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Relating Sick Building Symptoms to Environmental Conditions and Worker Characteristics

PAMELA A. OHMAN[1] AND L. E. EBERLY[2]

Abstract Recent concern has centered on "sick buildings" in which there has been an unusually high percentage of health complaints by the building's occupants. Typically, these symptoms are thought to be tied to indoor air quality characteristics, such as high levels of respirable particles or volatiles, thermal conditions, etc. In addition, recent studies have drawn connections between "sick building syndrome" (SBS) symptoms and *non*-environmental variables, i.e., personal and occupational factors. This paper presents a brief review of a study by Hedge et al. (1995) and additional analyses of their data. In a study of 27 air-conditioned office buildings, Hedge et al. measured nine indoor environmental conditions at various locations within each building and concurrently questioned workers on sixteen SBS symptoms and a number of other personal factors. The additional analyses presented in this paper attempt to draw formal statistical connections between SBS symptoms and both personal worker characteristics and indoor air pollutants simultaneously. The analyses were based on symptom severity response variables whic include information not only on the frequency with which an individual experienced a symptom, but also on how much the symptom disrupted the individual's work. Results from sixteen linear mixed effects models indicate that significant predictors are primarily personal and occupational in nature rather than environmental. For a number of the symptoms, additional variability attributable to buildings exists. However, any physical explanation of this variability remains unclear.

Key words Work-related illness; Occupational health; Indoor air quality; Linear mixed models.

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Introduction

Over the past decade, concerns about the relationship between indoor air quality in the workplace and a wide variety of health complaints have been increasing. The term "Sick Building Syndrome" (SBS) was first defined by the World Health Organization (WH in the early 1980s. It is used to describe a range physical symptoms reported by workers withi building to which no specific etiologic factor can attached (WHO, 1983). The American Thoracic Soci identifies the following as SBS symptoms: eye i tation, headache, throat irritation, recurrent fatig chest burning, cough, wheezing, concentration short-term memory problems, and nasal congestion addition to those listed above, the Commission European Communities and WHO add skin irritati such as red or dry skin (Godish, 1995).

In order to help identify causes of SBS sympto Mølhave (1987) grouped the WHO list into five phy logically similar categories: 1) sensoric irritation in e nose, or throat; 2) skin irritation; 3) neurotoxic syr toms; 4) unspecific hyperreactions; and 5) odor a taste complaints. Hodgson (1989) credits Mølhav grouping and argues that each of the various ca gories of symptoms could represent individually r ognizable pathophysiologic entities. For example, ne rologic symptoms, such as headaches, could be due solvent neurotoxicity, while eye and nose irritati could be caused by allergenic contaminants. A pro lem inherent in studying SBS is that it may or n not represent a single entity. Alternatively, an uns environmental condition does not always result in t same physiologic abnormalities among workers ir problem building.

In practice, in order to qualify as an SBS sympto the symptom must be primarily experienced while the workplace, although it may linger shortly af leaving. When an unusually high proportion of off workers complain of these types of symptoms, t building is considered to be "sick". In this paper will be concerned with "permanent" SBS. This ru

[1]*Department of Statistics, University of Florida, Box 118545, Gainesville, FL 32611, USA, Tel: (352) 392-1941, Fax: (352)392-5175, E-mail: pohman@stat.ufl.edu,* [2]*Division of Biostatistics, University of Minnesota, Minneapolis, MN, USA*

out instances in which, due to some particular event (such as office renovation or maintenance), a temporary outbreak of symptoms is followed by a return to previous conditions.

A number of causes of SBS have been suggested, including: insufficient ventilation or thermal control; inadequate building design or maintenance; macromolecular organic dust molecules of biological origin; airborne endotoxins; and other physical, chemical, biological, or psychosocial factors. See, for example, Mendell and Smith (1990), Gravesen et al. (1991), Skov et al. (1987), Teeuw et al. (1994) and Godish (1995). However, Hedge et al. (1995), in a study of 939 workers from 5 office buildings, failed to draw connections between SBS symptoms and levels of carbon monoxide, carbon dioxide, formaldehyde, respirable particulates, temperature, humidity, and illuminance. Teeuw et al. (1994) also reports that the small number of published studies on microbiological contamination have been contradictory.

Studies involving more controlled conditions have been more successful than purely observational ones, perhaps due to the more precise measurement of the air pollutants affecting the individual. These studies have identified connections between certain SBS symptoms and humidity, volatile organic compounds, and carbon dioxide. See, for example, Reinikainen et al. (1992), Otto et al. (1992), Koren et al. (1992) and Kjaergaard et al. (1992).

In addition, studies relating SBS symptoms to many personal and occupational factors (as opposed to environmental) have more consistently shown significant results (Godish, 1995). Burge et al. (1987) found that a variety of individual factors (gender, age, perceived environmental control and perceived environmental conditions), occupational factors (video display terminal (VDT) use and job stress), and organizational factors (organization type and office type), among others, played a significant role in the reporting of SBS symptoms. More recently, Zweers et al. (1991) found that a worker's gender, job satisfaction, history of allergies, and satisfaction with complaint handling had the highest correlations with symptom reports. However, only up to 20% of the variation in the data was explained by the predictors in a multiple regression.

In the literature reviewed for this study, the presence of a symptom, or at best, frequency, was used as the response variable to study the causes of SBS. Other medical literature suggests that the intensity of a symptom, in addition to occurrence, describes the severity of a symptom or illness and the resulting quality of life. For example, Langeveld et al. (1997) related both headache intensity and frequency to changes in quality of life. Quaynor et al. (1995), in measuring occurence of headache following lumbar muelography, measured headaches as being mild to severe. In studying generalized anxiety disorder, Starcevic et al. (1994) qualified the related symptoms in terms of both frequency and intensity. It is possible that studying intensity in addition to presence of a symptom will further elucidate causes of the SBS syndrome.

In addition, when studying SBS, the use of statistical techniques such as linear regression seems far less common than simple comparisons of prevalences or correlations. Nevertheless, regression, where applicable, more accurately and precisely measures associations because of its simultaneous control of other possible predictors. Thus, in an attempt to test the effect of environmental variables while controlling for personal variables, and perhaps thereby to better understand the true causes of SBS, this study reanalyzed the data of Hedge et al. (1995) using the linear mixed model. The study of Hedge et al. was conducted in order to help clarify associations of SBS symptoms with both indoor air quality and worker characteristics. The following section briefly describes the data collected by Hedge et al. and summarizes some analyses already carried out by them. This is followed by sections presenting the models proposed in this study, the results, and further discussion.

Data Collection and Previous Analyses

Hedge et al. (1995) surveyed 4,479 workers from 27 air-conditioned office buildings in the eastern and midwestern United States within the period 1990–1991. All buildings were air-conditioned and mechanically ventilated. Within each building, between four and eight distinct office areas, often located on different floors, were chosen in which to take environmental samples using air sample pumps. The environmental variables measured in each of the areas include (italics represent variable names): carbon monoxide *CO*, measured in parts per million, (ppm)); carbon dioxide CO_2, ppm); formaldehyde *form*, ppm); nicotine *nic*, μg per m^3); respirable suspended particles *rsp*, of less than 2.5 μm in diameter, mg per m^3); ultraviolet particulate matter *uvpm*, of less than 3.5 μm in diameter, μg per m^3); temperature *temp*, °C); humidity *hum*, %); and illumination *illum*, lux). See Hedge et al. (1994, 1996) for details on the sampling methods used. The indoor air quality of each building did meet the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) regulations (ASHRAE, 1989). Only one building had a history of occupant health complaints.

As these environmental variables were being measured in each area, approximately thirty questionnaires were handed out to workers with desks in the immediate vicinity. These workers answered questions on the occurrence of sixteen SBS symptoms, job characteristics, perceived ambient conditions, and other occupational and personal variables. In particular, workers were questioned about the following symptoms: dry eyes; irritated sore eyes; tired, strained eyes; sore, irritated throat; dry skin; hoarseness; stuffy, congested nose; runny nose; excessive mental fatigue; nervousness, irritability; headache across forehead; wheezing, chest tightness; nausea; dizziness; skin irritation, rashes; and unusual tiredness, lethargy. For each symptom, workers were asked with what frequency they experienced the symptom (never, 1 to 3 times a month, 1 to 3 times a week, almost every day) and how disruptive it was to their work (not at all, somewhat, very). Symptom point prevalences were calculated for each building as the number of workers experiencing the symptom at least once per month divided by the number of workers questioned. The mean and standard deviation of these prevalences for each symptom can be found in Table 1; some symptom prevalences are much more variable than others. Prevalences across buildings but within each frequency level can be found in Hedge et al. (1996).

Questions pertaining to the workers' personal and occupational backgrounds addressed the following: length of *time* worked in building; *age*; *sex*; history of *migraine*, *asthma*, *eczema*, *hayfever*, other *allergies*, or chronic *back* pain; smoking status *smoke*); use of correction lenses *eye*); use of office equipment (photo*copier*, self-copying/*carbon*less copy paper, or *correct*ion fluid); *job* type; and VDT use *vdt*). Details on the question formats can be obtained from the authors. In addition, to

Table 1 Symptom prevalences across buildings, with standard deviations

	Average prevalence	Standard deviation
Dry Eyes	0.386	0.134
Irritated, Sore Eyes	0.392	0.118
Tired, Strained Eyes	0.542	0.117
Sore, Irritated Throat	0.228	0.096
Dry Skin	0.152	0.065
Hoarseness	0.156	0.069
Stuffy, Congested Nose	0.288	0.106
Runny Nose	0.192	0.085
Excessive Mental Fatigue	0.428	0.117
Nervousness, Irritability	0.355	0.105
Headache	0.323	0.095
Wheezing, Chest Tightness	0.085	0.042
Nausea	0.083	0.049
Dizziness	0.109	0.054
Skin Irritation, Rashes	0.045	0.020
Unusual tiredness, lethargy	0.309	0.100

measure job stress and satisfaction, workers recoı their level of agreement (1=strongly agree, to strongly disagree) with the following statements: " *enthus*iastic about my job"; "My job is rather *mo* onous"; "My job is not very stressful" *nostress*) usually have to work *fast*"; "I often feel *stresse* work"; "My job demands a lot of *conc*entration"; "The office *environ*ment is satisfactory for my job."

Hedge et al. (1996) describes two sets of analy relating SBS symptoms first to the environmental tors measured, and second to occupational and sonal factors. The first set of analyses relates the p ence (at least once per month) or absence of symptom to the environmental variables only, thro logistic regression. The few environmental factors proved to be significant had odds ratios between and 1.55 only, thus, statistically significant but practically significant. Using only "presence" or " sence" of an individual symptom as the response not take advantage of all of the available informa about that symptom and may thus obscure signific relationships. Also, personal factors were not trolled for in these analyses. In addition, there problem of inflated sample size, since there were proximately 30 questionnaires but only one set of vironmental measurements per area. The sec analysis conducted by Hedge et al. linearly regres the total number of symptoms present on the vari non-environmental conditions separately for men women. The predictors found to be significant w VDT use; job stress; job satisfaction; perceived inc air quality; history of allergies; history of migrai eyewear use; and age. See Hedge et al. (1996) for m details.

Further investigation is needed to determine if environmental factors can predict symptom repor after controlling for the personal characteristics of workers. In addition, we are particularly intereste determining if, after accounting for all the varia measured in this study, there are additional differe in symptom reporting due to the buildings themsel Even though none of the buildings in the sample considered "sick", some prevalences are large variable enough (as shown in Table 1) that examir building differences is reasonable. Finding differer across bulidings could indicate that some buildings indeed "sick", or equivalently that important pre tors related to the buildings were not measured.

The Models

Both the amount of disruption that a person exp ences due to a particular symptom and the freque of symptom occurrence are important indicators of symptom "severity". Some measure of severity which combines these two pieces of information could be more likely to pick up differences in SBS symptoms than the original analyses, which merely considered absence or presence of any particular symptom. A linear mixed effects model is proposed for each symptom: all main effects due to the environmental and non-environmental variables are considered fixed, and effects due to building and area within a building are considered random. (For more details on linear mixed models, see SAS Institute, Inc., 1992, Chapter 16; Searle, 1971; or Searle et al. 1992.) The use of mixed models, with area and building as random effects, eliminates the problem of inflated sample sizes due to multiple people being surveyed within a single environmentally-sampled area, and thus gives better estimates of the error with which the effects of the environmental factors have been measured.

Five "severity scales" which combine this frequency and disruption information in different ways are proposed (see Table 2). As in Hedge et al. (1996), an individual may only be assigned a non-zero symptom severity value if the symptom is experienced at least once a month and if the symptom gets better when away from work. Severity scales #1 and #2 in Table 2 merely merge the variables' information in two logical ways: #1 ranks frequency within disruption, while #2 ranks disruption within frequency.

In Severity #3, a scale was created in which the distance between values relates to some real measurement, *e.g.*, days. The average number of days per month that a symptom was experienced was multiplied by 1, 2, or 3 depending on whether the symptom was "not at all", "somewhat", or "very" disruptive. The study assumed 5 working days per week and 4.5 weeks per month. As an example, a symptom experienced 1 to 3 times per week is assumed to correspond to a frequency of (2 times/week) (4.5 weeks/month)= 9 times/month. A worker for whom that symptom was very disruptive receives a Severity #3 value of (3)(9)=27, while a worker for whom that symptom was not at all disruptive receives a value of (1)(9)=9.

Severity #4 is based on the idea that severity might also be globally measured by the amount of disruption alone. It is plausible that when pondering the amount of disruption a symptom caused them, individuals either consciously or unconsciously included information about frequency. Lastly, Severity #5 considers frequency alone as a measure of severity. Analyses are carried out using each of the five severity responses and then the results are compared to each other.

As an empirical justification for studying disruption in addition to frequency, it should be confirmed that the two variables are not providing the same information about a symptom. To test for this, the correlation between frequency and disruption was considered using Kendall's τ_b statistic. These values for each symptom are shown along with their standard errors in Table 3. τ_b is a measure of association between two ordinal variables, can take values $-1 \leq \tau_b \leq 1$, and is based on the number of concordant vs. discordant pairs (Agresti, 1990). τ_b is 0 if and only if frequency and disruption are independent, and is +1 or −1 if and

Table 2 Scales for new severity response variables

If frequency[a] is	and disruption[b] is	then severity[c] #1 is	severity[d] #2 is	severity[e] #3 is	severity[f] #4 is	and severity[g] #5 is
1	1	0	0	0	0	0
	2	0	0	0	0	0
	3	0	0	0	0	0
2	1	1	1	2	1	1
	2	4	2	4	2	1
	3	7	3	6	3	1
3	1	2	4	9	1	2
	2	5	5	18	2	2
	3	8	6	27	3	2
4	1	3	7	20.25	1	3
	2	6	8	40.50	2	3
	3	9	9	60.75	3	3

[a] 1=never, 2=1–3 times per month, 3=1–3 times per week, 4=almost every day
[b] 1=not at all, 2=somewhat, 3=very
[c] Severity #1 ranks frequency within disruption
[d] Severity #2 ranks disruption within frequency
[e] Severity # 3 is Severity #2 with a basis in days; see p. 9 for a detailed explanation
[f] Severity #4 considers disruption alone
[g] #5 considers frequency alone

Table 3 Kendall's τ_b with standard errors for each symptom

	τ_b	standard error
Dry eyes	0.545	0.019
Irritated, sore eyes	0.368	0.019
Tired, strained eyes	0.367	0.016
Sore, irritated throat	0.363	0.026
Dry skin	0.316	0.031
Hoarseness	0.355	0.032
Stuffy, congested nose	0.304	0.024
Runny nose	0.361	0.028
Excessive mental fatigue	0.276	0.021
Nervousness, irritability	0.338	0.021
Headache	0.323	0.021
Wheezing, chest tightness	0.285	0.044
Nausea	0.202	0.052
Dizziness	0.263	0.041
Skin irritation, rashes	0.216	0.067
Unusual tiredness, lethargy	0.339	0.024

only if knowledge of frequency completely determines disruption (where the sign indicates the direction of the association). The τ_b values in Table 3 are all much different from +1 (and −1), indicating that frequency and disruption potentially carry different information about how a person experiences a symptom. Therefore, only through consideration of both variables can we be confident that we are capturing all of the potential predictors of the symptoms experienced by workers.

In modeling each scale of symptom severity, all the personal and occupational variables previously mentioned are included as predictors in the initial models. Also included are building number (*bldg*), area within building (*area*), year of study completion (*year*), and smoking policy (*policy*). All environmental factors are included as well. Finally, to account for a change in laboratory personnel between the 1990 and 1991 samples, interactions between the environmental factors and *year* are also added.

Sixteen linear mixed models (one per symptom) are considered for each of the five scales, initially with all main effect and interaction terms listed above. Since theories behind SBS have traditionally assumed a physical cause behind symptoms, personal and occupational main effects that are not significant are dropped first from each symptom's model based on the appropriate *F*-test (SAS Institute, Inc., 1992). Next, environmental by year interactions that are not significant are dropped. Main effect environmental variables are considered next, with the exception of *policy*, *building*, and *area(building)*. Because of the high collinearity among environmental variables, they are dealt with as follows: perform a simultaneous test to see if all can be dropped at once, and, if not, then include the minimal set of most significant predictors such that the remainder can be excluded from the model by a likelihood ratio test. *Policy* is temporarily removed from ‹ model while considering which environmental › ables to drop; it is then re-added if significant. *Poli* handled in this way so as not to obscure the effec the environmental measurements related to smok which include *nic*, *rsp*, and *uvpm*. Lastly, the sig cance of building and area within building are te using a likelihood ratio test. All of the above h thesis tests are carried out at a significance level of

The Results

Table 4 shows predictors which remain in at least or the final models for each of the sixteen symptoms u each severity scale in turn as the response. The tab read as follows: for any symptom (row), the digit 1 pears if that predictor (column) is significant at α= when Severity #1 is the response, and likewise for # 4, and 5. It was hoped that by considering disruptic addition to frequency in order to measure "severi more information might be obtained about the caus SBS. In general, there is a strong correspondence am the five response scales. The similarity of results ac scales reassures us that significance is not likely to manifestation of Type I error. There does remain, h ever, some disagreement. Most noticeable, perhap that there are virtually no environmental varia which are significant predictors. Frequency alone not identify any environmental predictors. Instead, ruption alone (Severity #4) identifies carbon mono as a predictor of nausea (P-value=0.011), Severit identifies respirable suspended particles as a predi of dry eyes (P-value=0.013), and Severity #3 point carbon dioxide as a preditor of nervousness or ir bility (P-value=0.072). While not concluding that tl give conclusive evidence for causes of symptoms, tl results do suggest relationships that warrant furthe vestigation, as they are significant after adjustmen worker characteristics.

The random effect of *bldg* is significant in at least of the sixteen final models at the 0.10 significance le This means that for these symptoms, variation e that is explained either by the buildings themselve equivalently by some unmeasured variable associ with the buildings. This significance is fairly stron these symptoms, giving slight credence to the exist of SBS.

In addition, it is striking that there are several sonal predictors which are significant for almos symptoms and scales. These include *sex*, *allergies*, *l* *stress*, and *environ*. Recall that *environ* measures s faction with the physical workplace environment. these variables are so often significant is by no m

Table 4 Significant predictors for each symptom for all severity response variables; α=0.10

	bldg	area	smoker	time	age	sex	eye
Dry eyes	12345		3		4	12345	12345
Irritated, sore eyes	12345				12345	12345	12345
Tired, strained eyes	12 45				1 4	12345	12345
Sore, irritated throat	12345			3	12345	12345	2
Dry skin	12345					12345	
Hoarseness	12 45				12345	12345	
Stuffy, congested nose	12345		123 5	4	1234	12345	
Runny nose	1 4				1234	12345	1 4
Excessive mental fatigue	5	5	12345	12 45		12345	
Nervousness, irritability	1 4	2				12345	
Headache across forehead	123 5			4	12345	12345	12345
Wheezing, chest tightness		5	1 45		12 4		
Nausea	12 5			23	12 45	12 45	1
Dizziness	123 5				45	12 45	
Skin irritation, rashes	4	1					12
Unusual tiredness, lethargy	123 5			12 45	12345	12345	

	migraine	asthma	eczema	hayfever	allergies	back	copier
Dry eyes	1 34			123 5	12345	12345	12345
Irritated, sore eyes	1 345			5	12345	12345	12345
Tired, strained eyes	1 345				12345	12345	12345
Sore, irritated throat	45			12 5	12345	12 45	1 4
Dry skin				1 4	123 5	1 4	
Hoarseness	1 345	123 5		12345	12345	12345	12 4
Stuffy, congested nose			12345	123 5	12345	12345	12345
Runny nose		3 5	23	12345	12345	123	
Excessive mental fatigue	1 3 5		1 4		12345	12345	1 4
Nervousness, irritability	1 345				12345	12345	
Headache across forehead	1 345			12345	12345		
Wheezing, chest tightness	1 345	12345			12345	45	
Nausea	1 345				12345	12345	
Dizziness	1 345				12345	12345	
Skin irritation, rashes		2 5	2345		12345		
Unusual tiredness, lethargy	3 5		3		12345	1 345	1 45

	carbon	correct	job	vdt	enthus	mono	nostress
Dry eyes				4	12345	2 5	
Irritated, sore eyes		3		12 45	123 5		
Tired, strained eyes		3		12345		23	
Sore, irritated throat						1 45	
Dry skin		1 4	4	5		12345	
Hoarseness	1 45	3		12 45	4		
Stuffy, congested nose		12345			1 3	1 4	3
Runny nose	3	12345		12345			12345
Excessive mental fatigue	12 4		1 4		123 5	4	12345
Nervousness, irritability	12345	5	45		23 5	12 45	12345
Headache across forehead	5		45		123 5	45	
Wheezing, chest tightness							1 4
Nausea		45		45	12345	12345	
Dizziness	12345					12	23 5
Skin irritation, rashes				3	1 34	12345	
Unusual tiredness, lethargy			4		123 5	12 45	

	fast	stress	conc	environ	polity	offlimit	year
Dry eyes		12345		12345	1 345	12 45	1
Irritated, sore eyes		12345		12345	1 5	1 4	
Tired, strained eyes		12345		12345	3	5	
Sore, irritated throat		12345		12345	45		
Dry skin				12345	2345		
Hoarseness	45	1 4		12345	23 5		
Stuffy, congested nose	4		12345	12345	4		
Runny nose		12 45		12345	3 5		
Excessive mental fatigue		12345		12345	123 5	12 45	
Nervousnes, irritability	1 4	12345		12345		1234	
Headache across forehead	12345	12345		12345		1 4	
Wheezing, chest tightness			123	12345	1 4		
Nausea		12 45	4	12345			
Dizziness		12345		12345			
Skin irritation, rashes		12 45	12 4	12345			
Unusual tiredness, lethargy		12345		12345		1 45	

Table 4 (continued) The presence of a digit, e.g. 1, indicates that that column's variable is a significant predictor of that row's symptom using Severity #1

	CO	CO_2	rsp	rsp*year
Dry eyes			1	1
Irritated, sore eyes				
Tired, strained eyes				
Sore, irritated throat				
Dry skin				
Hoarseness				
Stuffy, congested nose				
Runny nose				
Excessive mental fatigue				
Nervousness, irritability		3		
Headache across forehead				
Wheezing, chest tightness				
Nausea	4			
Dizziness				
Skin irritation, rashes				
Unusual tiredness, lethargy				

implausible. Consider one whose significance may seem anomalous, back pain: the study population consisted of office workers, who by the nature of their work are largely sedentary in the workplace. This lack of movement, for example, would exacerbate any slight back ache due to poor posture or poorly designed office furniture. Besides those mentioned above, just about every possible worker-related predictor is significant for at least one symptom.

Discussion and Conclusions

This multi-building study by Hedge et al. (1996) has allowed a comprehensive study of some of the suggested causes of SBS symptoms. It has been demonstrated that the reporting of symptoms can be explained largely by worker and job characteristics rather than by environmental factors. This confirms the results of Hedge et al. (1989) and some results discussed by Godish (1995) that suggest that personal differences more readily account for higher reporting of SBS symptoms. However, it must also be pointed out that it is undoubtedly easier to find statistical significance of worker characteristics, since they are measured with much less error than the environmental variables. Along the same lines, the lack of convincing significant results for the environmental variables could stem from either a lack of true effects or a lack of adequate exposure measurement.

There remains some significant differences between buildings not accounted for by the environmental factors measured. Some plausible predictors were not recorded, including architectural features of the buildings studied, such as office design or office facing (see Hedge et al., 1989), as well as airborne microorganisms or endotoxins. In addition, building-wide social fac such as management policies or type of business w not recorded, but are also possible predictors.

The specific data collected limits the kind of qu tions that may be addressed. For example, in attempt to obtain a homogenous sample of buildir only those with one kind of ventilation system w sampled. It has already been shown in multiple stuc that type of ventilation system does have an effect reporting of symptoms. This study was thus unabl address whether or not this effect is due to partic pollutants which are introduced into an office envir ment at a higher rate due to air-conditioning.

In addition, buildings already designated as "si (*i.e.*, with a strong history of worker health complair were intentionally not included in the sample. T eliminates the possibility that the statistically sign cant differences found between buildings are due some kind of mass hysteria or social phenomer within sick buildings. For example, general knowlec among the workers that their building is consider sick may create an inflated perception of the pre lence of symptoms. Godish (1995) concurs that the p chosocial dynamics of problem buildings may in f be a risk factor in the reporting of SBS symptor However, by not including designated sick buildin we may not be able to uncover the real causes of creases in SBS symptom reports.

Another potential complication arises because comparing environmental variables which were me ured on one day with symptoms experienced over t previous month, it was assumed that the one day which sampling took place gave a representative val for each of the environmental variables over the pr vious month. This type of problem is common studies of this kind due to the high cost of environme tal sampling; it is just not yet economically feasible monitor individuals over a long period of time. It w also assumed that the workers who were found in t immediate vicinity of a particular sampling area act ally spend the majority of their time in that area. model a very mobile worker's symptoms on the e vironmental variables found in one location could misleading. These weaknesses in data collection wou lead to greater error in the measurements in no pa ticular direction, and hence, one expects, to a le powerful test. This is in effect a bias towards a nu hypothesis of no effect of an environmental variable SBS symptom severity.

Despite the shortcomings of the data, this analys contains elements which suggest changes to the typic analysis of this type of observational study. For e ample, when studying SBS, the true number of expe mental units is equal to the number of environmental samples taken, not the number of workers surveyed. If, in addition, the buildings under study have central ventilation systems, it may be that the number of experimental units is equal to the number of buildings, not the number of areas environmentally sampled. The only analysis currently available which truly accounts for this while still controlling for and measuring potential confounders on the individual level is the mixed linear model. In addition, by combining measures of the impact of symptoms on workers, researchers may be more confident that they have fully measured any effect of environmental or non-environmental factors. With these ideas in mind, future studies may be better designed and analyzed.

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