Fie'd Studies on the Sick Building Syndrome[a]

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INTRODUCTION

Field studies of indoor air quality have been conducted in problem and in nonproblem buildings both as quasi-experimental and as cross-sectional investigations. Such studies are useful when examining the importance of different factors and their interplay in field settings, that is, in the work place, but generally fail to provide the information more rigorously controlled approaches need to answer questions about the mechanisms that lead to complaints in indoor environments. Chamber studies, on the other hand, generally serve to test specific hypotheses about postulated mechanisms or specific agents of interest. Experimental and quasi-experimental designs have been addressed elsewhere in this volume. Consequently, this paper will focus on a series of studies by the author and summarize the European cross-sectional questionnaire investigations.

Anecdotal reports of problem buildings appeared with increasing frequency after the early 1970s. The first formal investigation of the "sick building syndrome" that included more than one building, and that also included nonproblem buildings, was actually conducted as a search for the cause of humidifier fever.[1] An increase in symptoms of chest tightness was seen, albeit not statistically significant, in buildings with mechanical ventilation systems with humidification. The most striking result, though, was the excess of "nonspecific" complaints seen in most buildings with mechanical ventilation systems independent of humidity control. Of note was that several buildings with natural ventilation had markedly more frequent complaints than some of the mechanically ventilated buildings, suggesting that ventilation systems themselves were at least not the sole cause. A response to that paper suggested that similar complaints were quite frequent in tropical countries and might be in fact attributable to a variety of environmental conditions, including "allergies," low relative humidity, and other factors.[2] Several European studies have examined the relationship between the prevalence of complaints and the design of ventilation systems.[1,3,4] A recent reanalysis of the above-mentioned studies and four others has suggested that ventilation systems may have contributed to complaint rates in all studies, including even the Danish Town Hall Study.[5]

A different approach was undertaken in the Danish Town Hall Study, an investigation of over 4000 office workers in 14 Danish town halls and control buildings.[4,6] It was thought to demonstrate no influence of ventilation systems, ...

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initially analyzed, on complaints but to indicate several other important building and personal risk factors. Gender, hours spent at work, hours spent photocopying, crowding, "fleecing" materials, and control over work were considered important predictors of complaints. In addition, the authors measured dust, the immunologically active component of dust, temperature, volatile organic compounds, carbon dioxide, and radiant temperature in one room in each building. They found that both dust levels themselves and the immunological component of dust in the one sampled room appeared related to the levels of complaints in the building. No additional factors appeared important.

Interestingly, earlier attempts have generally failed to demonstrate dose–response relationships between exposures and effects. For example, Robertson *et al.*[7] found no difference between rooms in well-accepted buildings and rooms in poorly accepted buildings in radiant temperature, dry-bulb temperature, relative humidity, dust levels, carbon dioxide levels, noise, or carbon monoxide levels. Negative ions[8] were also unrelated to the level of complaints. Jansen and Wolff[9] similarly failed to find a relationship between symptoms and measured exposures. The single exception appears to be the consistent contribution of lighting.[10-12] On the other hand, investigations of problem buildings have frequently identified specific pollutants as a most likely or primary etiology.[13]

Two reasons may explain the failure to identify a specific cause. First, industrial hygiene literature is replete with examples of the inadequacy of area sampling to identify personal exposures. Second, the failure to address variability in exposures and effects may obfuscate actual relationships. Symptoms related to indoor air quality fluctuate over hours, if not minutes. Pollutant levels too may vary over relatively brief periods of time, as both source strengths and modifiers of exposure change rapidly. Dust and bioaerosols are generated by walking across carpets; laser printers and photoduplication machines operate intermittently; typewriter correction fluid containers are opened for relatively brief periods of time; and variable air volume systems may supply lower amounts of air with lower air exchange rates than expected because of inadequate design.

Because of these considerations, this author has conducted three separate investigations over several years in an attempt to identify a method to relate exposures and effects in indoor environments. The method was extended from one initially developed in an investigation of complaints in Danish child-care facilities[14] based on a linear analogue self-assessment scale (LASAS).[15] Similar questionnaires have been used by others.[8,16] The first investigation was undertaken in a building with a postulated cause to determine whether the method would actually confirm the author's concern. The second investigation was undertaken in a problem building where the etiology was not identified. The original plan was to intervene on the identified pollutant and to subsequently reinvestigate the building. The third investigation was carried out in a series of buildings without known problems in an attempt to develop a specific hypothesis on the cause of nonspecific health complaints in modern office buildings.

STUDY IN A BUILDING WITH A KNOWN PROBLEM: VIBRATION

The first study in this series was conducted in a parking office over a three-week period using three clerical workers as subjects. It implicated temperature and vibration as contributors to discomfort.[17] Vibration had been described previously as a potential cause of indoor air quality complaints.[18]

Background

Clerical workers in a parking office had complained of headaches, dizziness, weakness, difficulty concentrating, abnormal facial pallor, nausea, and mucous membrane irritation over a period of several years. Two industrial hygiene surveys had been conducted. The first found no abnormalities of note and made no recommendations. During the second, a defect was discovered in the wall connecting the office to the parking areas themselves, where a missing cinderblock allowed entrainment of exhaust into the parking space. Although no elevations in carbon monoxide levels were measured and no pressurization tests were undertaken, the complaints were attributed to entrained exhaust. The hole was sealed. The complaints did not resolve.

Approximately one year later, the author was asked to investigate the problem because of growing dissatisfaction on the part of the occupants. On an initial walk-through, strong vibration was noted, leading to visible movement of the fluid meniscus in coffee cups and to difficulties on the part of the author when using the videodisplay terminal units on the desks. On review of the building plans, the office had been placed directly above the central chilled water plant of the institution. One of four main pumps, situated directly beside a steel girder supporting the office floor, was poorly anchored and transmitted vibration to the floor and furniture. A study was designed to test the hypothesis that vibration was at least one cause of the complaints.

Materials and Methods

A LASAS questionnaire was designed.[14,15] It consisted of 10-cm lines between extremes of symptoms. Participants were asked to mark the line at a position corresponding to the degree of their symptoms at the time of questionnaire completion. Such questionnaires are analogous to the practice of physicians asking patients to quantify symptoms on arbitrary scales of one to ten. At the time the questionnaire was completed, measurements of several indoor environmental measures were obtained, including dry-bulb temperature, relative humidity, carbon dioxide, carbon monoxide, and vibration parameters of acceleration, frequency, and displacement. Measurements were obtained at each of the three workstations, at the same place, on consecutive days at the same time of the day, in the early afternoon. The study was to occur over a three-week period so that 15 were to be available for each individual, providing a total of 45 data points for analysis.

Data analysis was to be based on regression models despite the recognition that the strict requirement of "independence" was not met, as the measurements for each of the three individuals might be interrelated. Symptoms were grouped to two major categories: air quality (eye, nose, and throat irritation) and vibration symptoms (pallor, nausea, and difficulty concentrating). Regression models were developed for both groups of symptoms. Symptoms were used as outcome variables, and environmental measures were used as predictor variables.

Results

Data were available for only 27 of 45 possible measurements because of two holidays and days lost because of illness. Dry-bulb temperature was significantly related to the level of air quality and vibration-re d complaints, with t coefficients for both terms greater than 1.96. The variable acceleration was also significantly related to the level of vibration complaints.

Discussion

The results suggested that both indoor air quality and vibration complaints were related to temperature, and that the vibration complaints were also in fact related to a vibration parameter as had been hypothesized. The author felt justified in exploring this method further to examine the relationship between symptoms and environmental measures. Two potential uses were identified. First, this method might prove valuable in correctly attributing complaints in a building with recognized problems to the direct cause of discomfort. This might be especially useful if several deficiencies or potential causes were identified. Second, it might prove useful in identifying environmental factors involved in the sick building syndrome.

STUDY IN A BUILDING WITH AN UNKNOWN PROBLEM

The second study was undertaken in a building that had been associated with complaints from its initial occupancy. The authors wished to develop a specific hypothesis that might then lead to a specific intervention. The building was to be restudied to determine the effectiveness of the intervention. The results of this investigation suggested that complaints were related to dust concentrations, to lighting levels, and to the length of duct work leading from the six central ventilating units.[10] No follow-up has been undertaken since the completion of the intervention.

Background

The building in question was a 40,000 square foot, three-story building with a tinted glass envelope. Ventilation was provided by six variable air volume (VAV) units. The maintenance shop, with welding, soldering, and solvent use, had its own ventilation system and was not included in this survey.

Several investigations had been undertaken without identifying the cause of complaints or resolving them. At least one individual had been removed from the building and assigned to work elsewhere as she had been unable to perform satisfactorily in the building. Several additional individuals had fluctuating complaints that led to regular physician visits. One patient left the building permanently. An investigation patterned after the one described above was designed.

Materials and Methods

A four-week period was set aside for measurements. All measurements were obtained between 1:00 and 5:00 PM. A single measurement was obtained at each workstation where individuals were found. All faculty and staff were eligible; students were excluded. Environmental measurements were obtained with the

instruments d in TABLE 1. The respirable suspended particulates were measured with a piezo-balance-based instrument with a nominal particle-size cut-off of 3.5 μm.

A LASAS questionnaire similar to the one in the prior investigation was used with the exception of exclusion of the symptom "pallor." Questionnaire and environmental measurements were completed simultaneously. Demographic variables of age, smoking status, gender, years of education, hours spent at desks and computers, use of contact lenses and glasses, and history of allergies were recorded. The floor and building plans of the building were reviewed, and the length of duct work leading to each work station was coded to an ordinal variable (one to three). Each office received a duct-length code corresponding to the distance from its VAV unit.

TABLE 1. Instrumentation Used in Studies of a Problem Building and of Nonproblem Buildings

Parameter of Interest	Instrumentation: Problem Building Study	Instrumentation: Nonproblem Building Study
Dry-bulb temperature	Solomet MPM	Battery-operated psychrometer
Relative humidity	Solomet MPM	Battery-operated psychrometer
Sound level	Not measured	Bruel and Kjaer sound level meter
Illumination	Sylvania D-2000	Uitron LX-101
Respirable suspended particulates	TSI 5500	GCA miniram
Air speed	Alnor thermoanemometer	Kurz Series 490 anemometer
Volatile organic compounds	Century 128 OVA	AID Model 580 OVA
Formaldehyde	Draeger indicator tubes with activator extender tubes	Not measured
Carbon dioxide	Draeger indicator tubes	Draeger indicator tubes
Carbon monoxide	Draeger indicator tubes	Draeger indicator tubes
Vibration	Kinematics VM-1 Fotonic MT 1-Sensor	

The participating technicians discontinued measurement of volatile organic compounds (VOCs) after 10 days because all levels were at or below 1 ppm and were therefore considered to be "normal." This was not discussed with the investigators.

Individuals were grouped by gender and smoking status, as these categories have been associated with complaints in some buildings. A study published shortly before that investigation had suggested that symptoms in buildings could be assigned to two main categories, "systemic symptoms" and "mucous membrane effects."[19] Therefore, these two groups of symptoms were developed by adding the logarithms of the scores for eye, nose, and throat irritation—for the mucous membrane effects—and by adding the logarithms of the scores for headaches, dizziness, difficulty concentrating, and fatigue—for the systemic symptoms.

Analyses were undertaken using these two groups of symptoms as effects.

Standard statistical tests were used, including analyses of variance with smoking and gender as main effects. The *p* values below .05 were considered statistically significant; those below .10 were deemed to justify further scrutiny.

Results

The environmental measurements did not reveal any unusual levels. No carbon dioxide levels were above 1250 ppm, although fully 25% were above 1000 ppm. TABLE 2 presents a correlation matrix of several variables of interest. There was a high degree of correlation, suggesting that different indoor environmental parameters for which standards exist do not vary independently. Electron microscopic analysis of the building dust suggested it consisted of fibers from spray-on insulation, environmental tobacco smoke, and molds and spores.

TABLE 3 presents the results of analyses of variance for demographic data, symptoms scales, and environmental measurements that were considered of interest. Men, and smoking men in particular, had higher levels of mucous membrane complaints, higher levels of respirable suspended particulates (RSPs) in their breathing zones, and lower levels of air velocity. Regression models suggested that mucous membrane symptoms were related to the levels of lighting, to the length of duct work, and to the levels of RSPs. Systemic symptoms appeared related to lighting and particulate levels.

Discussion

Symptoms appeared related to several measured environmental exposures. The statistical phenomenon of colinearity makes it difficult to determine which are the most important predictors of symptoms and which merely reflect the lack of independent variation between the measures. This is an important issue in itself, as engineering design variables are usually assumed to vary independently. If edges of comfort or dissatisfaction envelopes are reached simultaneously, the interactions between different parameters such as noise and thermal comfort, lighting and noise, and others must be considered in workstation design.

Respirable particulate matter of that size had not previously been associated with indoor air quality events, although specific components, such as environmental tobacco smoke[20,21] and molds,[13] are potential causes. Nevertheless, the colinearity with VOC measures, carbon dioxide levels, and relative humidity made it difficult to attribute disease to only one factor, specifically since VOC determinations were discontinued prematurely.

The implication of this study was then twofold. First, the technique had identified specific factors that could guide a remediation strategy. Second, the method suggested that relatively large numbers of individuals would need to be studied because of colinearity.

NONPROBLEM BUILDING STUDY

Studies of occupant complaints in buildings with recognized problems may identify specific pollutants. It is, however, unreasonable to extrapolate the results of such problem investigations to the universe of buildings or to generalize for

TABLE 2. Correlation Matrix: Environmental Measures (Problem Building)

	RSPs	Temp.	Air Speed	Rel. Hum.	CO_2	VOCs	Form.	Light
Temp.	.029							
Air speed	−.113	−.31**						
Rel. Hum.	.366**	.018	.310**					
CO_2	.330**	.352**	.045	.481**				
VOCs	.515**	−.700**	−.116	−.594**	−.627**			
Form.	.109	.303*	−.024	.031	.140	−.094		
Light	−.002	−.198*	−.041	−.050	.137	−.155	.637**	
Sound level	−.102	.552**	.639**	.114	−.013	−.597**	−.092	−.025

ABBREVIATIONS: RSPs: respirable suspended particulates; Temp.: temperature; Rel. Hum.: relative humidity; CO_2: carbon dioxide; VOCs: volatile organic compounds; Form.: formaldehyde.

STATISTICS: *: $p < .01$; **: $p < .001$.

TABLE 3. Results by Smoking and Gender: Mean Levels with Standard Errors in Parentheses (Problem Building)

	Female		Male		Analysis of Variance (F value / p value)			
	Nonsmoker	Smoker	Nonsmoker	Smoker	Gender	Smoking	Interaction	Explained
Hours spent at computer	4.2	3.5	2.8	5.0	1.882	1.041	5.999	2.885
	(0.3)	(0.5)	(0.4)	(1.1)	0.173	0.310	0.016	0.039
Mucous membrane symptoms (log)	1.86	1.73	1.90	2.31	2.817	0.892	5.397	3.163
	.06	.16	.09	.14	.096	.347	.002	.028
Systemic symptoms (log)	1.91	1.86	1.97	2.25	1.599	0.606	1.756	1.399
	.07	.16	.11	.15	.299	.438	.188	.248
Air speed (ft/min)	23.5	23.9	25.6	15.6	0.066	3.278	6.327	3.326
	1.4	1.4	1.4	3.6	.798	6.074	.014	.026
RSPs (μm/m³)	31	36	34	50	3.227	8.303	2.339	5.006
	.1	.5	.2	.8	.075	.005	.129	.003
VOCs (ppm)	.75	.60	.40	.57	6.962	.437	.949	2.743
	.06		.15	.01	.014	.515	.339	.063
Total number	53	12	29	12				

ABBREVIATIONS: RSPs: respirable suspended particulates; VOCs: Volatile organic compounds.

indoor en ,nmental standard setting. Instead, the next investigation identified five areas in buildings that had not led to requests for outside investigations.[22] The same questionnaire and the same study design as in the prior investigation were used, although the measurement instruments were different (TABLE 1).

Material and Methods

The areas to be used were all administrative areas involved in some aspect of academic activities, including a nonprofit foundation, a university clinical administration facility, a data management group, an academic administration, and a college dean's offices. The five areas were air-conditioned by a central unit without central humidification. One had a wall humidification unit, but it remained unused. Two had perimeter induction units; two had ducts at least partially lined with fiberglass; one had a charcoal filter. One building had completed renovation approximately six months previously. Another building began renovation during the conduct of this survey.

One field technician collected all results. Radiant temperature was calculated from a commercially available software program. A sixth area that was initially to be studied was unoccupied by the time the survey was conducted.

The same symptom questions as in the previous survey were used. Data on age; hours spent in the building, at desks, at computers; and the use of contact lenses were recorded. The number of individuals sharing an office were coded according to an ordinal scale: 0: one person in office, none sharing; 1: one or two sharing; 2: three to five sharing; 3: six or more sharing. Whether these co-workers smoked was also recorded.

Symptoms were grouped according to the World Health Organization classification of symptoms presented by Molhave.[23] A summary variable for each group was calculated by summing the logarithms of individual component symptoms: 1) mucous membrane—eye, nose, and throat scores; 2) neurotoxic—headaches, fatigue, irritability, dizziness, and nausea; 3) skin irritation; and 4) chest tightness. These outcome variables were examined by analyses of variance across the five different building areas (one-way analysis of variance) and by smoking and gender groups (two main effects with interaction). Subsequently, regression models were developed using symptoms as dependent variables and demographic, building, and environmental measurements as predictor variables. The details of regression strategies are presented elsewhere.[22]

Results

Occupants of the five different areas did not appear drawn from the same population, as significant differences were noted in age, educational status, gender, and smoking distribution across the five areas. Mean levels of symptoms in these five areas were significantly different in analyses of variance.[22] When all symptoms were examined simultaneously by an analysis of variance using gender and smoking as main effects correcting for multiple comparisons, no significant differences were seen.

Environmental measures in these areas also appeared nonrandomly distributed. Significant differences were seen for 8 of 10 measured variables; mean VOC and lighting levels were not different. No further analyses by these strata were examined.

TABLE 4. Crowding and Environmental Characteristics: Mean Levels and Analysis of Variance (Nonproblem Building Study)

	Number of Individuals in the Office					
	1	2 or 3	4 to 6	7 or more	*F* value	*p* value
VOCs (ppm)	.48	.48	.60	1.75	7.30	.001
CO (ppm)	3.7	4.3	4.5	6.4	6.90	.001
CO_2 (ppm)	433	496	418	583	5.70	.001
Noise (dBA)	50	54	55	51	5.40	.002
					Chi-square	*p* value
Percentage of males	49	39	16	17	13.0	.001
Percentage with at least one smoker	7	40	72	64	13.0	.001

ABBREVIATIONS: VOCs: volatile organic compounds; CO: carbon monoxide; CO_2: carbon dioxide.

Several environmental measures appeared to be related to crowding (TABLE 4), or at least to be inhomogeneously distributed among the four groupings. Levels of VOCs, carbon monoxide, and carbon dioxide increased as the number of individuals who shared the space increased. Symptom levels, too, increased. No differences were seen in the number of hours spent at computers, age, or education.

There was a great deal of intercorrelation among the individual symptoms. An icicle plot suggested that the grouping according to the World Health Organization classification was in fact legitimate, as the three mucous membrane symptoms were more closely related to each other than to other symptoms, as were the "neurotoxic" symptoms. Nevertheless, even across these groups correlation coefficients were striking. The relationship between the symptom groupings meeting the World Health Organization/Molhave[23] listing and the initial epidemiologic description of the sick building syndrome[1] is presented in TABLE 5.

Regression models were developed to examine the relationships between symptom scales, exposure levels, and other environmental characteristics. Consistent predictors of complaints for grouped symptoms included VOC levels, lighting levels, crowding, layers of clothing, and hours spent at desks. Approximately 25% of the variance was explained for mucous membrane and for neurotoxic symptoms. When the models were rerun without the crowding variable, no differences were seen in the coefficients for gender, VOCs, CO, and CO_2.

Because of discussions with contributors to this volume, the consistency between the individual symptoms and these variables of interest were explored. TABLE 6 presents the results of this analysis. VOC and lighting levels were the most consistent predictors, although other factors did contribute. Overall, the proportion of outcome variability explained by these models (R^2) was on the same order of magnitude as the original models published elsewhere.[22]

TABLE 5. Correlation between Symptom Groupings

	Sick Building Syndrome	Neurotoxic Symptoms	Mucous Membrane Irritation	Skin Irritation
Neurotoxic symptoms	.950**			
Mucous membrane irritation	.900**	.712**		
Skin irritation	.582**	.559**	.512**	
Chest tightness	.600**	.568**	.540**	.552**

STATISTICS: **: $p < .001$.

Discussion

The results of this study in nonproblem buildings are consistent with the results of chamber studies, that is, that VOCs are primary predictors of complaints among office workers. It is remarkable that this was true despite the relatively imprecise nature of the measurement techniques, for example, photoionization detectors. Interestingly, other factors such as crowding and time spent at work also contributed. Lighting has been identified in previous studies as a contributor.[11,12,19] It may exert its effects directly either on emotional status or through intensity, glare, and contrast. Conversely, it may exert indirect effects through influencing microbial growth.

A major shortcoming of this survey was the failure to characterize the social and organizational aspects of work. For example, personal control over work appears to be related to the degree of health complaints in the work place.[6,24]

IMPLICATIONS OF THESE THREE STUDIES

Personal sampling with instrumentation that captures fluctuation in indoor environments and symptom definition over short periods of time may provide a method to identify specific pollutants that lead to discomfort and health complaints. Such studies may be performed in the field and not merely in chambers, where thermal comfort and VOC exposure studies have been conducted. These studies suggest that chamber experiments must address more than a single variable to fully explain occupant complaints.

Interestingly, CO_2 levels consistently failed to demonstrate any significant relationship with the degree of symptoms. This suggests that simply determining the overall ventilation rate in a building may not provide a very good indicator of health complaints. Sources of indoor pollutants, besides human sources, such as those described by Fanger *et al.*,[20] do not give off carbon dioxide. The majority of the indoor pollution load is then inadequately addressed.

FIELD STUDIES AND THE VENTILATION SYSTEM HYPOTHESIS

Mendell and Smith[5] in their reanalysis of prior cross-sectional field studies suggested that heating, ventilating, and air conditioning systems were associated with the development of problems, leading to a consistent 50% excess of complaint rates. On the other hand, it is widely acknowledged that even buildings without mechanical ventilation may have very severe problems. The excess could then have three explanations.

First, mechanical ventilation by itself is a source of pollutants. Evidence supporting this interpretation is also provided by Fanger *et al.*[20] The primary etiologic pollutant would then be microbial. The specific agent could be a mold or myco-

TABLE 6. Variables Associated with Individual Symptoms in Regression Models (Nonproblem Building Study)

Outcome Variable	Eye Irritation	Nose Irritation	Throat Irritation	Chest Tightness	Headache	Irritability
R^2	.25	.19	.23	.09	.18	.14
p value	<.001	<.001	<.001		<.001	<.001
	Layers of clothing	Layers of clothing			Layers of clothing	
	Gender					
	Age					
	Hours spent at computer	Hours spent at desk	Hours spent at desk			Hours spent at desk
	VOCs	RSPs	VOCs		VOCs	VOCs
	Lighting	Lighting	Lighting		Lighting	Lighting
	Noise	Radiant temperature				Crowding
		Carbon dioxide				

ABBREVIATIONS: VOCs: volatile organic compounds; RSPs: respirable suspended particulates.

toxin.[25,26] D[illegible] adsorbed onto fiberglass liners or lying in ducts or in mechanical rooms, and water, condensed or adsorbed onto duct liners,[27,28] provide an environment allowing the growth of molds and spores. These same organisms are found in ducts and in carpet,[29] also explaining the "fleecing factor" described in the Danish Town Hall Study.

Second, mechanical ventilation allows recirculation of pollutants. For example, strong indoor sources, Fanger's "hidden olfs," offgas pollutants and allow them to be transported to other areas in buildings. These could be either microbial agents, as described above, or VOCs from office machines and processes, furniture, caulks, and paints and coatings. This is consistent with a series of chamber studies demonstrating that humans respond to low levels of VOCs. Animal data supporting this hypothesis are presented in this volume.[30] Further evidence comes from Nordback *et al.*[24] The influence of environmental tobacco smoke[20,21] is also consistent with this hypothesis.

Third, mechanical ventilation may be associated with wider excursions around ideal comfort zones than office workers are willing to accept without complaining. They may interpret the broader excursions as uncomfortable, as they require different strategies. For example, relatively narrow temperature excursions are easily tolerable; excursions to one temperature extreme may require simply the addition of a sweater; excursions in both directions may require very different strategies on an individual level to provide comfort. Vibration levels, too, appear to fluctuate widely.[18] The greater excursions may then be perceived more clearly as a signal of inadequate control as compared to the background noise of usual environmental fluctuations.

CURRENT STUDIES AND THE MECHANICAL VENTILATION HYPOTHESIS

The data from this study can be reconciled with the large cross-sectional studies in two ways. First, VOCs offgas from man-made products, so that better materials selection and increased ventilation may be useful in reducing complaints. One aspect of this may be that different ventilation strategies are necessary for exhausting pollutants than for the provision of fresh air. Second, many viable organisms give off relatively small molecules with odorous and irritating properties, also measured as VOCs. If these are the primary cause, it is unlikely that materials selection alone will resolve the problem of the sick building syndrome. Different building operations and maintenance strategies will be necessary to reduce microbial loading. In any case, the failure of particulates to consistently appear related to complaints does raise the question of whether sampling for particulate matter or viable organisms will be an effective environmental monitoring approach.

Obviously, the sick building syndrome, as many syndromes, may lack a single explanation. Specific buildings with problems are often identified as having defined causes that allow remediation, although little scientific evidence supports that such remediation actually reduces the level of complaints. It may then be that specific buildings will always have one or more specific defects in design or maintenance that lead to health complaints. Attempts to identify the one and only pollutant of interest may in fact distract from two broader issues.

First, other effects besides the symptom categories listed here are increasingly associated with buildings, including upper respiratory tract infections[31,32] and decreased productivity. These must be considered in field studies of building problems in the future.

Second, desirable environmental characteristics for workstation design are defined by a series of professional standards, addressing thermal comfort, air quality, sound and vibration, and lighting. Traditionally, each factor is considered individually during the design of workstations. A more important interpretation of these field studies may be that the design of indoor environments should address all ambient parameters simultaneously.

SUMMARY

Field studies of the sick building syndrome have generally used questionnaires developed to define symptoms present over weeks and months, such as those asking ". . . do you usually . . . ?" Although such studies have implicated ventilation systems as a major contributor to indoor air quality complaints, no specific exposures have been identified. An alternative approach is based on the short-term quantification of symptoms and characterization of the indoor environment with direct-reading or short-term sampling techniques. This paper summarizes the development of such a method in two studies in problem buildings and its subsequent application in a study in nonproblem buildings. The method correctly identified the postulated cause in a first building and generated a hypothesis for intervention in the second. In the nonproblem buildings, the levels of complaints appear related to the levels of VOCs, lighting, hours spent at desks, and crowding. This approach has suggested that dose–response relationships do exist in the sick building syndrome. Weaknesses of this approach include an inability to adequately address microbial characterization of indoor environments and the social and organizational predictors of complaints that are recognized to be of importance.

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