INDOOR AIR QUALITY DESIGN GUIDEBOOK

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6. SICK BUILDINGS: PHYSICAL AND PSYCHOLOGICAL EFFECTS ON HUMAN HEALTH AND PREVENTIVE MEASURES

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Page

6.1 Introduction

The term "sick building" is often associated with buildings in which a majority of occupants experience a variety of health and comfort problems for which no specific cause can be identified (1). Other cases of indoor air quality (IAQ) problems may be related to building-related illness (BRI) in which a known agent or pollutant is involved. Health complaints from occupants often include irritation of the eyes, nose, throat, upper respiratory system, headache, and general fatigue. This complex set of symptoms experienced by the occupants of modern buildings has been named as the sick-building syndrome (SBS) or the tight-building syndrome (TBS) (2), causing substantial increase in absenteeism and, therefore, loss of productivity among occupants suffering from SBS (3, 4). The majority of these sick buildings, constructed in the past ten years, are well-sealed, mechanically ventilated and air-conditioned and have few windows that can be opened. Several reviews (5, 6) have documented that sealed, air-conditioned buildings such as modern office buildings, contain a wide variety of pollutants often at very high concentrations (7).

To date, a large number of sick buildings has been investigated by the government agencies and independent researchers. Although most studies on sick buildings have been inconclusive, there exists a substantial amount of data in both the published and unpublished forms. These data include such parameters as IAQ, ventilation, lighting, acoustics, and reported effects on the health and comfort of occupants as well as research and instrumentation. A careful review of these data in addition to experience gained from numerous other investigations can be quite helpful in developing a systematic approach on how to diagnose a sick building, identify the cause of problems, and prescribe a course of action designed to correct the situation.

Case studies and other research have identified the following nine features common to unhealthy buildings (8):

- **A sealed building envelope.** Generally, the amount of fresh air introduced into a sealed, mechanically controlled building is minimized because it is energy efficient to recirculate as much of the building air as possible.

- **Heating, ventilating and air-conditioning.** The mechanical system helps the distribution of many indoor air pollutants generated by materials and equipment in a building. It may also incubate and spread fungi, bacteria, and viruses.

- **Location of vents and exhausts.** Air supply vents can introduce outdoor air contaminants into a building. For example, supply vents located near a busy street, parking garages, or freeways are often the source of entry for motor vehicle exhaust. Also, inadequate placement of supply and exhaust vents can prevent exhaust from escaping.

- **Location of ventilation diffusers.** Both the inlet and exhaust diffusers are commonly located in the ceiling, which often creates stratification and shortcircuiting of supply air at the ceiling resulting in dead air and poor circulation.

- **Lack of individual control over environmental conditions.** Not everyone is equally comfortable in the same indoor environment. Elimination of the possibility to change the environment may contribute to discomfort, stress, and other minor health problems.

- **Use of new materials and equipment.** Synthetic materials, modern office equipment, industrial soaps, detergents and waxes used for maintenance generate many irritating and sometimes toxic fumes and dusts including formaldehyde, hydrocarbons, amines, ozone and respirable particulates.

- **Fluorescent lamps.** The fluorescent lamps emit ultraviolet light and may provide energy for photochemical reactions among pollutants, thus creating indoor smog.

- **Parking garages, restaurants and other non-office space use.** Many parking garages, access to transportation such as buses and subways, restaurants, health clubs, laundry and recreation facilities may add substantial amounts of combustion byproducts.

- **Energy conservation methods.** Most energy conservation methods usually involve reduction of fresh air ventilation rates, which increases the rate of accumulation of pollutants by reducing the volume of air exhausted. The efficiency of standard air filters is reduced substantially as the ventilation air velocity is lowered. Many buildings use a variable-air-volume (VAV) system, which introduces fresh air only when cooling or heating is required. Consequently, occupants of a building, often complain of stale, stuffy air which indicates insufficient ventilation.

High cost of fuels in the 1970's placed immediate pressure on energy conservation. Building construction, maintenance, and service practices and standards were revised to allow energy conservation. The majority of new office buildings today are being designed and built to comply with the revised environmental standards to achieve energy conservation goals. Also, many existing contemporary office buildings are being retrofitted to reduce the amount of energy consumed. The cost in terms of human health, comfort, and productivity that may result from the revised environmental standards in office buildings are still unclear.

6.2 Health Effects

The common symptoms of SBS include headache, eye problems, nasal problems, throat problems, fatigue and lethargy, chest problems, skin problems, and problems in maintaining concentration among the occupants of a building.

Research conducted to date has not isolated a causal agent or agents for SBS. Studies comparing ambient conditions in air-conditioned and naturally ventilated buildings have typically found little difference in any of the environmental parameters measured (9,10). One of the major difficulties associated with such comparisons is the lack of any clear consensus on both defining symptoms of the SBS and the rate of occurrence at which such symptoms become indicative of an SBS.

In a survey administered to the air-conditioned and naturally ventilated buildings, the symptoms included those of frequently encountered in SBS as shown in Table 6-1 (11). However, it may be unwise to generalize the results of this survey to all types of buildings. More extensive research in a larger number of buildings with a wide range of ventilation systems is essential. Investigation of such symptoms in different types of office buildings may be useful in the development of a standard diagnostic questionnaire for identification of sick buildings.

Table 6-1. Comparison of Health Complaints in Air-Conditioned and Naturally Ventilated Office Buildings.

Symptom	Air-Conditioned Offices (% usually)[A]	Naturally Ventilated Offices (% usually)[A]
Sleepiness	69.2	44.5
Fatigue	68.0	52.4
Headache	67.2	50.5
Eye irritation	52.1	45.9
Concentration problems	50.9	41.2
Cold/flu symptoms	50.2	32.4
Sore throat	47.9	28.3
Nose irritation	45.5	26.5
Focusing problems	42.9	28.8
Backache	41.8	41.4
Neckache	41.2	39.5
Cold extremities	40.7	38.8
Tension	36.1	33.1
Skin dryness	29.9	16.7
Depression	25.1	25.2
Dizziness	23.6	15.5
Muscular aches	21.1	17.2
Weakness	20.3	9.1
Nausea	19.4	7.8
Respiratory problems	12.2	5.7
Chest tightness	9.8	6.8
Fever	8.1	2.0

A: % usually = % sometimes + % always

According to several investigations, certain syndromes with recognizable symptoms may occur in offices, homes and hospitals in response to specific toxic dusts, fumes, or viable microorganisms. Some of these factors are identified to be (12): (a) dry detergent residues, (b) fibrous glass dust from ductwork, (c) formaldehyde off-gassing from insulation, (d) photochemical smog formation, and (e) diseases from viable microorganisms located in duct systems, cooling towers, or humidification chambers. Cigarette smoking is sometimes associated with such symptoms.

6.3 Preventive Measures

In more than 350 investigations conducted by the National Institute of Occupational Safety and Health (NIOSH) in the United States (13), cigarette smoking was suggested as a suspected cause in only 2% of the investigations. By far the most prevalent problem was that of inadequate ventilation (48.3%). The most common cause of inadequate ventilation is the diminished intake of fresh air into the air circulation system, usually to conserve energy and save on cost of building operations. A recent review of 94 building investigations by Health and Welfare Canada (HWC) (14) also found problems with ventilation systems in high percentage (68%). In this study, the combined category of photocopy machines and tobacco smoke was associated with SBS in only 5% of all cases.

The detailed monitoring of ventilation and indoor air contaminants necessary to document possible mechanical system inadequacies can be time-consuming and expensive. However, a multiphase program of gathering information from building occupants and maintenance personnel, combined with the measurements of specific indoor air pollutants and the inspection of easily observable ventilation parameters, can provide a timely and cost-effective method of investigation. Such an approach may provide a practical means of making judgments about the adequacy of performance of a building ventilation system and other potential sources of indoor air contaminants. The following approach for building performance evaluation consists of five phases, and is used to (15): (a) determine whether an IAQ problem exists in a building, (b) identify the probable causes of the IAQ problem, (c) design and implement modifications to alleviate the problem, and (d) reevaluate IAQ conditions after modifications have been made to test the effectiveness of the design solutions.

Phase 1:

Phase 1 consists of a checklist that should be completed by the building owner, operator, or representative such as the maintenance personnel. This checklist contains information on the architectural and mechanical system design and performance (including maintenance), use of the building (both by employees and visitors), workspace design and layout, equipment use and occupant health, and the comfort concerns and complaints. Review of the information from the building owner/operator provides basic information about the mechanical system performance and occupant problems.

Phase 2:

Phase 2 includes two parts:

a. Administration of an "Office Work Environment Survey" questionnaire to all building occupants as a method for documenting IAQ problems and health symptoms experienced by the occupants and to locate areas where complaints are more acute for detailed monitoring in Phases 3 and 4, if required.

b. A walkthrough evaluation of the building that would be conducted by the state government officers. It includes an inspection of the mechanical systems and review of the mechanical and architectural plans to obtain an overview of building performance. The review of plans also allows comparison of the design specifications of the mechanical systems with the established standards such as ASHRAE Standard 55-1981 and ASHRAE Standard 62-1989.

Phase 3:

Phase 3 consists of measurements of the selected major IAQ parameters, with locations for air-sampling determined by the results from Phase 2. Some of these parameters are:

- Carbon dioxide as an indicator of the buildup of contaminants generated indoors;

- Carbon monoxide as an indicator of combustion byproducts infiltrating the building, especially from parking garages or other sources of indoor combustion;

- Temperature and relative humidity as indicators of occupant thermal comfort conditions; and

- Respirable particulates as an indicator of ventilation filtration system efficiency and complaints related to environmental tobacco smoke (ETS).

Each of the parameters can be measured using a portable direct reading instrument, which can be easily carried in a building. Other parameters such as formaldehyde, ozone, and microorganisms may also be used in Phase 3 as determined by the data obtained from Phases 1 and 2. Present measurement methods for these additional parameters often involve an extensive laboratory analysis of collected samples. However, measuring microorganisms, a simple method for providing counts of total microbes is under development and when available, following field testing, may be incorporated into Phase 3. Additional information on sampling equipment and screening techniques may be found in Chapter 15, Part 3.

Phase 4:

Phase 4 is a detailed ventilation evaluation of a building using smoke pencil tests, tracer gas, and air flow measurements to determine:

- Total building air exchange rates;
- Floor air exchange rates; and
- Patterns of air movement throughout the building including air leakage from potential indoor air pollutant sources, such as parking garages.

Following Phase 4, investigators will be in a position to make recommendations based on the combined results of Phases 1 through 4.

Phase 5:

Phase 5 represents the implementation of design solutions in a building. Phase 5 may be reached at the completion of any of the first four phases, as dictated by the results of specific evaluations.

After modifications have been made, a vital further step in total building performance investigation is a reevaluation of IAQ conditions to determine whether recommended modifications have been effective. Reevaluation begins with the readministration of Phase 1. If modifications to the building have been effective, the completion of Phase 1 will indicate that no further IAQ problems exist. If IAQ problems still exist in the building, a strategy is to continue through the components phases until IAQ and related ventilation system performance problems are eliminated.

The five-phase approach outlined above has been developed as a practical strategy to locate and identify the probable causes of IAQ problems in a building in a timely and cost-effective manner, and to formulate retrofit actions to improve conditions.

The adoption of a standard approach to investigate buildings may be beneficial to both the researchers and building owners/occupants because the findings from different buildings may be directly compared. In addition, as more investigations are undertaken, the baseline data from health and comfort complaints, and measured IAQ and ventilation parameters would be developed with which future investigations may be compared.

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