International Journal of Facilities Management **1**(4), 185–192
1365–702X © 1997 E & FN Spon

A study of indoor environment and sick building syndrome complaints in air-conditioned offices: benchmarks for facility performance

Alan Hedge and William A. Erickson
Department of Design & Environmental Analysis, Cornell University, USA

This paper discusses a method for conducting building surveys of environmental climate, comfort and health (sick building syndrome), along with measures of ambient environmental conditions. This method was used to poll 6250 employees working in 35 air-conditioned (CAV and VAV) eastern US office buildings. Data are presented as a normative database of physical environmental conditions and weekly reports about environmental conditions and work-related sick building syndrome complaints. Results are presented in quartile tables for each climate measure and questionnaire survey item. A short-form questionnaire is provided for others to collect comparable data. Use of this survey database serves as a benchmark for facilities performance for air-conditioned, open plan office buildings.

Introduction

Do you manage a 'sick' building? Does your company run the risk of litigation because of occupant health complaints? Are you adversely affecting your company's bottom line because of indoor climatic conditions that jeopardize productivity? These are just some of the questions facing today's facility manager in the USA. Reports of 'sick' buildings frequently appear in the media, and sometimes the concerns about the widespread health complaints in a building result in evacuation of the facility, often without knowing the causes of complaints. Unfortunately, until now there has been no way for a facility manager to know how well his or her building fares when compared with others of similar design. There is a pressing need for benchmark standards for building performance and occupant complaints. This paper clarifies the nature of 'sick building syndrome' and describes benchmark results from the Cornell Office Environment Survey of 35 air-conditioned office buildings.

What is sick building syndrome?

Sick building syndrome (SBS) is characterized by symptoms of eye, nose and throat irritation, mental fatigue, headaches, nausea, dizziness and skin irritation, that are thought to be associated with occupancy of a building (WHO, 1983). It has been suggested that SBS also includes odour or taste complaints (Mølhave, 1989). Usually, SBS symptoms cannot be objectively diagnosed because they do not show obvious clinical signs. Mostly they are assessed by self-reports from occupants. Most individual SBS symptoms are not unique but are relatively commonplace in any large population (Pennebaker, 1982). What distinguishes SBS is the pattern with which symptoms are experienced. Typically, SBS symptoms are

Address for correspondence: Dr Alan Hedge, Department of Design & Environmental Analysis, NYS College of Human Ecology, MVR Hall, Cornell University, Ithaca, NY 14853-4401, USA. Email: ah29@cornell.edu

experienced intermittently and only while the occupant is in the building; the symptoms are readily reversible and are alleviated when away from the building without any medication. Because of this pattern of complaints SBS does not behave as a disease, and SBS does not include clinically definable building-related illnesses, such as Legionnaire's disease, which persists after exposure whether in a building or not. SBS symptoms are suggestive of temporary irritation phenomena.

Although SBS is thought to be associated with poor indoor air quality, clear associations between environmental conditions, air pollutants and symptoms have seldom been reported by studies in US office buildings (Hedge *et al.*, 1992, 1994, 1995, 1996; Mendell, 1993). By definition, a 'sick building' is a building with a high prevalence of SBS reports, and this building may or may not have associated environmental problems, such as poor indoor air quality. Studies have shown consistent associations between symptom reports and factors such as occupant perceptions of indoor environmental conditions. Menzies *et al.* (1994) compared office buildings categorized as either 'healthy' or 'sick' by the facility manager, and found considerable overlap in the prevalence of self-reported environmental and health problems. They concluded that the labels 'healthy' or 'sick' are misleading, and they suggest replacing these with operational terms, such as 'nonproblem' and 'problem' buildings.

The absence of any normative data on occupant reports of either SBS or indoor environmental conditions makes it impossible for any facility manager to know whether her/his building is performing as well as, better, or worse than comparable buildings. The only guidance available is the ASHRAE ventilation standard which includes a definition of acceptable indoor air quality (ASHRAE 62-1989R), suggesting a threshold of 20% occupant complaints above which indoor air quality is deemed unacceptable. This standard gives no guidance on how complaints shall be measured, which complaints shall be measured, and over what time period complaints shall be measured. The standard also excludes consideration of health complaints. Research studies of SBS typically show that occupant complaints of poor indoor air quality and SBS symptoms typically exceed this 20% threshold in many buildings (Hedge *et al.*, 1989, 1992, 1994, 1995, 1996; Mendell, 1993; Menzies *et al.*, 1994). This could indicate that 'sick' buildings are widespread in North America. Alternatively, it could simply indicate a relatively high baseline level for occupant complaints in air-conditioned office buildings in which occupants are not being exposed to hazardous air quality.

There is no consensus on a case definition for a 'sick', or conversely a 'healthy' building. Menzies *et al.* (1994) showed that buildings labelled as 'sick' by their facility manager performed comparably to those labelled as 'healthy' by their facility manager. Building occupant survey studies always find variability among buildings in the prevalence of environmental and health complaints. A standard assessment method is needed for a facility manager to determine the relative performance of a building. Results from this assessment for a specific building then need to be compared to a normative database on indoor environment and SBS complaints in comparable buildings. In this way the facility manager can gauge how her/his building is performing compared to other similar buildings. Such a method is described here, along with normative data for 35 eastern US air-conditioned office buildings.

Methods

Survey sample

Thirty-five air-conditioned US office buildings were selected according to the following criteria:

1. geographical location (eastern USA: Alabama, Georgia, Indiana, Kentucky, Massachusetts, Michigan, New Jersey, New York State, Ohio and Virginia);
2. type of organization (private sector financial, insurance, sales and marketing companies, and some State government offices performing intensive office work);
3. ventilation system design (either constant or variable-air volume system with air recirculation);
4. building size (multi-storey office building with more than 200 workers);
5. office layout (large open-plan office areas);
6. non-smoking office areas.

The building sample was selected by contacting regional chapters of the International Facilities Management Association (IFMA) in the eastern USA with a request for buildings that satisfied the above criteria. Facility managers provided information on the ventilation system design and in many of the buildings the systems were visually inspected immediately prior to the environmental survey. A detailed engineering examination of the ventilation systems was not undertaken. Buildings were studied in the period from January to June, and the total sample was completed over a five-year period. Buildings were not selected because of known complaints, indeed few facilities managers were aware of any widespread problems with their buildings. Results for the sample represent the spread of complaints in non-smoking air-conditioned office buildings.

Survey method

In each building a physical survey of indoor environmental conditions was performed, along with a questionnaire survey of occupants.

Environmental survey

In each building, indoor environmental conditions were measured at several sample sites in the main open office areas. Typically, two sites were surveyed in a morning and two different sites in an afternoon on each of two consecutive days, giving a total of 8 sites per building. Depending on the size of the floorplan, a maximum of 4 sites could represent one floor. Measures for carbon monoxide, carbon dioxide, formaldehyde[1], respirable suspended particulates, air temperature, relative humidity, and illuminance were taken. The instruments used to collect the ambient environmental data are summarized in Table 1. Details of the indoor air quality sampling methods using these instruments follow standard procedures and have been described previously (Hedge *et al.*, 1994).

Survey questionnaire

A self-report questionnaire was distributed in each building. This questionnaire gathered data on employee perceptions of ambient environmental conditions. All questionnaires contained a core set of 7 questions on indoor environmental conditions and 7 questions on SBS symptoms. These core questions were those that constituted independent factors from factor analysis of a larger questionnaire data set (Hedge *et al.*, 1995, 1996). Additional indoor climate and symptom questions were asked in a subset of 13 buildings. Answers to the indoor environmental and the SBS symptoms questions were made for the past month in each building using the same frequency scale (never; 1–3 times/month; 1–3 times/week; almost every day or every day). For each SBS symptom the respondent was also asked whether or not this was alleviated at times away from work (e.g. evenings, weekends). Other questionnaire items included occupational and personal information (sex, age, smoking status, allergy). The core survey questions are shown in Tables 2 and 4, and the ancillary questions in Tables 3 and 5. Based on the results of this survey a modified short-form of the questionnaire[2] has been developed (Fig. 1).

Occupant survey

In each building, indoor air quality measures were taken in different areas, to a maximum of 8 areas per building. In each area approximately 30 questionnaires were manually distributed to employees. In each building approximately 235 questionnaires were distributed and around 170 were returned. Overall, 6250 questionnaires were returned (average 72% return rate). Most questionnaires were collected on the day of distribution. A pre-addressed envelope was provided for any employee who could not complete the questionnaire in time for collection. Less than 1% of employees who were approached at work refused outright to participate in the survey.

Data analysis

Statistical analyses were performed using software packages SAS (v.5.18), and SPSS (v.7.5). Missing values for individual environmental conditions and symptom

Table 1. Environmental conditions measurement apparatus

Environmental variable	Measurement apparatus
Air temperature	Digital thermometer
Relative humidity	Digital hygrometer
Illuminance	Digital light meter
Carbon monoxide	Portable electrochemical meter
Carbon dioxide	Portable electrochemical meter
Formaldehyde	Sorbent tube (2,4 dinitro-phenylhydrazine reagent) + air sample pump (15 buildings), Portable electrochemical meter (26 buildings)
Respirable particulates by weight	Portable piezobalance (3.5 μm cutoff)
Respirable particulates by count	Laser particle counter with 4 size fractions (0.3 μm, 0.5 μm, 1.0 μm, 5.0 μm)

[1]In most buildings the airborne formaldehyde concentration was measured using a portable electrochemical meter. In some buildings a sorbent tube (2,4 dinitrophenylhydrazine reagent) and air pump apparatus was used to obtain a time-weighted average air concentration for the sampling period. In some buildings both apparatus were used. Data from these buildings confirm a statistically significant correlation between results from these two methods ($r = 0.649$, $n = 23$, $p < 0.001$).

[2]The short and long forms of the actual survey questionnaires that were used are more detailed than the modified short-form questionnaire presented. Copies of the original survey questionnaires to be used for research purposes are available from the first author.

Building ID# ☐☐   Floor # ☐☐   Department/Area # ☐☐   Case ID# ☐☐

Please anwer the following questions about environment comfort conditions and health symptoms that you may have experienced in the office during the past month (4 weeks).

1. What is your gender? Woman ☐ Man ☐

2. Please indicate whether you have experienced each of the following environment conditions in the office during the past month:

		Condition experienced at least once per week during the past month (4 weeks).	
		YES	NO
a.	Air temperature too cold	☐	☐
b.	Air temperature too warm	☐	☐
c.	Too little air movement	☐	☐
d.	Air too dry	☐	☐
e.	Unpleasant odour in air	☐	☐
f.	Air too stale	☐	☐
g.	Air too dusty	☐	☐

3. Please indicate whether you have experienced any of the following symptoms on at least a weekly basis during the past month (4 weeks), and whether this symptom got better when you were away from the office (e.g. evenings, weekends):

		Symptom experienced at least once per week during the past month (4 weeks) and symptom got better when away from work.	
		YES	NO
a.	Irritated, sore eyes	☐	☐
b.	Sore, irritated throat	☐	☐
c.	Hoarseness	☐	☐
d.	Stuffy, congested nose	☐	☐
e.	Excessive mental fatigue	☐	☐
f.	Headache across forehead	☐	☐
g.	Unusual tiredness, lethargy	☐	☐

Figure 1 Cornell Office Environment Survey questionnaire (short form).

questions ranged from 3–7% and for analysis these were recoded to 'never'. Only the frequency response for items experienced at least weekly (1–3 times/week + almost every day or every day) were included in the database. All results were calculated separately for men and women in the buildings. If a building sample included less than 15% of either gender then that gender was omitted from the subsequent analyses. Frequency of responses to each individual question was calculated for each building and the affirmative responses to each individual question were used. The percentages of responses indicated at least a weekly incidence[3] of either an environmental or work-related complaint. For each SBS symptom, occupants were asked if this improved when away from the building (e.g. evenings, weekends). A symptom was defined as work-related only if it was reported that this symptom improved when away from the building. The prevalence of each SBS symptom was calculated for each building. We reasoned that an environmental condition or a symptom was problematic and most likely related to the building operation if it was experienced at least once a week inside the building. These percentages were then used to calculate quartiles[4] for the whole sample of buildings. The quartile data were calculated separately for men and

[3]Although data were collected for reports over a one-month period, a weekly incidence criterion was applied to denote persistent problems. Data for the responses '1–3 times per week' and 'Every or almost every day' were aggregated to calculate the weekly percentages.
[4]Quartiles are the percentiles that group data into 4 ranges, 0–25%, 26–50%, 51–75%, and 76–100%. The 25th, 50th and 75th percentiles summarize the bounds of the quartiles.

women because previous research has shown significant gender differences in reports of environmental conditions and SBS symptoms in offices (Hedge et al., 1989, 1995, 1996). For the indoor environmental data the numerical means were used to calculate quartiles. Quartiles were computed separately for each item, not for each building. Thus, a building that might have performed at the first quartile for one item might have performed at the fourth quartile for another.

Interpretation of quartile results

The results are expressed in quartiles so that a facility manager can easily check her/his own survey results against the data tables and determine how her/his facility is performing on a particular item. The tabulated results show the 25th, 50th and 75th percentiles for each item. These percentiles are the cut points that separate the first quartile (lowest 25% of buildings), the second quartile (25–50% of buildings), the third quartile (50–75% of buildings), or the fourth quartile (highest 25% of buildings). For the survey results, the quantities given in the percentile column are the percentage of respondents of a given gender stating that they experience the given problem at least once per week. For all items apart from illuminance, a first quartile score indicates the best building performance for that item and a fourth quartile score indicates the worst performance for that item. For illuminance, the higher the quartile the higher the ambient light level which may or may not be desirable depending on the type of work being undertaken in the building. The tables allow the manager to benchmark her/his facility for any question by determining whether the results for her/his building fall into the first, second, third or fourth quartile of comparable buildings.[5]

Results

Table 2 summarizes the quartiles for the physical environmental conditions measured in these non-smoking, air-conditioned offices. Results generally show very low levels of pollutants in these offices. The office environmental conditions in these buildings were, on average, well within levels for acceptable indoor air quality given in the appendices of the ASHRAE 62-1989 standard (ASHRAE, 1989). According to the ASHRAE standard, the ventilation systems in these buildings should be performing adequately.

The quartiles for the occupant survey sample profile are shown in Table 3. Results show that proportionally more women office workers than men were smokers, and that women worked slightly longer on computers each day. Proportionally more women also reported other general health symptoms, especially migraine and 'other allergies'.

Table 4 shows the quartiles for the perceived indoor climate questions. Previous research has shown that these questions comprise a perceived indoor air quality scale (Hedge *et al.*, 1995, 1996). Results show that the greatest complaints among all workers are that conditions are too warm and that there is a lack of air movement. Odour complaints are relatively scarce among men but more commonplace among women, although

Table 2. Quartiles for the physical environmental conditions in the office buildings

Environmental measurements	Number of buildings	Percentiles		
		25th	50th	75th
CO (ppm)	35	0.5	0.6	0.7
CO_2 (ppm)	35	549	581	638
RSP ($\mu g/m^3$)	35	12.0	16.0	22.0
Temperature (°C)	35	22.6	23.2	23.8
Relative Humidity (%)	35	29.0	38.0	42.3
Illuminance (lux)	35	352	439	526
Formaldehyde (ppm)	15	0.004	0.007	0.014
Formaldehyde metered (ppm)	26	0.011	0.015	0.019
Particle count (#/ft^3)				
0.3 μm	26	20 896	48 615	82 114
0.5 μm	26	10 780	24 553	39 702
1.0 μm	26	2 910	5 990	7 940
5.0 μm	26	149	192	275

[5] If data can be shared, the authors request the percentage data from anyone conducting a survey using the same measures so that an updated database of building performance can be maintained.

Table 3. Quartiles for profile of the occupant sample in the office buildings

	Number of buildings	Number of men	Percentiles 25th	50th	75th	Number of buildings	Number of women	Percentiles 25th	50th	75th
Sample profile										
Current smokers	31	2629	7.1	9.6	15.9	34	3621	14.3	19.6	23.7
Hours per day on computer	31	2629	4.0	4.7	5.2	34	3621	5.0	5.5	5.9
General health										
Migraine	27	2340	3.3	5.1	6.3	30	3118	13.2	16.5	19.7
Asthma	27	2340	1.3	3.2	5.3	30	3118	3.1	4.8	6.8
Eczema	27	2340	0.0	1.6	2.6	30	3118	3.2	4.7	7.0
Hayfever	27	2340	15.0	18.2	22.8	30	3118	15.5	18.1	19.7
Other allergies	27	2340	15.0	18.2	21.0	30	3118	25.0	28.7	31.0
Backpain	27	2340	7.0	9.1	10.5	30	3118	8.7	12.9	16.3

Table 4. Quartiles for the weekly Perceived Indoor Air Quality conditions in the office buildings related to indoor air quality

Perceived Indoor Air Quality	Number of buildings	Number of men	Percentiles 25th	50th	75th	Number of buildings	Number of women	Percentiles 25th	50th	75th
Temperature too cold	26	2250	12.2	19.4	26.9	29	3044	42.4	49.7	54.7
Temperature too warm	31	2629	22.1	28.7	49.2	34	3621	27.4	39.9	50.9
Too little air movement	31	2629	23.0	30.3	39.8	34	3621	41.6	54.5	61.8
Air too dry	31	2629	15.3	20.7	29.0	34	3621	35.9	49.2	59.7
Unpleasant odour in air	31	2629	4.0	6.4	8.3	34	3621	9.5	13.5	18.7
'Stale' air	31	2629	16.6	21.3	27.0	34	3621	31.2	44.9	52.1
Dusty air	31	2629	8.9	11.9	14.0	34	3621	22.9	31.0	34.5

odour complaints are still made less frequently than are those for the other climatic conditions that were evaluated. Interestingly, the frequency of complaints is generally higher than the 20% limit suggested by ASHRAE (ASHRAE, 1989), even though physical measurements of climatic conditions show that these should be acceptable.

Additional questions on indoor environmental conditions were asked in a subset of the buildings and results are summarized in Table 5. Results show that the most common of these complaints are insufficient ventilation, distracting noise and glare, which are reported by more women than men.

The quartiles for weekly work-related SBS symptoms are shown in Table 6. Results show that in average buildings (i.e. those with a percentage of weekly SBS symptom reports at the 50th percentile) symptom reports for men fall well below a 20% level, whereas those for women do not.

Table 7 shows the quartiles for other weekly work-related symptoms. These show a relatively high percent-

Table 5. Quartiles for the weekly Perceived Indoor Environment conditions in a subset of 13 office buildings

Perceived Indoor Environment	Number of buildings	Number of men	Percentiles 25th	50th	75th	Number of buildings	Number of women	Percentiles 25th	50th	75th
Insufficient ventilation	12	838	14.3	24.9	42.1	13	1429	34.9	54.0	62.7
Uncomfortable drafts	12	838	3.7	5.6	11.3	13	1429	21.7	30.7	38.8
Air too humid	12	838	0.5	2.8	8.5	13	1429	3.9	7.1	14.5
Distracting ambient noise	12	838	27.3	31.1	33.4	13	1429	25.0	35.5	42.1
Lighting too dim	12	838	5.2	12.0	18.0	13	1429	14.9	20.7	25.8
Glare problems from lighting	12	838	19.1	22.7	28.4	13	1429	30.7	33.3	38.9
Static electricity shocks	12	838	6.1	7.9	13.8	13	1429	10.3	14.5	23.1

Table 6. Quartiles for the weekly work-related SBS symptoms in the office buildings

Work-related SBS symptoms	Number of buildings	Number of men	Percentiles			Number of buildings	Number of women	Percentiles		
			25th	50th	75th			25th	50th	75th
Irritated, sore eyes	31	2629	12.9	15.3	20.8	34	3621	24.4	30.5	34.7
Sore, irritated throat	31	2629	2.7	5.1	8.3	34	3621	9.1	13.0	16.3
Hoarseness	31	2629	2.5	3.5	5.3	34	3621	6.6	8.7	11.6
Stuffy, congested nose	31	2629	10.2	11.1	15.3	34	3621	18.9	26.9	32.4
Excessive mental fatigue	31	2629	13.3	16.7	23.7	34	3621	21.9	27.1	30.3
Headache across forehead	31	2629	7.1	8.3	14.5	34	3621	18.9	24.8	29.6
Unusual tiredness, lethargy	29	2416	9.4	12.7	14.8	32	3296	14.6	20.0	27.2

Table 7. Quartiles for the weekly work-related office health symptoms in a subset of 13 office buildings

Work-related office health	Number of buildings	Number of men	Percentiles			Number of buildings	Number of women	Percentiles		
			25th	50th	75th			25th	50th	75th
Dry eyes	12	838	12.1	17.9	26.5	13	1429	30.0	36.8	39.0
Tired, strained eyes	12	838	25.4	32.3	36.4	13	1429	41.2	45.2	48.7
Dry skin	12	838	4.4	8.9	10.6	13	1429	14.8	16.3	18.0
Runny nose	12	838	3.4	4.4	5.7	13	1429	8.1	10.3	16.0
Nervousness, irritability	12	838	8.5	10.9	15.8	13	1429	16.8	19.1	21.0
Wheezing, chest tightness	12	838	0.0	0.6	1.5	13	1429	3.0	3.9	5.8
Nausea	12	838	0.0	0.0	1.5	13	1429	1.0	1.4	2.3
Dizziness	12	838	0.0	0.0	1.0	13	1429	1.5	3.7	4.0
Skin irritation, rashes	12	838	0.0	0.3	2.3	13	1429	1.0	2.3	4.0

age of complaints about eyestrain compared with other symptoms, and again more women report symptoms.

Discussion

Results from the survey of 35 non-smoking, air-conditioned offices provide a normative database against which the performance of non-smoking offices ventilated by either a constant air volume (CAV) or variable air volume (VAV) air-conditioning can be benchmarked. Results are presented as quartiles (the 25th, 50th and 75th percentiles), and survey data are separated for men and women, to allow easy comparison with any future survey data.

If a facility manager uses the sample questionnaire shown in Fig. 1, or their own questionnaire containing the same survey questions and follows a comparable study protocol, a direct comparison can be made with the data presented here. Survey results for a building will show the percentages of weekly environmental complaints and of weekly work-related SBS symptoms. If results for any item fall below the 25th percentile that building is ranked in the top 25% of buildings surveyed to date. If they fall above the 75th percentile that building is ranked in the bottom 25% of buildings surveyed to date, and the facility manager may need to undertake further investigation and implement remedial measures as appropriate. If results fall between the 25th and 75th percentiles that building is performing in a mid-range for US air-conditioned office buildings. This method allows the facility manager to benchmark the performance of her/his facility. Becker (1990) describes the benefits of operational benchmarking for tracking various facilities factors such as cost, response time and employee reactions. He suggests an annual employee survey is required to maintain a good database of facilities performance based on employee attitudes. The short-form 'Cornell Office Environment' questionnaire presented here is a modification of our questionnaire that has been designed for easy use, either as a stand-alone survey questionnaire or as part of an annual employee survey. Results from this survey questionnaire can be used to provide both **intrinsic** and **extrinsic** benchmarking measures. **Intrinsic** benchmarking provides an organization with a performance measure over time, for example, over time a database of annual survey results will let a facility manager plot trends for views on ambient environmental conditions and SBS reports. Trends can be used to determine whether conditions are improving or deteriorating in a facility. **Intrinsic** benchmarking also allows an organization to compare the performance of various areas within a facility, for example, different floors of a facility or different zones served by different HVAC systems. **Intrinsic** benchmarking can be used to compare performance between different facilities occupied by the same organization. **Extrinsic** benchmarking provides an organization with a performance measure of their facility compared with other facilities of similar design. Thus, if an organization administers the survey questionnaire presented here they can compare the results for their facility to those for other facilities nationwide and even worldwide as the comparison database grows. Both intrinsic and extrinsic benchmarking information can have economic value. For example, rental property developers could use trend data to lure prospective tenants.

The facilities performance data presented in this paper are restricted to a sample of eastern US, multi-storey, open-plan office buildings ventilated by either CAV or VAV systems. In the future we hope to expand this database to include other types of building with different ventilation systems and in different countries, to allow for worldwide comparison in facilities performance from a comfort and health standpoint. For this reason we are encouraging others to share their survey data with us so that we can maintain an up-to-date database for benchmarking.

Administering the 'Cornell Office Environment' survey will allow the facility manager to gauge the prevalence of comfort and health concerns within her/his facility, and the performance of the facility relative to others. Of course, even in the best of buildings some occupants will experience some comfort and health problems occasionally. Regardless of the overall performance of the facility, the facility manager should continue to respond to individual concerns about environmental conditions or health symptoms whenever they arise. However, the ability to benchmark the performance of a whole building allows a facility manager to know how well, overall, that building compares with counterparts. The availability of extrinsic benchmark data helps eliminate confusion about whether or not an office building is atypical of its genre, and whether the level of concern is sufficiently high to merit the description as a 'nonproblem' or 'problem' building.

Acknowledgement

This research was supported by grants from the Center for Indoor Air Research, Linthicum, MD, USA.

References

ASHRAE (1989) *Ventilation for Acceptable Indoor Air Quality 62-1989.* Atlanta, Georgia, American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc.

Becker, F. (1990) *The Total Workplace: Facilities management and the elastic organization.* New York, Van Nostrand Reinhold.

Hedge, A., Burge, P.S., Wilson, A.S. and Harris-Bass, J. (1989) Work-related illness in office workers: a proposed model of the sick building syndrome. *Environment International*, **15**, 143–58.

Hedge, A., Erickson, W.A. and Rubin, G. (1992) Effects of personal and occupational factors on sick building syndrome reports in air conditioned offices, in Quick, J.C., Murphy, L.R. and Hurrell, Jr., J.J. (eds) *Work and Well-being: Assessments and interventions for occupational mental health.* Washington, D.C., APA, pp. 286–98.

Hedge, A., Erickson, W.A. and Rubin, G. (1994) The effects of alternative smoking policies on indoor air quality in 27 office buildings. *Annals of Occupational Hygiene*, **38**, 265–78.

Hedge, A., Erickson, W.A. and Rubin, G. (1995) Psychosocial correlates of sick building syndrome, *Indoor Air*, **5**, 10–21.

Hedge, A., Erickson, W.A. and Rubin, G. (1996) Predicting sick building syndrome at the individual and aggregate levels, *Environment International*, **22**(1), 3–19.

Mendell, M.J. (1993) Non-specific symptoms in office workers: a review and summary of the epidemiologic literature, *Indoor Air*, **3**, 227–36.

Menzies, R., Pasztor, J., Leduc, J. and Nunes, F. (1994) The 'sick building' – a misleading term that should be abandoned in *IAQ94: Engineering indoor environments.* Atlanta, ASHRAE, pp. 37–48.

Mølhave, L. (1989) The sick buildings and other buildings with indoor climate problems, *Environment International*, **15**, 65–74.

Pennebaker, J.W. (1982) *The Psychology of Physical Symptoms.* New York, Springer-Verlag.

WHO (1983) *Indoor Air Pollutants: Exposure and health effects.* EURO Reports and Studies 78, World Health Organization.

Note:

Results from this study were reported to a 1996 National Research Council colloquium on building performance.