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PHASE 1 OF THE CALIFORNIA HEALTHY BUILDING STUDY: A SUMMARY

William J. Fisk[1], Mark J. Mendell[1,2,*], Joan M. Daisey[1], David Faulkner[1], Alfred T. Hodgson[1], Matty Nematollahi[1], and Janet M. Macher[3]

[1]Indoor Environment Program, Lawrence Berkeley Laboratory
Building 90, Room 3058, Berkeley, California 94720

[2]Health Investigation Branch, California Department of Health Services
5900 Hollis St., Emeryville, California 94608

[3]Indoor Air Quality Program, Air and Industrial Hygiene Laboratory
California Department of Health Services
2151 Berkeley Way, Berkeley, California 94720

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[*]Present address is Industrywide Studies Branch, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, R-16, Cincinnati, Ohio, 45226.

ABSTRACT

Twelve public office buildings were selected for a study of relationships between worker's health symptoms and a number of building, workspace, job, and personal factors. Three buildings were naturally ventilated, three were mechanically ventilated, and six were air conditioned. Information on the prevalences of work-related symptoms, demographics, and job and personal factors were determined via a questionnaire completed by 880 occupants. Several indoor environmental parameters were measured. Logistic regression models were used to evaluate associations between symptom prevalences and features of the buildings, indoor environments, jobs, and personal factors. A substantial fraction of the occupants in these typical office buildings reported frequent work-related symptoms. The occupants of the mechanically ventilated and air conditioned buildings had significantly more symptoms than occupants of the naturally ventilated buildings after adjustment for confounding factors. Increased prevalences of some symptoms were associated with several job and workspace factors including: presence of carpet, increased use of carbonless copy paper and photocopiers, space sharing, and distance from a window.

Key Words: air conditioning, cross sectional study, health, indoor air quality, office buildings, sick building syndrome

INTRODUCTION

In surveys of office buildings selected without regard to worker complaints, European researchers have determined that many of the occupants report frequent work-related health symptoms. The symptoms, which include irritation of the eyes, nose, or throat, headache, fatigue, dry or itchy skin, and difficulty breathing or chest tightness, have many potential causes and do not generally indicate a specific disease or pollutant exposure. The same symptoms are associated with sick-building syndrome (SBS). Although not precisely defined, SBS is evident in a building when symptoms are unusually severe, frequent, or widespread. It is not known if sick buildings represent the high-symptom tail of the distribution of normal buildings or if unique factors in sick buildings are responsible for the increased health effects.

Prior surveys have consistently shown that occupants of air conditioned buildings report more symptoms than occupants of naturally-ventilated buildings (see: Hedge et al. 1989, Skov et al. 1990, Harrison et al. 1992, Zweers et al. 1992, and the reanalysis by Mendell and Smith 1990). In the U.S., no comparable survey of buildings with different ventilation types had been reported.

STUDY DESCRIPTION

Between June and September of 1990, we conducted Phase 1 of this cross-sectional study, called the California Healthy Building Study (CHBS), in twelve office buildings located in the San Francisco area. The primary research objectives were to obtain background data on health symptom prevalences and indoor air quality and to test several hypotheses about associations between health symptoms and features of the buildings, indoor environments, and jobs. The overall approach was: (1) to obtain symptom prevalences, demographic information, and job and workspace characteristics via a questionnaire; (2) to characterize the buildings through inspections and interviews; (3) to measure indoor pollutant concentrations, temperature and humidity; and (4) to use statistical models to assess relationships between symptom prevalences and factors considered likely to influence these symptoms.

Buildings were selected from a list of all city- or county-owned buildings in a defined geographic region. Eligible buildings had more than 45 full-time workers and one of three specific ventilation types: natural ventilation via openable windows, mechanical supply and exhaust ventilation with openable windows and no air conditioning (henceforth "mechanical ventilation"), and mechanical supply and exhaust ventilation with sealed windows and air conditioning ("air conditioning"). We selected all eligible buildings to which access was granted (Mendell 1991, Mendell et al. 1993), yielding three naturally ventilated buildings, three mechanically ventilated buildings, and six air conditioned buildings. Data are not available to determine the degree to which these buildings are representative of a larger population of buildings in the San Francisco area.

One of the air-conditioned buildings in the study has a long history of occupant health complaints and associated (unsuccessful) investigations and would normally be described as a "sick" building. In some buildings, smoking was permitted in designated, enclosed smoking rooms from which air was not mechanically circulated to other rooms, otherwise, smoking was prohibited.

Within each building, only the workers from a selected study space, or study spaces, were included in the study. Large open study spaces with at least 45 workers were selected when possible, along with the adjoining enclosed offices. When necessary, several smaller spaces, with a total occupancy of at least 45, were studied. Questionnaire data were collected from 29 study spaces.

We used a shortened version of a self-administered questionnaire from a study of several U.S. government buildings in Washington, DC (NIOSH 1990, Nelson et al. 1991). The questionnaire has been evaluated as described by NIOSH (1990). The modified version is included in Daisey et al. (1990). Occupants were asked about the frequency of 15 health symptoms at work during the previous week and previous year and also asked if symptoms changed when they were not at work. Other questions assessed health, demographic, psycho-social, and work-related parameters. Eighty five percent of the eligible workers completed the questionnaire, yielding 880 completed questionnaires.

Relevant characteristics of the buildings and study spaces were determined through inspections and interviews. This information included the type of ventilation, operability of windows, building age and size, type of floor surfaces, and presence of fabric-covered partitions.

Indoor environmental parameters were measured at one to three locations in 26 of the study spaces. Limited quantities of instrumentation prevented measurements in 3 spaces. Measurements were completed during all or part of the work week preceding administration of the questionnaire; consequently, symptom data and environmental measurements were available for the same time period. Air temperature and relative humidity were measured every 15 seconds and 15-minute averages were logged. Work-week-average carbon dioxide and carbon monoxide concentrations were determined by pumping air samples at constant rates into sample bags during the 45-hour work week and subsequently analyzing the concentrations in the bags. Air samples were also drawn through multi-sorbent sample tubes for approximately an eight-hour period on a single work day. These samples were analyzed using a flame-ionization detector to determine the TVOC concentration (in μg carbon/m^3) and via gas chromatography-mass spectrometry to determine the concentrations of specific volatile organic compounds (VOCs). Total airborne concentrations of viable fungi and bacteria were also measured using a single stage impactor (Surface Air Sampler with a 50% cut point of 2 μm). Fungi were collected on malt extract agar and incubated at 25 ^{o}C. Bacteria were collected on soybean-casein digest agar and incubated a 35 ^{o}C. The sampling for fungi and bacteria was performed twice at each measurement location during a single work day; however, the sampling period was only a few minutes. The outdoor air at the site of each building was characterized using the same measurement techniques, except outdoor temperature and humidity were not measured. Additional information on the measurement procedures is provided by Daisey et al. (1990).

Two approaches were used to evaluate the temperature and humidity data. First, the number of hours during the work week with temperatures and humidities outside of the bounds of the summer thermal comfort zone defined by ASHRAE (1989a) were computed. Second, the measured temperatures and humidities and an assumed typical air velocity of 0.137 m/s were entered into a comfort model (Fobelets and Gagge 1988) to obtain the Predicted Percentage Dissatisfied (PPD) with the thermal environment.

Because of the large variation in the sensory irritancy and neurotoxicity of different VOCs, we did not expect TVOC concentrations to correlate with symptom prevalence. To obtain a parameter more likely to correlate with symptoms, we computed values of an irritancy index (Daisey et al. 1990) based on the concentrations of individual VOCs and estimates of the relative irritancy of each VOC.

Two definitions of work-related symptoms were used in the analyses. For comparisons of symptom prevalence to permanent parameters, e.g., ventilation type, a work-related symptom was defined as one that occurred often or always last year and improved when the respondent was away from work. For comparison of symptoms to the measured environmental parameters, a work-related symptom was one that occurred on three or more days last week and improved when the respondent was away from work. Six groups of related symptoms were defined from the symptoms considered likely to be related to the indoor air quality or to factors that may affect indoor air quality (see Table 4). Reporting of at least one work-related symptom in a group constituted a positive response.

Associations between work-related symptom groups and various factors were determined using SAS and BMDP software (SAS 1989, BMDP 1990). Odds ratios (ORs) and 95% confidence intervals for independent variables were calculated, both crude and adjusted for potential confounders, in unconditional multiple logistic regression models. For ventilation type, natural ventilation was the reference category. For environmental measurements, the measured parameters were categorized in quartiles and the lowest quartiles were used as reference categories. A model was constructed for each symptom group using a modified reverse stepwise algorithm. Final models contained all terms for ventilation type, job type, and personal and psychosocial factors (gender, age, race, education, smoking, working in a known "sick" building, job stress, job dissatisfaction). Any other job and workspace variables that contributed significantly ($p < 0.05$) to the model were also included (initial variables were: hours per week in building, use of carbonless copy paper, use of photocopiers, use of computers, sharing of workspace, cloth partitions, carpets, new carpets, new walls, new paint, distance from a window, ability to see out a window, and amount of natural light). The data analysis procedures are described in greater detail elsewhere (Mendell 1991, Mendell et al. 1993). Each environmental parameter, categorized in quartiles, was then added individually to the reduced models. None was retained because no variable contributed significantly at $p < 0.05$.

RESULTS

Buildings and Study Population

Descriptive information for the buildings is provided in Table 1. The air conditioned buildings tended to be newer than other buildings and the naturally ventilated buildings tended to be smaller than other buildings. Demographic information for the study population is provided in Table 2. Approximately 70% of the respondents were female. Approximately 40% of the respondents were clerical workers.

Environmental Measurements

Table 3 provides the means and standard deviations of selected measured environmental parameters for study spaces grouped by type of ventilation. The low p values for most parameters indicate that there were statistically significant, but not necessarily important (with respect to health), differences in some pollutant concentrations and thermal comfort conditions between spaces with different ventilation types.

The mean TVOC concentration in the air conditioned spaces was approximately three times as high as the means in naturally ventilated and mechanically ventilated spaces. This difference was not due to any factor inherently related to ventilation type but was a consequence of the emission of VOCs by wet-process photocopiers in only three of the air conditioned spaces (see Figure 1). The VOCs emitted by these photocopiers were not expected to be strong irritants, thus, the VOC irritancy index was only moderately higher in the air conditioned spaces. Daisey et al. (1993) provide a detailed analysis of the concentrations of individual VOCs.

Total viable fungi concentrations were much lower in the air conditioned spaces. We suspect that the lower concentrations were a consequence of reduced entry of outdoor fungi into the air conditioned spaces which is explained by the sealed windows and filtered supply air. The lower ratio of indoor-to-outdoor fungi in the air conditioned spaces is consistent with this explanation.

The number of hours during the work week with an air temperature above 26 ^oC (the approximate upper limit of ASHRAE's comfort zone) was also much lower in the air conditioned spaces. This is a consequence of the cooling of the indoor air in the air conditioned spaces. However, the predicted work-week-average percentage of occupants dissatisfied with thermal conditions was only a couple of percent smaller in the air conditioned spaces. Average values of relative humidity for the work week ranged from 33% to 58%. Within this relatively narrow range, relative humidity is expected to have a small impact on thermal comfort.

Concentrations of carbon monoxide, measured primarily as an indicator of vehicle exhaust, were low (below 2 ppm) in all buildings.

In some cases, the measured indoor environmental parameters varied substantially between locations within the same building. As examples of the variation, Figure 1 illustrates the difference between indoor and outdoor carbon dioxide concentration, TVOC concentration, and work-week-average temperature at each indoor measurement location.

Health Symptom Prevalences and Adjusted Odds Ratios

The prevalences of symptoms in each building are provided in Table 4. These prevalences are based on symptoms that occurred often or always last year and improved when the respondent was away from work. For the entire study population, the prevalence of eye, nose, or throat irritation, was the highest (40.3%) and the prevalence of chills or fever was the lowest (4.5%). For three symptom groups, the prevalence was approximately 20% or greater. Symptom prevalences varied substantially between buildings. The prevalences of most symptoms were highest in the "sick" building, but this building was not dramatically different from others in terms of symptom prevalences.

Table 5 contains selected values of adjusted ORs, with 95% confidence intervals, for the prevalences of work-related symptoms. For all symptoms except headache, the ORs for both mechanical ventilation and air conditioning (relative to natural ventilation) were above unity. A reanalysis which excluded data from the "sick" air conditioned building, rather than including a term for sick-building history in the statistical model, yielded similar ORs.

Job or workspace factors that were associated with increased prevalences of one or more symptom groups included use of carbonless copy paper or photocopy machines greater than one hour per day, sharing of the workspace with two or more other workers, the presence of any carpet in the test space, and the absence of a window within 5m of the work location. The use of computers was not significantly associated with symptom prevalences.

None of the environmental parameters, in the form used, added significantly to the regression models (at $p < 0.05$). Additional analyses, suggested by the results of other studies, are underway.

Calculation of adjusted odds ratios using alternative definitions for work-related symptoms did not change the general pattern of results.

DISCUSSION

Environmental Data

Work-week average CO_2 concentrations in this study ranged from 370 to 580 ppm. The maximum concentrations reported from previous multi-building surveys tend to be moderately higher, possibly because the other surveys have integrated over a shorter time period. In a survey of 39 commercial buildings in the Pacific Northwest of the U.S. (Turk et al. 1987), work-day mean concentrations ranged from approximately 325 to 825 ppm. In a study of three U.S. buildings by Hodgson et al. (1991), concentrations (basically instantaneous measurements) ranged from 370 to 840 ppm. Some examples of the reported ranges of CO_2 concentrations from multi-building surveys within other countries are: 500 to 1300 ppm (Skov et al. 1987); 400 to 1300 ppm (Skov et al. 1990);and 485 to 1329 ppm (Zweers et al. 1992).

Because measurement methods for TVOC, airborne bacteria, and airborne fungi are not standardized, it is difficult to relate the concentrations measured in this and other studies. In addition, very few measurements of these parameters from "non-sick" office buildings are available in the literature for comparison to our results. Qualitatively, the airborne concentrations of these pollutants appear to be in the normal range. In particular, none of the measured concentrations is considered to be unusually high.

The spatial variability of environmental parameters within some buildings (Figure 1) makes it difficult to accurately characterize the exposures of individual occupants without a large number of measurements. Most multi-building surveys of symptoms and environmental conditions have relied on measurements at relatively few locations to characterize exposures. Inaccurate characterization of individual exposures to pollutants or other environmental conditions reduces the ability to identify associations between symptom prevalences and environmental parameters. Recognizing this fact, Hodgson et al. (1991) have employed monitoring in each individual's work environment to characterize exposures. Although their short term (20 min) measurement period may be inadequate, they did find an association between symptoms and the measured VOC concentrations. Better characterization of personal exposures is suggested as an important element of future studies.

Symptom Prevalences

The prevalences of work-related health symptoms in this set of typical office buildings were substantial. For example, more than 40% of the workers responded that work-related eye, nose, or throat irritation occurred often or always. Because other multi-building surveys have typically used different questionnaires and different definitions for work-related symptoms, we can not rigorously compare our symptom prevalences to those reported from other studies. However, the prevalences of symptoms in this and other studies (e.g. Hedge et al. 1989; Jaakkola et al. 1991; Menzies et al. 1993; Skov et al. 1987, 1989, 1990; Valbjorn and Skov 1987, Zweers et al. 1992) are in the same general range (from several percent to roughly 50 %). These substantial prevalences of work-related symptoms are evidence of a widespread health problem that requires further study.

As indicated in Table 4, symptom prevalences varied markedly between buildings (the ratio of maximum to minimum always exceeded three). Consequently, some factor or factors associated with buildings appears to substantially impact occupant health.

Associations of Symptoms with Building, Job, and Environmental Factors

The association found between increased symptom prevalence and air conditioning is consistent with the results of European surveys (see: Hedge et al. 1989, Skov et al. 1990, Harrison et al. 1992, Zweers et al. 1992, and the reanalysis by Mendell and Smith 1990). In this study, buildings with mechanical supply and exhaust ventilation, openable windows, and no air conditioning were also associated with increased symptom prevalences. This type of building is not commonly associated with SBS or health complaints, thus, this finding requires confirmation in other U.S. studies. Recently, a similar finding was reported by Zweers et al. (1992); however, they did not include operability of windows in the ventilation type criteria.

Since ventilation type cannot be a direct cause of symptoms, these findings suggest that it is a surrogate for other direct causes. Mendell et al. (1993) provide a detailed discussion of the connection found between health symptoms and type of ventilation system. One of several potential explanations for the association between mechanical ventilation, with or without air conditioning, and symptoms is that the mechanical ventilation systems are sources of unmeasured pollutants that directly cause symptoms. As summarized by Fisk et al. (1992), there is substantial evidence that ventilation systems could be sources of bioaerosols, fibers, and VOCs; however, few measurements have been completed to actually characterize the rates of pollutant emissions by ventilation systems. Building ventilation type may also correlate with numerous other factors, such as building age, ventilation rate, or type in interior furnishings, that may affect symptoms. In this study, building age was not a significant variable ($p < 0.05$) in the regression models when other variables (e.g., ventilation type) were included. At this time, we cannot identify the specific factors that are responsible for the associations found between symptoms and ventilation type.

The use of computers was not associated with increased symptoms in this study although use of video display terminals has been associated with symptoms in several other studies (e.g., Hedge et al 1989, Menzies et al. 1992, 1993, Skov et al. 1989, Zweers et al. 1992).

Our finding of an association between symptoms and the use of carbonless copy paper replicates the previous findings by Skov et al. (1987, 1989). Users of carbonless copy paper may potentially be exposed to organic chemicals in the paper that cause symptoms. These chemicals may be the ink, solvents used as a carrier for the ink, polymers used to encapsulate the solvent, desensitizing ink used on some papers, or paper coatings. The exposure route could be inhalation of vaporized compounds. or physical contact with the paper.

The association between symptoms and carpets is consistent with previous findings of associations of symptoms with either carpets; total surface area of fleecy materials; weight of floor dust; and the concentration of macromolecular organic dust of biologic origin on floors and carpets (e.g., Valbjorn and Skov 1987, Skov et al. 1990, Norback and Torgen 1989, Gravesen et al. 1990). In theory, carpets could be a source of increased symptoms because they release VOCs or fibers. Carpets could also be a reservoir for microbiological material such as fungal spores and dust mites. The exposure route for loose fibers and microbiological materials may involve episodic resuspension and inhalation or direct contact with the skin and transport via hands to mucus membranes. We suspect that the association between symptoms and carpets in our study is not due to the release of VOCs by carpets. Virtually all of the carpets were greater than one year old (most were many years old) and existing data indicate that the emission rates of VOCs from carpets decline rapidly (Hodgson et al. 1993) and are probably insignificant approximately six months after carpet installation.

Several studies indicate that symptoms increase with temperature (Menzies et al. 1993, Jaakkola et al 1991, Skov et al. 1989, 1990, Wyon 1992). Our measures of thermal discomfort, calculated from measured values of temperature and humidity, were not significant variables ($p < 0.05$) in the regression models. We cannot explain these seemingly conflicting findings.

Implications of This Study

Our findings, in conjunction with those reported previously, indicate that office workers commonly report work-related health symptoms. The associations found between symptoms and features of the buildings, workspaces, and jobs can be the basis for more detailed hypotheses regarding the causes of symptoms. Additional studies, with improved measurements of occupants' exposures to pollutants and environmental conditions, are required to identify the etiologic factors.

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Table 1. Descriptive information for buildings.

Vent. Type	Bldg. Number*	Occupied Floor Area (m^2)	Number of Floors	Year Built	Number of Eligible Workers$	Number of Study Spaces
Natural	1	3440	10	1964#	54	2
Natural	10	2690	3	1895	35	4
Natural	12*	36200*	6	1915	69	1
Mechanical	6	5390	2	1955	44	1
Mechanical	9	2280	4	1954	59	4
Mechanical	11*	36200*	6	1915	99	1
Air Cond.	2**	11100	9	1978	186	2
Air Cond.	3	19100	7	1982	113	3
Air Cond.	4	3760	3	1987	117	4
Air Cond.	5	9010	12	1957	53	3
Air Cond.	7	8590	5	1964	106	2
Air Cond.	8	5950	4	1964	97	2

* Buildings 11 and 12 were isolated spaces of 1300 and 1020 m^2 floor area within a single large building.

\# Date rebuilt, originally constructed in 1912

$ Number in the selected study spaces.

** History as a sick building

TABLE 2. Distribution of individual characteristics within ventilation categories and in total population.

	Ventilation Categories			
Variables	**Natural Ventilation (n=130*) %**	**Mechanical Ventilation (n=170*) %**	**Air Conditioning (n=581*) %**	**Total (n=880*) %**
Gender				
male	35.4	37.7	24.8	28.9
female	64.6	62.3	75.2	71.7
Age in years				
<30	8.0	13.4	10.5	10.7
30-39	24.8	32.3	21.4	24.0
40-49	34.4	30.5	38.4	36.3
50+	32.8	23.8	29.7	29.0
Job category				
managerial	25.6	12.5	18.2	18.2
professional	3.9	34.5	12.1	15.2
case worker	22.5	0	17.0	14.5
technical	4.7	3.0	7.4	6.1
clerical	41.9	47.6	42.8	43.6
other	1.6	2.4	2.5	2.3
Race/ethnicity				
White	37.0	35.5	50.2	45.5
Black	3.9	15.7	19.3	16.3
Asian/Pacific Isl'r	41.7	30.7	17.3	23.5
Hispanic	11.8	14.5	8.6	10.2
other	5.5	3.6	4.6	4.5
Education				
less than bachelor's	41.3	42.8	50.1	47.4
bachelor's degree	36.5	39.2	31.5	33.7
grad./prof. degree	22.2	18.1	18.5	18.9
Smoking status				
never	62.5	50.6	50.4	52.3
former	26.6	30.7	30.6	30.0
current, 1-10 cig./day	3.1	10.2	9.9	9.0
current, 11-20 cig./day	7.8	8.4	9.0	8.7

*Denominator for each variable may vary due to non-response.

Table 3. Space-Average Environmental Parameters as a function of Ventilation Type

Parameter	**Natural Ventilation (6 spaces)+** Mean (s.d.)	**Mechanical Ventilation (4 spaces)+** Mean (s.d.)	**Air Conditioning (15 spaces)+** Mean (s.d.)	**Wilcoxon Rank Sum Test** p Value
CO_2 (ppm)	420 (40)	390 (10)	440 (60)	0.07
ΔCO_2 (ppm)*	81 (35)	48 (12)	110 (72)	0.07
TVOC ($\mu g/m^3$)	340 (140)	380 (100)	1200 (1700)	0.28
VOC Irritancy Index	54 (33)	63 (16)	89 (36)	0.04
Fungi (cfu/m^3)	72 (12)	59 (20)	12 (4.9)	0.01
Indoor-Outdoor Fungi Ratio	0.72 (0.4)	0.62 (0.1)	0.12 (0.08)	0.0003
Bacteria (cfu/m^3)	180 (82)	120 (47)	180 (68)	0.59
Indoor-Outdoor Bacteria Ratio	3.9 (3.1)	2.2 (0.9)	2.2 (1.3)	0.62
Hours Temp > 26 ^oC	4.3 (4.8)	14.5 (10.8)	0.6 (1.32)	0.01
Thermal Discomfort (hrs PPD>10%)	8.1 (2.4)	9.9 (2.5)	7.6 (3.7)	0.04

* difference between indoor and outdoor concentration

+ The number of study spaces in which measurements were successful varied slightly between the different environmental parameters. The number of spaces with CO_2 measurements is provided.

Table 4. Crude prevalences (%) of work-related symptoms in each building. A work-related symptom was defined as a symptom that occurred often or always last year and that improved when the occupant left the building. The numbers in parentheses indicate the prevalence for the entire study population.

	Building Number and Ventilation Type*											
Symptom Group (total prevalence)	1 NV	10 NV	12 NV	6 MV	9 MV	11 MV	2# AC	3 AC	4 AC	5 AC	7 AC	8 AC
eye, nose, throat (40.3)	31.7	34.4	20.0	41.5	26.0	39.7	66.9	34.1	46.9	22.0	38.2	32.5
chest tightness, difficult breathing (7.5)	0	6.3	1.8	7.3	0	10.8	16.6	3.4	10.0	4.0	6.7	4.9
chills or fever (4.5)	0	6.3	0	7.3	0	5.6	5.6	5.8	3.7	0	11.5	2.4
fatigue or sleepiness (33.2)	31.6	18.2	20.0	26.8	17.4	37.8	57.1	22.5	38.9	26.0	36.8	18.3
headache (19.8)	19.2	15.6	10.9	17.1	6.5	23.3	31.0	14.4	26.6	24.0	16.3	13.8
dry or itchy skin (10.8)	2.6	3.2	1.9	7.3	2.0	15.4	22.4	9.0	11.1	2.0	19.1	3.8

* NV = natural ventilation, MV = mechanical ventilation, AC = air conditioned
\# "sick" building history

Table 5. Adjusted Odds Ratios and 95% Confidence Intervals for Selected Risk Factors

	Risk Factor (95% Confidence Interval)						
Work-Related Symptom Group	Mechanical Versus Natural Ventilation	Air Conditioning Versus Natural Ventilation	Carbonless Copy Paper Use (>1 hr/day)	Photocopy Machine Use (>1 hr/day)	Space Sharing (with 2 or more)	Any Carpet in Study Space	No Window Within 5m
Eye, Nose, or Throat	1.7 (0.9-3.0)	1.3 (0.7-2.4)	1.6 (1.0-2.6)	1.6 (0.8-3.1)	1.3 (0.9-1.9)	1.7 (1.1-2.6)	1.6 (1.1-2.3)
Chest Tight or Difficulty Breathing	3.6 (0.9-15)	4.3 (1.1-16)	2.3 (1.1-4.9)	1.7 (0.6-4.7)	2.0 (1.0-3.9)	2.5 (1.0-6.2)	1.6 (0.8-3.2)
Chills or Fever	2.3 (0.4-14)	2.3 (0.5-12)	1.7 (0.7-4.6)	0.4 (0.1-2.1)	1.3 (0.6-2.9)	1.4 (0.5-3.7)	2.4 (1.1-5.6)
Fatigue or Sleepiness	1.9 (1.0-3.6)	2.2 (1.2-3.9)	2.1 (1.3-3.5)	1.4 (0.7-2.8)	1.6 (1.1-2.3)	1.1 (0.7-1.7)	1.5 (1.0-2.5)
Headache	1.0 (0.5-2.2)	0.9 (0.4-1.9)	1.4 (0.8-2.4)	1.5 (0.7-3.1)	1.8 (1.2-2.7)	2.0 (1.1-3.4)	2.1 (1.3-3.3)
Dry or Itchy Skin	5.8 (1.5-22)	5.6 (1.6-20)	0.9 (0.5-1.9)	3.1 (1.4-6.9)	1.6 (0.9-2.8)	0.9 (0.5-1.8)	1.6 (0.9-2.7)

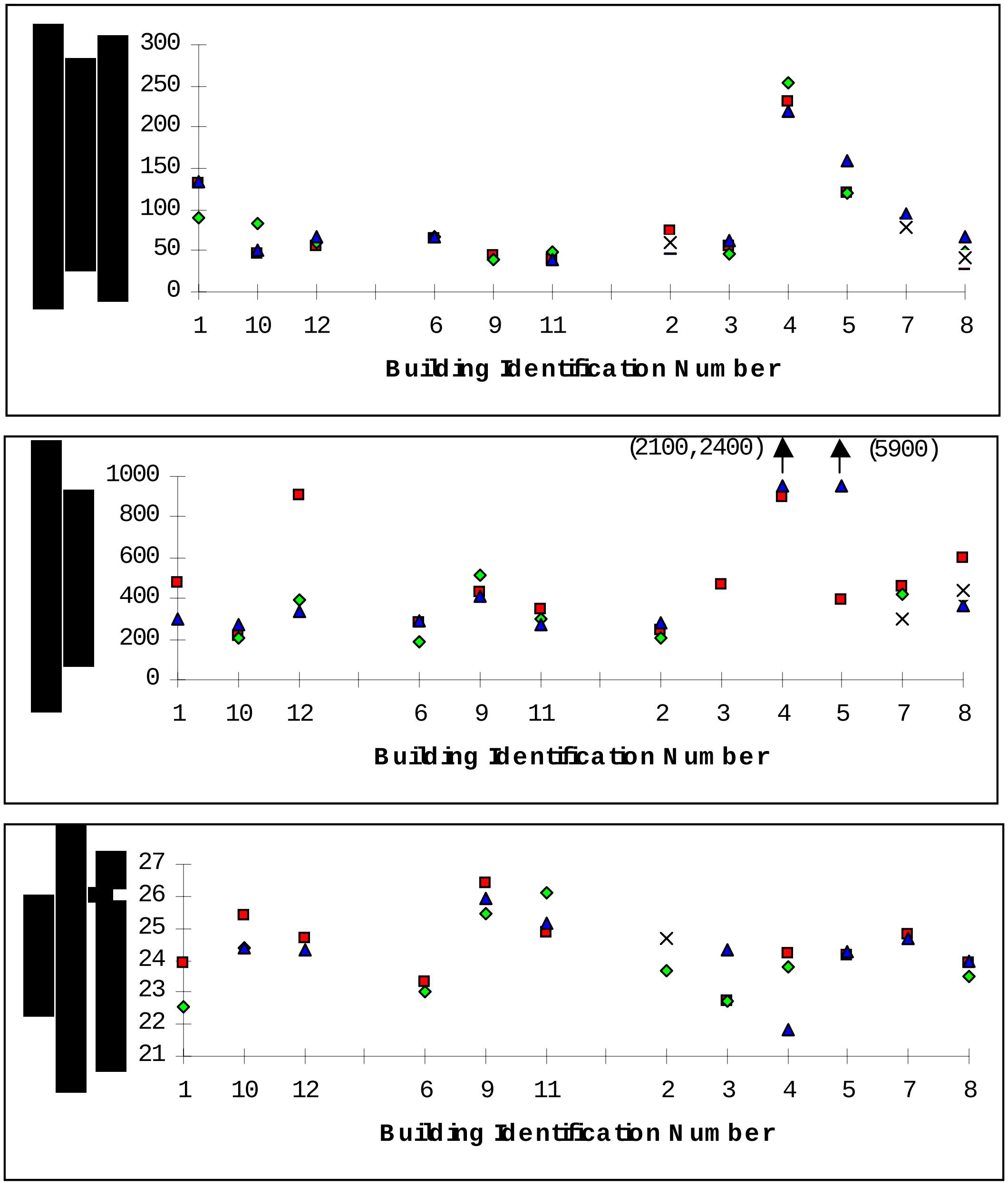

Figure 1. Indoor environmental parameters at each measurement location are plotted to illustrate their spatial variation within buildings. Each style of data point represents a different measurement location.