Indoor air quality — total environment performance: Comfort and productivity issues in modern office buildings

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Synopsis

Reduction of fresh air ventilation is becoming the major means of energy conservation in office buildings. Simultaneously health and comfort problems experienced by occupants resulting in increased absenteeism are often suspected to be associated with reduced fresh air ventilation. However, there is little data available on health and comfort problems experienced by occupants of buildings operated under normal ventilation rates.

Baseline data needed to compare occupant health and comfort complaints in buildings with reduced ventilation to complaints in "normal buildings" was provided by a survey of 1106 occupants in nine office buildings with no prior history of health and comfort problems. Buildings were screened for energy conserving retrofits and architectural and ventilation factors.

Introduction

New modes of design, construction, ventilation and energy management have had profound effects on the manner in which pollutants are generated, entrapped or eliminated in buildings. A number of extensive reviews have now documented that sealed, air conditioned buildings, especially modern office buildings, contain a wide variety of pollutants often exceeding levels found outdoors[1,2,3,4,5]. Occupants of these same buildings often also suffer from a complex of symptoms including headaches, burning eyes, irritation of the respiratory system, drowsiness, fatigue and general malaise, now termed Building Illness or Tight Building Syndrome[6,7]. In addition, studies have shown a substantial increase in absenteeism and associated loss of productivity among occupants suffering from these symptoms[8,9]. Many public health authorities believe building illness may be reaching epidemic proportions in sealed, air conditioned buildings.

The acceleration of fuel costs in the 1970's placed immediate pressures to conserve energy on the building sector. Building construction, maintenance and service practices and standards were altered to allow energy reduction. Ventilation was drastically decreased and occupant control over ventilation and lighting was reduced. New ventilation standards proposed by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the U.S. Department of Energy recommend and permit a reduction of ventilation air by up to 90%[10,11]. For example, the previous ASHRAE "Standard for Natural and Mechanical Ventilation" recommended 25 cubic feet per minute (CFM) per person of fresh air ventilation in general office areas of air conditioned office buildings[12]. However, the new ASHRAE standard, "Ventilation for Acceptable Indoor Air Quality" requires only 5 CFM per person of fresh outside air providing smoking is either not allowed or restricted to designated areas.

Problems experienced by occupants are often suspected to be a direct result of reduced fresh air ventilation. Without comparative data it is difficult to determine whether the situation experienced by occupants under reduced ventilation conditions is better or worse than under previous conditions. However, *baseline* data needed to compare occupant health and comfort complaints in buildings with reduced ventilation to complaints in "normal buildings" is now available from a detailed survey of 1106 occupants of 9 "normal" office buildings.

Method

A self-administered Work Environment Survey questionnaire designed to collect perceptions of environmental conditions and prevalence of Building Illness symptoms among office occupants was administered to 1106 office workers (45% men and 55% women). As far as was determined, there was no prior history of health and comfort complaints among the study group, no prior investigations of the office environment, and no major energy conservation retrofits.

The work environment survey questionnaire requested information about:

Environmental conditions: air movement, air quality, lighting, glare, unpleasant odors, temperature, humidity, seating.

Lighting type: fluorescent ceiling light, fluorescent table light, incandescent ceiling light, incandes-

cent table light, natural window light.

Health related symptoms: headache, dizziness, fatigue, sleepiness, nausea, skin rashes, ringing in ears, nose irritation, breathing difficulty, chest pain or tightness, blurred vision, eye irritation, sore throat or cold symptoms.

Control over environmental conditions: windows, illumination, heating, ventilation, air conditioning, smoking.

Questions were so constructed that they could be scored on 3 point scale, with a 1 indicating a favorable, 2 an intermediate and 3 an unfavorable response. The distribution of responses for health and environment related questions were evaluated by constructing comprehensive indices which combined related and non-conflicting questions.

Table 1 shows the indices used to assess overall effects of working conditions on *health related symptoms* and *environmental conditions*. Health and environment indices were cross tabulated with responses to individual questions about control of environment (such as opening windows). Cross tabulations were also tested for independence by use of Chi Square statistics.

Results

Distribution of complaints about environmental conditions

Seventy-five percent of office workers reported too little air movement as opposed to only 35% reporting too much air movement "Sometimes or Often". Unpleasant odor, often used as an indicator of inadequate ventilation, was reported by 40% of respondents as occurring at least "Sometimes" and by 14% as occurring "Often or Always". Temperature was a consistent problem with 77% reporting conditions too cold and 72% reporting conditions too hot "Sometimes or Often". Although 44% of respondents complained of smoky air in the workplace, 74% reported stuffy conditions. These results seem to indicate a need for more appropriate regulations or control by office workers of conditions affecting temperature and air quality. Current air quality regulations[10] are based on restriction of tobacco smoke, however from the survey results it would appear that "stuffy air" rather than "smoky air" would be a better indicator of overall air quality.

Lighting conditions were considered satisfactory. However, responses indicated that brightness and glare could be improved. Forty-three percent reported that lighting was too dim and 45% reported glare on work surfaces "Sometimes or Often". Lighting conditions are not now a significant problem among office workers, however with illumination levels and window area being reduced to conserve energy, future problems could result.

Building Illness symptoms commonly reported in the indoor air pollution literature

Headache, fatigue, nose irritation and eye irritation (symptoms indicating general discomfort with environmental conditions) were reported most frequently. Thirty-seven percent of office workers reported headaches, 52% reported fatigue, 32% reported nasal irritation and 37% reported eye irritation more than once a week. Twenty-one percent of respondents reported sore throat or cold symptoms once a week or more.

Ventilation

Results of the cross tabulation between answers to the question, "In your primary work area do you feel that there is too little air movement?" and the Building Illness, and the association between "Too Much Air Movement" and Building Illness

There is a highly significant relation between Building Illness symptoms and insufficient air movement. This is also shown by the approximately four times as many respondents in the insufficient as in the sufficient air movement group who scored "poor" on Building Illness. On the other hand, the responses of "Too much air movement?" do not show a significant association to Building Illness. Again this lack of relationship is made obvious by the comparison of the almost equal proportion of respondents in the group that scored low and high on this question.

While movement of air by itself does not ensure better fresh air ventilation, it seems to be so perceived and in fact may be the case in buildings that are better ventilated.

The association between conditions of ventilation in the work place and Building Illness symptoms

There is a highly significant relation between poor ventilation and Building Illness. As fewer occupants of well ventilated buildings complain of Building Illness symptoms, air movement and quality of ventilation appear to be major determinants of health and comfort among office workers.

Lighting

The association between office lighting conditions and Building Illness symptoms

There is a highly significant relation between poor lighting and Building Illness.

The association between lighting conditions and visual health

Again, the relationship is significant and substantial.

Effects of Smoking

Some of the office workers surveyed smoked (57%) and some of them did not (43%). Some of them worked in places where smoking was permitted, some in places where smoking was prohibited, and some in places where smoking was restricted.

Thus a number of groups were constructed for comparison:

- Nonsmokers working in places where smoking was permitted.
- Nonsmokers working in places where smoking was restricted.
- Nonsmokers working in places where smoking was prohibited.
- Smokers working in places where smoking was permitted.
- Smokers working in places where smoking was restricted.
- Smokers working in places where smoking was prohibited.

As responses to questions were almost identical for places where smoking was restricted and where it was prohibited, we combined workplaces where smoking was restricted or prohibited into a single category.

The effect of smoking on nonsmoking office workers

There is no significant association between smoking at work and either Building Illness or Visual Health among office workers who either smoke or do not smoke.

The association between Smoking at Work and the Odor Index

There is no significant difference in the perception of unpleasant odors among nonsmokers or smokers regardless of whether smoking was or was not permitted.

Control over Environment

In most modern office buildings, but not in all of them, control of air conditioning and lighting is centralized and thus removed from office occupants.

The association between control by occupants of air conditioning and lighting on the Building Illness index

Air conditioning is used here as a generic term referring to the heating, ventilation and air conditioning (HVAC) system. There is a significant relationship between control of air conditioning and incidence of Building Illness. There is also a significant relationship between control of lighting and incidence of Building Illness. In both cases respondents who had control over conditions were approximately three times less likely to suffer symptoms of building illness than those with no control.

Discussion

The results indicate that even among occupants of buildings operated under normal ventilation and lighting conditions, there exist problems with environmental conditions as well as a relatively high level of health and comfort complaints that could result in increased absenteeism. There is a consistent pattern of association of factors relating both ventilation and lighting with frequency of reported illness symptoms. Office workers judging their ventilation and lighting environments as poor were more likely to have health complaints than those who considered ventilation and lighting to be good. Office workers with control over

Table 1 — Groups of questions used to construct health and environmental indices

Health Indices

Visual
- blurred vision
- eye irritation
- split or double vision
- trouble focusing eyes

Cardiorespiratory
- nose irritation
- breathing difficulty
- chest pain or tightness
- racing heart

Musculoskeletal
- neck ache
- sore arms, hands, wrists
- backache

Neurophysiological
- headache
- dizziness
- fatigue
- sleepiness
- moodiness
- depression
- lightheadedness
- confusion

Building Illness
- headache
- fatigue
- nose irritation
- eye irritation
- sore throat or cold symptoms

Absenteeism
- days absent during past six months
- days left work due to illness in past six months

Medication
- aspirin
- stomach or digestive aids
- cough, cold or sinus medication
- stimulants (pep pills)
- prescription medicine
- laxatives
- depressants
- sleep inducing aids

Environment Indices

Lighting
- lighting too bright
- lighting too dim
- glare on work surface

Ventilation
- too little air movement
- too much air movement
- air too stuffy

Temperature
- too cold
- too hot

Humidity
- too dry
- too moist

Odor
- unpleasant odor
- too smoky

environmental and lifestyle factors such as controlling air conditioning, opening and closing windows, switching on and off lighting and smoking had fewer complaints about health and stress symptoms than did office workers with no control over environmental and lifestyle factors.

No significant association was found between Building Illness, Visual Health and Odor indices and either active or passive smoking. The findings here however relate only to the association of smoking to perceived health and/or comfort levels, not to irritation to highly sensitized nonsmokers.

The majority of new office buildings are now designed and built to comply with environmental standards that have been revised in order to achieve energy conservation goals. Also, many existing contemporary office buildings are being retrofitted to reduce the amount of energy used. The cost in terms of human health, comfort and productivity that may result from reduced environmental standards for energy conservation in office buildings are still unclear. This study presents baseline data showing the relation of environmental parameters to health and comfort of office workers in buildings prior to energy conserving adjustments or modifications. These questionnaire survey results can be used for comparison with similar data collected from occupants of energy conserving office buildings to provide background for adoption of prudent standards to ensure that energy efficient buildings are designed, built and operated to provide conditions acceptable for human occupations.

Footnotes

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This study was taken from submissions made to the British Columbia Energy Management Task Force for their Symposium on Energy Management — Indoor Air Quality and Building Performance Testing, September 25, 1985. The study was conducted by E.M. Sterling, Research Director, Theodor D. Sterling Ltd., Vancouver, B.C.