SYMPTOMS AND THE MICROENVIRONMENT IN NON-PROBLEM BUILDINGS

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This study presents an extension of a method used by the authors in prior investigations of problem buildings (1,2) to non-problem buildings. The authors wished to test the hypothesis that specific environmental exposures might be related to the level of complaints, specifically lighting level and respirable suspended particulates. The authors were not interested in determining which occupants were had expressed disatisfaction with their environment and made no attempt to identify social or organizational aspects of work.

METHODS

The study was conducted during the months of July and August, 1987. Five groups of possible building-related symptoms were studied in a cross-sectional investigation of 147 office workers in five building areas using a linear-analog self-assessment scale questionnaire to define symptoms at a specific point in time. Simultaneously the environment in the breathing zone was characterized by measuring thermal parameters (dry-bulb temperature, relative humidity, air speed, and radiant temperature), volatile organic compounds (VOC), respirable suspended particulates (RSP), noise and light intensity, and carbon dioxide (CO2) and carbon monoxide levels.

One individual (C.T.) conducted all measurements. Approximately 20 minutes were required to conduct the measurements at each work station. Measurements were performed while the individual was completing the questionnaire. The questionnaire collected several kinds of information: 1) demographic data, including age, gender, years of education, years of work at a specific institution and building, and smoking status; 2) the magnitude of 10 complaints (eye, nose, and throat irritation, chest tightness, headaches, difficulty concentrating, irritability, fatigue); 3) work characteristics, hours per day spent in the building at individual offices, and at computer screens; number of individuals sharing offices and the percentage of smokers; and 4) personal issues, such as the wearing of contact lenses and glasses, the number of layers of clothing, etc.

Ten indoor air quality characteristics were measured with direct reading instruments or short term indicator tubes to obtain levels during the time that individuals were actually completing the questionnaire. The instruments with their performance characteristics are presented in Table 1. The Organic Vapor Analyzer was calibrated to butadiene, and results were expressed as parts per million of four-carbon fragments. Measurements were obtained only once at each work station. No attempt was made to validate the performance characteristics of the instruments provided by the manufacturer, as exposure levels are known to vary over short periods of time. Samples were measured in the order: 1) temperature, relative humidity, air speed, and wet bulb globe temperature, 2) noise intensity, 3) light intensity, 4) carbon monoxide and carbon dioxide concentrations, 5) VOCs and 6) RSPs.

The percentage of occupants disatisfied from draft was calculated from the equation of Fanger and Christensen (3). The "percent dissatisfaction" was arbitrarily used as a measure of the degree of discomfort which a specific individual can be expected to suffer at the same environmental conditions. Radiant temperature and humidity ratio (W) were calculated using a commercially available software program.

The percentage of smokers in each of the five areas who admitted to current smoking was used as a continuous variable, as a surrogate of smoking intensity. Because of additional information that dust might substantially contribute to complaints, the authors collected 20 representative bulk dust samples from the sites, approximately three months later. Endotoxin analyses were performed using a Limulus amebocyte lysate assay.

Data were analyzed using the Statistical Packages for the Social Sciences for Microcomputers (SPSS\PC 2.0). The maximum number of complete records available for each comparison of interest was used. Differences were accepted as statistically significant when the associated P value was less than .05. Where P values fell between .10 and .05, the differences were considered suggestive of an effect and more closely scrutinized. Data were plotted. Where they were log-normally distributed (all measures, including symptoms, except draft and radiant temperature), appropriate transformations were undertaken for analysis. Where the results of a measurement fell below the limit of detection, the lower limit of detection was used as the actual measured number. Radiant temperature was distributed bimodally, so that an indicator variable for high versus normal radiant temperature was included. An indicator variable was also used for the presence or absence of perimeter units.

For data analysis, symptoms were grouped into several summary variables by adding the logarithms of the individual symptom scores. For purposes of this investigation, the symptoms were grouped to 1) mucous membrane symptoms, i.e., eye, nose, and throat irritation; 2) central nervous system symptoms, i.e., headaches, nausea, irritability, difficulty concentrating, and fatigue; 3) skin irritation; 4) chest tightness; and 5) the SBS as defined by Finnegan (4), i.e., headaches, fatigue, and mucous membrane symptoms. Indicator variables were calculated for age (greater or less than 35), computer work (more or less than one hour per day), and wearing contacts (yes vs. no). Education (completed high school, completed college, or entered graduate school) and crowding (alone in an office, up to three individuals, four to seven individuals; eight or more individuals) were used as ordinal variables.

The data were initially examined through grouped analyses using analyses of variance (AOV) or t-tests for parametrically distributed and chi-square tests for nonparametrically distributed variables. All analyses were undertaken first for demographic variables, then symptoms, and then measured environmental data. For AOVs, main effects were either gender and smoking status, together with an interaction term or the five building areas (without an interaction term). The method of least significant differences was used to adjust for multiple comparisons within all analyses of variance. No attempt was made to adjust significance levels for multiple comparisons in the overall study. The zero-order correlation between symptoms and micro-environmental measures was examined with simple correlation. Three different approaches to multi-variable regression modelling were used with backward-stepping techniques, a sequential, a hierarchical, and a simultaneous approach to variables. The five symptoms categories were used as dependent variables and environmental and demographic data as predictor variables. Models were first developed for building characteristics, office characteristics, and personal characteristics and then all significant variables were included in a fuinal model. The hierarchical approach included significant variables from each of the previous models in the next model. The simultaneous approach made no attempt to restrict the number of available variables and offered them all at the same time. The coefficients were very similar in all three sets of models.

RESULTS

Table 2 presents the building characteristics of the five areas, all with central HVAC systems. Table 3 presents a correlation matrix for the environmental measures, showing a great deal of colinearity. Table 4 presents the results of environmental measures obtained with the instruments. Correlation coefficients between individual symptom scales and environmental measures were generally randomly distributed, although eye, nose, and throat irritation appeared related to radiant temperature and draftiness and chest tightness with lighting intensity.

In regression models the strongest predictors of complaints, explaining up to 25% of the variance were percent of smokers, perimeter units, hours spent at desks, crowding, VOC concentrations, and lighting. No relationship between endotoxin levels and symptoms was found.

DISCUSSION

This study suggests that non-specific symptoms in indoor environments may not be as independent of environmental exposures as has been assumed. Implicated factors include aspects of the building (perimeter units, smokers in the building), aspects of work and personal practices (hours spent at desks, layers of clothing worn), and specific pollutants (VOC, lighting).

The study attempted to identify causes of symptoms in non-problem buildings. It is therefore not at all certain that the relationships demonstrated here are applicable in any specific problem building. In addition, because individuals were not asked to state whether they were satisfied with their environment, the authors are unable to relate the measurements here to any standards.

A major weakness of the approach is the measurement imprecision of the instruments in the ranges used. Nevertheless, since long-term measurement of pollutants was considered unlikely to demonstrate dose-response relationships, this approach may stimulate more innovative use of sampling equipment.

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Table 1

INSTRUMENTATION CHARACTERISTICS

PARAMETER	INSTRUMENT	SENSITIVITY/ACCURACY
Temperature (F) Relative humidity	battery-operated psychrometer	1 °F/0.5 °F
Noise	Bruel and Kjaer Sound level meter	0.5 dB/ .25 dB
Illumination	Uitron LX-101 Lux meter	1 L/ 2%
Carbon monoxide	Draeger Detector Tubes	1 PPM// 3%
Carbon dioxide	Draeger Detector Tubes	10 PPM/ 3%
Volatile Organic Compounds	AID Model 580	0.1 PPM/ .1 PPM
Respirable Dust	GC Miniram	0.01 mg/m^3/.03 mg/m^3
Airspeed	Kurz Series 490 Anemometer	10 fpm/ 3%
Heat stress	Reuter-Stokes Wibget	1 °F/ .4 °F

TABLE 2

Characteristics of five building areas

Area	Year Built	Last Renovated	Area Sq. Ft.	Humidity control	Perimeter Units	Duct linings
1	1935	1984	10500	no	Yes	Yes
2	1935	1981	11200	partial	Yes	No
3	1935	1987	11400	No	No	No
4	1940s	1983	4000	No	No	No
5	1979	1987	3000	No	No	Yes

Table 3:

Correlation Matrix of Environmental Measures

	Temp	W	Draft	GLOBE	CO_2	CO	RSP	VOC	Light
W	.45#								
draft	.07	.05							
GLOBE	.16	-.16+	.23^						
CO_2	-.19*	-.06	-.07	-.27#					
CO	-.08	-.04	-.05	.08	.42#				
RSP	.18*	.20*	-.14+	-.14+	-.12	.07			
VOC	.14	-.36#	-.14+	-.21*	.18*	.25^	.25^		
Light	-.11	.04	-.06	-.10	.02	-.06	-.01	.12	
Noise	.10	-.06	.24^	.31#	-.11	.10	-.02	.00	-.16

+p<.1; *p<.05; ^P<.01; #p<.001

1., temp: Logarithm of dry-bulb temperature; 2., W: humidity ratio; 3., draft: "perception of draught" as calculated by Fanger and Christensen[15]; 4., globe: radiant temperature[16]; 5., CO2: logarithm of the carbon dioxide concentration; 6., CO: logarithm of the carbon monoxide concentration; 7., RSP: logarithm of respirable suspended particulates; 8., VOC: logarithm of the concentration of Volatile Organic Compounds; 9., lite: logarithm of light intensity; 10., noise: logarithm of noise intensity

Table 4: Analyses of Variance: Environmental Measures by Areas - Means and standard errors

	Area 1	Area 2	Area 3	Area 4	Area 5	F-ratio (probability)
Number of samples	52	50	23	9	13	
Temperature (F)	79.1 (1.01)	75.6 (1.00)	75.6 (1.01)	73.3 (1.00)	70.3 (1.01)	23.0 (<.001)
W	.106 (3.60)	.109 (1.77)	.112 (1.55)	.082 (1.28)	.095 (2.05)	6.91 (<.001)
Draft (% dis-satisfied)	13.3 (.14)	13.6 (.18)	13.2 (.30)	12.7 (.15)	12.6 (.13)	2.77 (.030)
Wet bulb globe temperature	84.3 (1.73)	88.4 (2.94)	74.8 (1.16)	72.0 (.96)	69.8 (1.00)	7.47 (<.001)
CO2 (in parts per million [ppm])	372.4 (1.04)	510.3 (1.04)	408.9 (1.02)	841.6 (1.02)	444.3 (1.05)	28.34 (<.001)
CO levels (ppm)	3.5 (1.07)	4.22 (1.07)	3.66 (1.10)	8.81 (1.08)	3.15 (1.08)	9.47 (<.001)
Respirable parti-culates (ug/m3)	63.3 (1.11)	46.0 (1.08)	50.0 (1.09)	65.4 (1.04)	2.62 (1.09)	(.037)
Volatile organic compounds (ppm)	.40 (.12)	.14 (.11)	.16 (.11)	3.59 (.10)	.697 (.12)	43.5 (<.001)
Light intensity (in lumen)	569.9 (1.08)	554.5 (1.11)	649.1 (1.14)	750.1 (1.22)	761.6 (1.05)	1.21 (.309)
Noise level (on dB(A) scale)	54.5 (1.02)	52.2 (1.02)	50.1 (1.02)	46.7 (1.04)	49.0 (1.03)	4.41 (.002)