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Key terms: [epidemiology](#); [general symptom](#); [indoor air quality](#); [mucosal irritation](#); [office work](#)

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Health symptoms and the work environment in four nonproblem United States office buildings

by Nancy A Nelson, PhD, Joel D Kaufman, MD, James Burt, BS, Catherine Karr, MS¹

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Objectives The objective of this study was to quantify health symptom reports in four “nonproblem” buildings and to assess the relationship between symptoms and air quality measures, workstation characteristics, and psychosocial aspects of the workplace.

Methods Environmental sampling was conducted in four office buildings occupied by employees working for the state of Washington in March of 1992. A questionnaire was concurrently administered to building occupants.

Results While measured contaminant levels were low, symptoms were frequent. Fifty-five percent of the 646 respondents reported recent symptoms which affected the eyes, nose, or throat and improved when away from work. Symptoms were not associated with measured contaminant levels, but, rather, with perceptions about air movement, dryness, odors, and noise. Psychosocial factors were less strongly associated with symptoms.

Conclusions Even in nonproblem buildings, symptom reports can be frequent and may represent overall satisfaction with the work environment. In response to symptoms ascribed to air quality problems, it may be appropriate to address employee perceptions regarding the work environment in addition to evaluating environmental characteristics relating to chemicals, biological contamination, air movement, temperature, and humidity.

Key terms epidemiology, general symptoms, indoor air quality, mucosal irritation, office work.

In recent years, studies of the office work environment have increased dramatically in number: the United States (US) National Institute for Occupational Safety and Health (NIOSH) completed over 500 nonindustrial health hazard evaluations in the 1971—1988 period; in 1990, NIOSH received more than 2000 telephone calls requesting health hazard evaluations concerning indoor air quality in office buildings (1, NIOSH, unpublished results). Several investigations examining office workplace characteristics and employee health symptoms have been conducted in buildings in which large numbers of workers have experienced adverse health effects, sometimes termed “problem buildings,” where employees frequently reported respiratory, skin, or central nervous system (CNS) symptoms. In many cases, no single exposure hazard could be identified, but sometimes improvements made to ventilation systems appeared to relate to a reduction in symptoms. A recent study suggested that changes in ventilation rate alone may not lead to a reduction in symptom reporting (at least not when ventilation levels are already adequate) (1, 2). In other studies carried out

in nonproblem buildings in Great Britain and Denmark, similar symptoms have been observed (3).

The current study examines relationships between employee health and measures of indoor air quality, workstation characteristics, and psychosocial factors in a large group of state government employees working in four “nonproblem” buildings without known exposure hazards or high rates of complaints or symptom reporting. The objective was to quantify symptom reports, characterize physical conditions, and identify risk factors that are associated with respiratory, dermal, and CNS symptoms in an environment experienced by employees working in US office buildings.

Subjects and methods

Study group

The target population included 922 employees of the Department of Labor and Industries in the state of Wash-

¹ Department of Labor and Industries, State of Washington, United States.

Reprint requests to: Dr N Nelson, SHARP, Department of Labor and Industries, State of Washington, PO Box 44330, Olympia, Washington 98504—4330, USA.

ington; these employees worked in four buildings, termed A through D in the following report. The agency functions carried out in these buildings included the administration of the state workers' compensation claim system and the workplace inspection plan. Employee job responsibilities included clerical, administrative, and professional support. Approximately 60% of the employees were women; two-thirds were in the 30- to 50-year age range.

Study buildings

Three buildings were located in semiurban areas; building D was an older facility located in a dense urban area. The structures varied in age and size; three had operable windows (table 1). Building D was extensively renovated in 1987, including the addition of a third floor (the study space). Smoking was prohibited inside all four buildings. Workspaces included private offices, shared rooms, and open spaces with or without partitions. The buildings were included in the Indoor Air Building Assessment Survey and Evaluation program of the US Environmental Protection Agency (EPA) and as such had to fulfill selection criteria stating that they were free of obvious water damage, obvious contaminant sources, or physical characteristics that would significantly influence indoor air quality or occupant comfort (4). Because they fulfilled these criteria and because they had not generated sufficient complaints to lead to formal indoor air quality investigations, as suggested by others (3, 5), they were considered to be "nonproblem" buildings.

Questionnaire

Potential study participants were invited to complete a self-administered questionnaire in March of 1992. Participation in the survey was encouraged but voluntary. The study was approved by the State of Washington Department of Social and Health Services Human Subjects Research Review Board.

The questionnaire items included questions regarding respiratory, mucosal, CNS, and dermal symptoms; demographic characteristics; physical and psychosocial attributes of the work environment; job satisfaction; workplace and influence over responsibilities; and nonwork-related stressors. The questionnaire was adapted from a variety of instruments used by other researchers, including the EPA Indoor Environmental Quality Survey, the NIOSH National Center for Health Statistics building and Library of Congress building study questionnaires, and the NIOSH Job Stress Instrument (6–8). The questionnaire responses were anonymous.

The following four groups of symptoms commonly associated with complaints about indoor air quality were selected for analysis according to groupings suggested by other investigators: upper respiratory or mucosal irritation (dry, itching, irritated or watery eyes; sore throat; nasal symptoms or sneezing; tired or strained eyes; dry throat; cough), lower respiratory problems (tight chest; difficulty breathing; shortness of breath; wheeze), CNS symptoms (headache; depression; tiredness; tension or irritability; difficulty remembering; dizziness or lightheadedness; mental fatigue), and dermal problems (skin rash or dry skin) (3). A case was defined as any individual reporting at least one of the symptoms

Table 1. Characteristics of the buildings and participants.

	Building				Total
	A	B	C	D	
Building description					
Year built	1985	1990	1954	1958	.
Number of floors	4	4	5	3	.
Operable windows	Yes	No	Yes	Yes	.
Square footage ^a	32 210	56 000	280 000	69 000	.
Study area					
Floor	Fourth	Third	Third	Third	.
Square footage ^a	7 370	14 000	38 970	23 000	.
Carpeting	Yes	Yes	No	Yes	.
Heating, ventilation and air conditioning system	Variable air volume	Variable air volume	Constant air volume	Constant air volume	.
Study participants					
Number of respondents	142	126	325	53	646
Response (%)	59	57	82	79	70
Mean age (years)	44	43	39	44	42
Gender female (%)	79	65	75	44	71
Current smokers (%)	21	24	22	14	21
Mean employment time in building (years)	4.4	1.6	6.1	5	4.8
Mean length of education (years)	14	14	14	14	14

^a 1 foot=0.3048 meters.

in each group for 1–3 d per week in the previous four weeks (or more) with symptom improvement when away from work.

The other constructed variables included several scales to score psychosocial job characteristics that have been associated with symptoms reported to be related to indoor air in other studies (ie, overall job satisfaction, decision latitude, hard or fast work, or conflicting supervisory instructions) (8–12). A scale for “job stress,” combining scores for the perception of influence over work and having to work hard (according to the job demands-control model) was also constructed (13).

Exposure assessment

Environmental sampling was conducted in the four buildings, concurrent with questionnaire administration. The sampling strategy followed a protocol prepared in cooperation with the EPA (4). For each building, one floor was designated as the sampling zone, and three individual sites were monitored. The sites were considered to be representative of the entire building; additional data were collected from other floors to determine if this assumption was valid. Air samples were also collected outside each building to compare indoor and outdoor contaminant levels.

The sampling methodology has been described in detail elsewhere (4). Each sampling survey was conducted for one day between 0800 and 1700. Each sampling station was equipped to measure total particulates, selected aldehydes and other volatile organic compounds, carbon dioxide, and carbon monoxide. Approximately 60 volatile organic compounds, including aliphatic, aromatic and chlorinated hydrocarbons, ketones, chlorofluorocarbons, and esters, were inventoried. Exposure to such compounds was expressed as the sum of the levels of each compound identified as present in a particular sample. Samples for particulates, volatile organic compounds, and aldehydes were analyzed in an EPA-approved laboratory. Measurements for temperature, relative humidity, noise, and illumination were also recorded.

Viable bacterial and fungal bioaerosols were collected with methods commonly employed in NIOSH investigations of indoor air quality and recommended by the American Conference of Governmental Industrial Hygienists (4). The sampled bacteria included thermophilic (cultured at 55°C) and mesophilic (cultured at 35°C) species. For each sample, the number of colony-forming units per cubic meter ($\text{cfu} \cdot \text{m}^{-3}$) was determined. Biological samples were analyzed by the laboratories of the University of Nevada.

Physical characterization of two buildings and their heating, ventilation, and air conditioning (HVAC) systems was also carried out (not reported here).

Statistical methods

Relationships between health outcomes and potential risk factors were examined with the computation of correlation coefficients (Pearson product moment and Spearman), parametric and nonparametric analyses of variance (ANOVA and Wilcoxon ranked sum tests), a computation of odds ratios for categorical comparisons, and multivariate logistic regression (including stepwise) for developing final models. Data from all four buildings were combined for the multivariate statistical analyses; indicator variables were included in the models to identify the building in which a person worked. Potential risk factors that were statistically significantly related to health outcomes in two-way analyses were included in subsequent multivariate analyses. Models that included health outcomes, exposure variables, potential confounders, and terms for interactions between exposure and other variables were examined with forward stepwise logistic regression procedures. The criteria used to determine the variables that would remain in the final models included significance levels of 0.05 for entry into and removal from models. SAS (statistical analysis system) software was used (SAS/PC version 6.04).

Results

Questionnaire findings

Table 1 presents the characteristics of the workers and buildings under study. The study population included 646 participants at the four locations, with a total response rate of 70%. It was not possible to determine response rates by age and gender group, as this information was not available by building at the time of the study. (However, when the study was repeated in 1993 and the respondents were compared with the target population, the response rates were slightly higher for the women and the response rate appeared to increase with age.) The study group was 71% female, with an average age of 42 years.

Tables 2 and 3 summarize the responses to selected questions from the questionnaire. Fifty-four percent of the employees were at least somewhat satisfied with their overall workstation environment (table 2). Less than half thought their workstations were reasonably clean, and substantial numbers felt the environment had problems with temperature, noise, odors, or air circulation (table 2). Respondents from building C gave the poorest evaluation of their facility. Overall, 83% were at least somewhat satisfied with their jobs (table 3). Job demands were high in that 77% felt their jobs required hard or fast work.

A large percentage of the group reported health symptoms. Over half of the reported upper respiratory symp-

Table 2. Satisfaction of the respondents (N=646) with the physical characteristics of the workstation and environment, by building.

	Building				Total (%)
	A (%)	B (%)	C (%)	D (%)	
Perceived satisfaction ^a					
Workstation environment	55.6	77.9	42.0	64.2	53.9
Workstation comfort	77.5	92.0	80.5	88.7	82.8
Amount of space	58.2	83.1	54.1	81.1	62.9
Privacy	29.0	44.4	22.6	37.7	29.6
Experienced problems ^b					
Chair comfort	23.1	21.8	36.9	32.0	30.4
Key board height	33.0	21.7	31.4	39.5	30.4
Glare	49.5	41.0	61.6	48.4	53.1
Workspace ^c					
At least reasonably clean	45.7	81.0	26.3	71.7	45.0
Too hot or too cold	52.9	46.4	62.1	60.8	56.9
Too noisy	48.6	31.2	56.2	39.2	48.3
Odorous	27.0	18.4	42.9	37.3	34.1
Too drafty or has too little air	55.7	33.1	64.8	46.2	55.1

^a At least somewhat.^b At least fairly often.^c Percentage of subjects agreeing with statement.**Table 3.** Perceived job satisfaction and job stress of the respondents (N=646), by building.

	Building				Total (%)
	A (%)	B (%)	C (%)	D (%)	
Satisfaction					
Job ^a	83.0	86.5	80.9	82.4	82.6
Salary ^a	67.4	83.3	78.8	70.6	76.5
Supervisory treatment ^a	75.2	76.8	71.8	62.8	72.8
Competence of supervisor ^a	76.6	74.6	77.4	58.8	75.2
Influence over amount of work ^b	78.9	73.6	63.0	66.7	68.9
Other					
Job requires hard or fast work ^c	71.9	73.0	81.4	69.8	76.7
Job has clear expectations ^c	71.0	93.7	87.3	81.1	73.9

^a At least somewhat satisfied with.^b At least moderate.^c At least fairly often.

toms that occurred 1—3 d per week or more over the last four weeks and that improved when away from work (table 4). Forty-eight percent reported CNS symptoms. Most of the workers who reported one of the symptom groups also reported symptoms in other categories. For example, 245 persons (39% of the total study group) reported both upper respiratory and CNS symptoms.

Environmental measures

Table 5 shows selected environmental measurements made for the four facilities. The formaldehyde, acetaldehyde, and particulate levels were below the legal and recommended exposure limits. The summed levels of the volatile organic compounds were also below the

values recommended for office environments. Averaged across all buildings, the highest concentrations were observed for acetone ($8.3 \mu\text{g} \cdot \text{m}^{-3}$), toluene ($5.0 \mu\text{g} \cdot \text{m}^{-3}$), 1,4-dichlorobenzene ($4.8 \mu\text{g} \cdot \text{m}^{-3}$), xylenes ($3.8 \mu\text{g} \cdot \text{m}^{-3}$), and benzene ($3.7 \mu\text{g} \cdot \text{m}^{-3}$). Carbon dioxide ranged from 541 to 792 ppm, values below the recommended exposure limits and generally within the range considered to provide adequate ventilation. No carbon monoxide was detected.

The fungi levels were low, ranging from 10 to $86 \text{ cfu} \cdot \text{m}^{-3}$. Although no specific exposure limits are recommended for biological contaminants, internal fungal contamination is generally not suspected if indoor concentrations are less than half the outdoor concentrations when the HVAC system is in operation. Outdoor

Table 4. Health symptoms of the respondents (N = 646), by building.

	Building				Total (%)
	A (%)	B (%)	C (%)	D (%)	
Upper respiratory or mucosal symptoms ^{a, b}	57.1	38.9	61.4	47.2	54.8
Dry eyes	36.2	16.7	33.9	32.1	30.0
Tired eyes	39.7	23.0	43.6	35.9	38.1
Nasal symptoms	27.9	11.9	21.8	20.8	21.1
Sneezing	17.7	11.1	20.5	24.5	18.4
Dry throat	12.8	5.6	18.3	15.1	14.3
Sore throat	6.4	2.4	7.8	9.4	6.5
Cough	2.8	0.8	6.8	5.7	4.7
Lower respiratory symptoms ^{a, b}	6.4	1.6	8.7	7.5	6.7
Chest tightness	3.6	0.8	5.6	7.6	4.4
Shortness of breath	2.8	0.0	3.4	5.7	2.8
Chest wheeze	0.7	0.8	3.1	3.8	2.2
Central nervous system symptoms ^{a, b}	51.1	29.6	55.0	44.2	48.3
Headache	22.7	11.1	29.5	28.9	24.3
Depression	6.5	4.0	13.7	7.6	9.7
Unusual tiredness	27.7	15.2	26.7	28.3	24.8
Tension	23.4	9.5	29.6	19.2	23.4
Difficulty remembering	10.6	3.2	14.0	15.4	11.3
Dizziness	9.2	1.6	6.5	13.2	6.7
Mental fatigue	19.9	4.0	18.4	22.6	16.2
Dermal symptoms ^{a, b}	5.7	2.4	9.1	11.3	7.2
Skin rash	1.4	0.0	1.9	0.0	1.3
Dry skin	5.0	2.4	7.8	11.3	6.4

^a Symptoms occurred 1—3 d a week in the last four weeks (or more) and symptoms improved after work.

^b Includes occurrence of any of the symptoms appearing below it.

Table 5. Environmental measurements made in the buildings under study.

Measure ^a	Building			
	A	B	C	D
Volatile organic compounds ($\mu\text{g}/\text{m}^3$) ^b	54.7	22.9	27.5	30.8
Formaldehyde ($\mu\text{g}/\text{m}^3$) ^c	18.0	12.1	5.5	14.2
Acetaldehyde ($\mu\text{g}/\text{m}^3$) ^c	9.8	5.4	4.6	6.9
Carbon dioxide (ppm) ^c	792	588	541	550
Carbon monoxide (ppm) ^c	0	0	0	0
Particulates ($\mu\text{g}/\text{m}^3$) ^c	14.1	10.5	24.4	4.6
Fungi (cfu/ m^3) ^d	10	68	86	54
Mesophilic bacteria (cfu/ m^3) ^d	165	222	153	72
Thermophilic bacteria (cfu/ m^3) ^d	0	0	0	0
Temperature ($^{\circ}\text{C}$)	23.7	22.7	24.1	23.2
Relative humidity (%)	38.7	37.8	31.1	27.7
Illumination (lx)	376	615	153	853
Noise (dB_A)	54	52	55	53

^a Average of four or five measurements.

^b Summed for selected volatile organic compounds (currently no permissible exposure limit).

^c Permissible exposure levels: formaldehyde 1300 $\mu\text{g}/\text{m}^3$, acetaldehyde 180 000 $\mu\text{g}/\text{m}^3$, carbon dioxide 5000 $\mu\text{g}/\text{m}^3$, carbon monoxide 35 ppm, particulates 10 000 $\mu\text{g}/\text{m}^3$, noise 85 dB_A .

^d Colony-forming units per cubic meter (currently no permissible exposure limit).

samples ranged from 264 to 696 cfu $\cdot$ m⁻³, with an average of 492 cfu $\cdot$ m⁻³. The fungi most commonly identified indoors were *Penicillium*, *Cladosporium*, *Saccharomyces*, and *Aspergillus* species. The bacteria levels were also low. No thermophilic bacteria were identified at any site. The total mesophilic bacteria levels ranged from 72 to 222 cfu $\cdot$ m⁻³. (Levels above 500 cfu $\cdot$ m⁻³ of certain types of bacteria can suggest unusual sources.) The most

commonly identified mesophilic bacteria were *Micrococcus*, *Bacillus*, and *Staphylococcus* species.

Relationships between health symptoms and work environment characteristics

Upper respiratory or mucosal symptoms. In the two-way analyses, upper respiratory or mucosal irritation was sta-

tistically significantly related to the personal characteristics of gender (women being approximately twice as likely as men to report symptoms), age and education level (likelihood of symptoms decreasing with increasing age and education level), and contact lens use (wearers of contact lenses being twice as likely to report symptoms). Cigarette smoking was not related to the occurrence symptoms.

Several self-reported underlying medical conditions were also related to the development of symptoms, including a history of migraine headaches, asthma, hay fever, or allergy to dust or molds.

The medical symptoms differed by building. The rates were significantly higher for buildings A and C. The symptoms did not appear to be related to the environmental air levels for aldehydes, carbon dioxide, humidity, or bacteria. The symptoms were statistically signifi-

cantly related to increases in volatile organic compounds, particulates, and noise (and a decrease in illumination), although the changes in risk were small. Several job characteristics were related to the development of upper respiratory symptoms, including perceptions of workstation cleanliness, comfort, privacy, and overall satisfaction with the physical workstation.

Many variables related to psychosocial job characteristics — including overall job satisfaction, influence over job tasks, working hard or fast, conflict in supervisory instructions, and job stress — were statistically significantly related to the development of upper respiratory or mucosal irritation, but the odds ratios were not large.

Stress from personal life outside the workplace, including stress from childcare responsibilities, volunteer work, part-time schooling, or lengthy commutes, did not appear to contribute to the reporting of upper respiratory or mucosal irritation.

Final multivariate analyses were carried out to determine which factors were the most strongly related to the development of respiratory symptoms when all were considered simultaneously. The building in which a person worked, the air contaminant levels, temperature, and noise were not related to the development of respiratory symptoms; however, factors related to a person's perception of work environment characteristics did appear to be related to respiratory symptoms. Employees who thought their work environment was not clean or had too little air movement or thought the atmosphere was too dry or noisy were more likely to report upper respiratory symptoms than those who did not (table 6).

Other factors that continued to be related to the development of symptoms in multivariate analyses were contact lens use, overall satisfaction with the physical work environment, report of sensitivity to chemicals found in the workplace, and job stress.

Central nervous system symptoms. Statistical analyses similar to those for upper respiratory or mucosal irritation were carried out to determine which factors were the most highly predictive of CNS symptoms. In the multivariate analyses, the reporting of CNS symptoms was related to several factors (table 6). The strongest was gender; women were 2.6 times more likely to report symptoms than men.

Lower respiratory and dermal symptoms. In the multivariate analyses, lower respiratory symptoms were statistically significantly associated with the perception of too little air movement, odors, and job stress (table 6). Factors related to the reporting of dermal symptoms included gender, perception of workplace odors, and workstation discomfort (table 6).

Table 6. Factors related to the reporting of symptoms.^a

Factor ^b	Odds ratio	P-value
<i>Upper respiratory or mucosal symptoms^c</i>		
Contact lens use	3.15	0.0001
Perception of air as too dry	2.29	0.0009
Perception of too little air movement	2.01	0.0011
Perception of workspace as too noisy	1.99	0.0012
Dissatisfaction with overall physical environment	1.74	0.0133
Job stress	1.62	0.0204
Perception of high sensitivity to chemicals in workplace	1.55	0.0390
Perception of workplace as not clean	1.55	0.0402
<i>Central nervous system symptoms^d</i>		
Female gender	2.58	0.0001
Perception of too little air movement	2.40	0.0001
Perception of workspace as too noisy	2.18	0.0001
Dissatisfaction with overall physical environment	1.86	0.0023
Job stress	1.73	0.0060
<i>Lower respiratory symptoms^e</i>		
Perception of too little air movement	3.96	0.0009
Perception of workplace as odorous	3.80	0.0003
Job stress	3.05	0.0049
<i>Dermal symptoms^f</i>		
Female gender	3.32	0.0265
Perception of workplace as odorous	2.31	0.0100
Discomfort with workstation	2.16	0.0268

^a See table 4 for a definition of the symptom groups.

^b Variables that were statistically significantly associated with the respondents' experiencing upper respiratory symptoms at $P < 0.05$, when these and other variables were considered simultaneously in the stepwise multiple logistic regression analyses.

^c Number of respondents = 646.

^d Number of respondents = 572.

^e Number of respondents = 600.

^f Number of respondents = 604.

Discussion

The air contaminant levels were generally low in the buildings under study in comparison with current permissible exposure levels. [It can be noted, however, that some persons have argued that US permissible exposure levels are too high to protect the health of those exposed (14)]. The contaminant levels did not appear to be associated with health symptoms; this finding is similar to the results of other studies (15, 16). The measured chemical levels did not vary according to the study participants' perceptions regarding environmental conditions. There were no differences in the mean measured contaminant levels for the participants who did or did not rate their work areas as clean or as having too much or too little air movement or as having chemical or other odors. There may be several reasons for this lack of differences. First, environmental samples were collected in three locations on one floor of each building. It is possible that contaminant levels fluctuate considerably by site and that these sampling stations did not represent individual worksites. However, when the analysis was limited to only those working on the floors where the air samples were collected, the results did not change. Of course it is possible that the floor-specific information was still insufficient to describe conditions at individual workstations. Second, it is possible that intermittent exposures or point sources were particularly effective in inducing symptoms and our monitoring techniques did not record at this level of detail (as results were recorded as time-weighted averages over an 8-h sampling period). Human beings may be sensitive to minute environmental changes that cannot be measured by usual industrial hygiene monitoring methods. Third, we may have failed to measure some unknown but important environmental exposure or characteristic. Finally, and most likely, it is possible that the observed levels were too low and invariable for any relationship with symptoms to be observed.

Seventy percent of the eligible employees participated in the survey, the response rates varying from 57 to 82% by building. It is possible that the respondents were not representative of the entire eligible group, if those who experienced health problems were more (or less) likely to participate than those who did not. There was some indication that the response rates were positively correlated with the symptom report rates for these buildings (although correlations were based on only four observations and were not statistically significant). In addition, it should be pointed out that these symptoms were self-reported; thus they represent subjective evidence of health problems that might be over- or under-reported. For example, 12.4% of the study group reported a personal history of asthma; this percentage appears high in comparison with population-based estimates of this disorder (17).

Other studies have also examined relationships between health symptoms and environmental characteristics in office buildings. Some of these were initiated because of workers' complaints about their workplaces. Such buildings are generally referred to as "problem" buildings, where symptom report rates are high. In the current study, nonproblem buildings were selected for examination. While it is difficult to compare the results with those from other studies because of differences in workplace characteristics and ways in which health outcomes are defined, our rates were similar to those observed in other groups. In a study by Skov et al (5) approximately 25, 16, and 11% of the study group reported mucous membrane, nasal, and eye irritation, respectively. In another study of a "problem" building, 30% reported mucous membrane irritation and 35% reported headaches (18).

Other studies have shown several factors to be related to the development of "indoor air quality" symptoms, including female gender, age, hay fever, contact lens use, exposure to biological agents, inadequate ventilation, work with copiers or carbonless paper, type of workstation, and a number of factors related to job stress and satisfaction (5, 10, 18–24). Our study had many similar findings (although the relationships were not strong and often became statistically nonsignificant when a number of factors were considered simultaneously); some of the similar findings are an increase in symptom reporting for younger age groups, female gender, contact lens wearing, self-reported allergies and hay fever, and associations with several factors related to job stress and satisfaction and perceived physical workspace conditions (workstation cleanliness and comfort, air movement, noise, odors, etc). Our study was also similar in that no consistent relationships between symptoms and measured air contaminant levels were observed. Symptoms were generally the most strongly associated with perceptions about workstation comfort and cleanliness, air movement, dryness, odors, and noise. Psychosocial aspects of the work environment were less strongly associated with symptoms.

It is unexpected and notable that, in the current study, cigarette smoking did not appear to be associated with respiratory symptoms. In other studies in which the effects of smoking were considered, the results varied. In some, smoking was associated with respiratory symptoms (10, 11), whereas in another, it was not (21).

In a study such as ours, in which the health outcomes of interest relate to the self-reporting of symptoms and many potential causative factors are examined, it is sometimes difficult to determine relationships among them (25). Because of the cross-sectional nature of the survey, it is possible that the observed associations may not represent cause-effect relationships, but rather may be measures of the same perception. As has already been

mentioned, many employees reported more than one indoor air-related symptom group, a finding which might be expected. In addition to these interrelationships, the likelihood of indoor air-related symptoms was associated with the reporting of musculoskeletal problems. For example, those with upper respiratory or mucosal irritation were eight times as likely to report back problems as those without such irritation. One would expect the two types of problems to be independent, unless they were associated with the same relatively nonspecific causal factors. Other observed associations included relations between health symptoms and perceived environmental characteristics (such as problems with air movement or dryness). For these associations in particular, it seems possible that both may be measures of the same perception (eg, eye irritation may be caused by air dryness, but irritation might also lead a person to believe the environment must be dry). Thus, although we have identified a number of factors that are related to reported symptoms, it is not clear that these factors are causal.

A comparison of the questionnaire responses with the results of more objective measures of health outcomes, such as the neuropsychological test battery used by Midhaugh et al (26), and the measures of biomicroscopic eye manifestations used by Franck et al (27), might help to determine the sensitivity and specificity of symptom survey instruments. It is of interest that, in both of these studies, objective measures were associated with reports of subjective symptoms, but the relationships were not necessarily strong. For example, in the study by Franck et al (27) the strongest relationship between an objective sign (absence of foam at the inner eye canthus) and the reporting of eye complaints had an odds ratio of 2.9.

In conclusion, our results suggest that, even in nonproblem buildings, reports of health symptoms can be frequent. Although our study did not suggest that symptoms were associated with air contaminant levels or other measured aspects of the physical environment, it is possible that the health symptoms were related to microenvironmental factors that we were not able to measure. It is also possible that symptoms reported in a questionnaire represent perceptions regarding workplace physical comfort and cleanliness rather than objective measures of health.

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