of air-conditioning or humidification systems, especially with wet or dirty surfaces
• Inadequate amount or quality of outdoor air	Inadequate outdoor air ventilation rate (<10 l/s-person, or possibly <20-25 l/s-person)
• Surface dust	Airborne and surface particles or dust indoors Fungi in floor dust
• Gases and odors	Carbon monoxide from attached vehicle garages Emissions from carpets, new computers
• Inadequate thermal control	High temperatures even within recommended comfort range
• Inadequate attention by management to preventing adverse effects of the indoor environment on occupants	None

[1] excluding radon, asbestos, lead, tobacco smoke, and *Legionella* bacteria
[2] identified as risks by either definite, persuasive, or suggestive scientific evidence, based on an informal literature review by coauthor 1; not ordered by strength of evidence or estimated importance