Consistent Pattern of Elevated Symptoms in Air-conditioned Office Buildings: A Reanalysis of Epidemiologic Studies

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Abstract: Published studies of the relation between type of building ventilation system and work-related symptom prevalence in office workers have been contradictory. A reanalysis was performed of six studies meeting specific eligibility criteria, combining published data with unpublished information obtained from study authors. Five eligible studies were from the United Kingdom, and one was from Denmark. Standardized categories of building ventilation type were created to allow comparison of effects across studies. Within each study, prevalence odds ratios (PORs) were calculated for symptoms in each ventilation category relative to a baseline category of naturally ventilated buildings. Air-conditioned buildings were consistently associated with increased prevalence of work-related headache (POR = 1.3-3.1), lethargy (POR = 1.4-5.1), and upper respiratory/mucus membrane symptoms (POR = 1.3-4.8). Humidification was not a necessary factor for the higher symptom prevalence associated with air-conditioning. Mechanical ventilation without air-conditioning was not associated with higher symptom prevalence. The consistent associations found between type of building ventilation and reported symptom prevalence have potentially important public health and economic implications. (*Am J Public Health* 1990; 80:1193–1199.)

Introduction

Health problems and non-specific symptom complaints apparently related to buildings or indoor air, sometimes referred to as "sick building syndrome" or "tight building syndrome," have been recognized for over 15 years[1]. Although particular chemical,[2] biological,[3] physical,[4] or psychological[5] factors have been implicated in some episodes, specific causes have generally not been identified.[6] Studies of this problem to date, generally carried out in buildings identified by worker complaints (referred to herein as "complaint" buildings) have demonstrated mostly what these episodes are *not*. They are not caused by known toxins at concentrations exceeding current health standards nor are they generally associated with known diseases. We still have little idea how frequently the excess symptoms reported in such episodes actually occur among office workers, or what if any chronic health problems in this population are related to office buildings.

It is difficult to study a phenomenon characterized only by self-reported non-specific symptoms with no accepted syndrome definition or objective tests available. A major weakness of investigations in buildings with widely recognized worker complaints is that occupant concerns are likely to upwardly bias symptom reporting, thus distorting the only outcome available for study. Until the development of useful objective tests, it will therefore be preferable to study buildings without recognized worker complaints (referred to herein as "non-complaint" buildings).

Reports on building-related health problems in the United States are almost without exception case studies of complaint buildings;[2–4,7–10] only one study compared the building under investigation to even a single noncomplaint building.[11] A number of recent European studies, however, have provided data from non-complaint buildings on relations between work-related symptoms in office workers and type of building ventilation.[12–16] Preliminary review of the European studies shows that mechanical ventilation, relative to natural ventilation, has been associated with increases,[12,16] with decreases,[17] and with no differences[22] in work-related symptoms; air-conditioning, has been associated with increases[17] and with no differences[16] in symptoms. Previous reviews of the literature on illness episodes in office buildings[6,27–30] have summarized available studies but have not discussed these discrepancies.

This paper presents a reanalysis of data from non-complaint building studies. The purpose was to determine if there were consistent relations between prevalence of specific symptoms and certain building ventilation factors: mechanical ventilation, air conditioning, and humidification. Although differences between the original studies did not allow direct comparison of results, additional information obtained from study authors allowed creation of a standardized set of ventilation categories, calculation of prevalence odds ratios, and comparison of findings across studies.

Methods

Selection of Studies for Reanalysis

Studies of work-related symptoms in office workers were selected from the literature, using specific eligibility criteria. For inclusion in this reanalysis it was required that:

- studies compared multiple non-complaint office buildings;
- data allowed comparison of prevalence for specific work-related symptoms between buildings of different ventilation type; and
- data were available allowing classification of buildings as naturally or mechanically ventilated, as air-conditioned or not air-conditioned, and as humidified or not humidified.

Six studies of worker symptoms in multiple office buildings[12–26] were included in this reanalysis. The studies included were all cross-sectional and compared work-related symptom prevalence in buildings with different ventilation types to a baseline symptom prevalence in naturally ventilated buildings. All studies tested for statistical independence of ventilation categories and symptom prevalence (using chi square or analysis of variance tests) but used no epidemio-

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logic effect measures (such as prevalence ratios or odds ratios) to assess this relationship. Five studies were conducted in the United Kingdom, and one in Denmark. (Findings of the six studies are summarized in the Appendix.)

Methods of Analysis

Five standard categories of building ventilation type were established, as described in Table 1. Information for this classification was extracted from published materials; where necessary, additional information was obtained directly from the authors, and subsequent classification of buildings was confirmed with them.* Ultimately, sufficient information was available for unequivocal classification of all buildings from the six studies into this common set of categories. Correct conversion of ventilation categories in the original studies to the ventilation categories in this reanalysis was not always straightforward; in such cases, the appropriate conversions are provided in footnotes to Table 2, along with publications from which the data were obtained.

Symptoms were organized into four groups:

- lower respiratory (tight chest, difficulty breathing, shortness of breath, wheeze, and flu-like symptoms);
- upper respiratory/mucus membrane (nose, throat, and eye symptoms);
- central nervous system (headache and lethargy); and
- skin (dry skin, itching skin, and skin rash).

From sample size and prevalence data reported for either individual buildings or groups of buildings in each study, numbers of subjects with and without each specific work-related symptom were calculated within each category of building ventilation type. Prevalence rates were then calculated. "Work-related symptoms" in all studies referred only to symptoms reported as improving on weekends or days away from work (and in study 1 and parts of study 2, also as having begun or worsened since starting work in the current building). Symptom frequency requirements varied between studies.

Baseline symptom prevalence varied widely between studies. Using the naturally ventilated building category as the reference group within each study, prevalence odds ratios and 95% test-based confidence limits[31] were calculated from prevalence rates for each work-related symptom within each of the other ventilation categories. The prevalence odds ratio was chosen as the most informative epidemiologic effect measure for cross-sectional prevalence data.[32,33]

*Personal communications: M. Finnegan, S. Burge, A. Pickering, A. Robertson, J. Harrison, O. Valbjorn.

Results

Table 2 gives the sample sizes for each study reviewed, in terms of number of workers and number of buildings in each ventilation category.

Table 3 gives prevalence data for specific work-related symptoms, as calculated for each study using the new building ventilation categories.

Table 4 gives prevalence odds ratios (PORs) for each work-related symptom in each ventilation category. Symptom prevalence in category II buildings (with simple mechanical ventilation) was comparable to that in category I buildings or lower, with one exception (headache prevalence in study 4, based on only one building in category II). This was in sharp contrast to the general pattern of higher symptom prevalence in air-conditioned buildings (categories III, IV, and V) found in all six studies.

The prevalence of central nervous system and upper respiratory/mucus membrane symptoms was almost without exception higher in the air-conditioned buildings than in the naturally ventilated buildings. Data on lower respiratory problems were relatively sparse and less consistent. Data on skin-related symptoms suggested higher prevalence in air-conditioned buildings.

Data on differences between air-conditioned buildings with different kinds of humidification were mixed. In studies 1 and 3, where these data were available, symptom prevalence in buildings with steam humidification was similar to that in those with no humidification. There was some suggestion in both studies of higher symptom prevalence in buildings with water-based humidification relative to both categories III and IV. For 18 of the 21 symptoms assessed between these two studies, point estimates in category V equaled or exceeded those in both categories III and IV.

In study 2, on the other hand, symptom prevalence in air-conditioned buildings with water-based humidification was generally comparable to or lower than that in air-conditioned buildings without humidification. More complete data from this study, however, were presented at a scientific meeting. They showed consistently *lower* symptom prevalence in air-conditioned buildings with water-based humidification than in those without humidification; symptom prev-

TABLE 1—Building Ventilation Categories for Comparison Across Studies

	Building Ventilation Categories				
	I	II	III	IV	V
Ventilation Characteristics	Natural*	Simple Mechanical**	Air-Conditioned No Humidification	Air-Conditioned Steam Humidification	Air-Conditioned Water-Based Humidification
Mechanical ventilation	No	Yes	Yes	Yes	Yes
Air-conditioning	No	No	Yes	Yes	Yes
Steam humidification	No	No	No	Yes	No
Drip, spray, or evaporative humidification	No	No	No	No	Yes

*operable windows only
**ducted airflow without cooling or chilling

TABLE 2—Study Sample Sizes by Building Ventilation Category

Study	Sampling Unit (Total N)	I Natural* (N)	II Simple Mechanical** (N)	III Air-Conditioned No Humidification (N)	IV Air-Conditioned Steam Humidification (N)	V Air-Conditioned Water-Based Humidification (N)
1*	Workers (951)	259	—	73	91	528
	Buildings (8)	3	—	1	1	3
2**	Workers (2587)	537	—	507	—	1543
	Buildings (27)	8	—	6	—	13
3***	Workers (4373)	442	944	1017	421	1549
	Buildings (47)	11	7	10	4	15
4†	Workers (1332)	206	118	—	—	1008
	Buildings (5)	2	1	—	—	2
5††	Workers (106)	47	—	—	—	59
	Buildings (2)	1	—	—	—	1
6†††	Workers (2778)	1166	1430	—	—	182
	Buildings (14)	6	7	—	—	1

*Source: Reference 15 was used, as it included an additional, steam-humidified, building not included in the initial report, reference 12, and it omitted two buildings included in the initial report specifically because of worker complaints. Category III buildings were described as having "mechanical ventilation."

**Source: Reference 16. Category III buildings were described as having "mechanical ventilation only." Category V buildings were described as "fully air-conditioned, with or without recirculation," or "humidified."

***Source: Reference 17 was used for data in categories I and II, but reference 19 was used for categories III-V, as it was the only report to include data from air-conditioned buildings by type of humidification, for all symptoms.

†Source: Reference 20. Category I buildings were described as "conventional" and category II as "unconditioned."

††Source: Reference 21.

†††Source: Reference 22. Data used were from the 14 town halls; buildings number 10, 20, 30, 40, 50, and 90 were in category I, number 121 was in category V, and the rest were in category II.

alence was still substantially higher than in naturally ventilated buildings.**

Buildings without natural ventilation may be sealed (i.e., have non-operable windows) or not. Although sufficient information was not available to allow incorporation of this factor into ventilation categories used for reanalysis, enough information was available to show a very strong relation between the presence of air-conditioning and presence of sealed windows in the buildings studied: only one of the 48 non-air-conditioned buildings had sealed windows, whereas 52 of the 57 air-conditioned buildings had sealed windows. Thus, given the limits of these data, symptom increases found to be associated with air-conditioned buildings may more appropriately be regarded as associated with air-conditioned, sealed buildings.

Discussion

This reanalysis suggests that sealed buildings with air-conditioning are associated with higher prevalence of work-related headache, lethargy, and eye, nose, and throat symptoms than unsealed buildings with no air-conditioning, even in the absence of humidification. It also suggests that although air-conditioned buildings with steam humidification are associated with symptom prevalence no higher than air-conditioned buildings without humidification, air-conditioned buildings with water-based humidification *may* be associated with higher prevalence of eye, nose, and throat symptoms than those with steam humidification.

Apparent discrepancies between the original reports were resolved by reclassification based on new information from authors of the studies. Buildings described as mechanically ventilated were actually air-conditioned without humidification in studies 1 and 2, and simply mechanically ventilated in study 3; in study 6, they were simply mechanically ventilated or, in one case, air-conditioned with water-based humidification.

The prevalence of some work-related symptoms was strikingly high in several studies in even the least problematic office buildings, suggesting a measurement problem. High prevalence of lethargy in category I buildings in studies 3 and 5 (50 percent and 62 percent) in fact reflects a very broad definition of "work-related" symptoms in these two studies, the least restrictive such definition in all studies reviewed (see Appendix). (That such high prevalence resulted from specifics of the study protocol is evident from the fact that study 5 remeasured buildings from study 1 with the protocol from study 3, and obtained prevalence estimates two to four times those in study 1, comparable to those in study 3.)[21] Symptom prevalences reported in study 6, also somewhat high, represented combinations of two to three specific symptoms assessed.[10] Such differences emphasize the need for standardized questionnaire design and data reporting.

One must be cautious in generalizing results of this reanalysis. The studies reviewed were all carried out in the United Kingdom or Denmark, and other countries may have differences in climate as well as in building and ventilation system design or operation.

Also, limitations in the data restrict conclusions that can be drawn from this reanalysis, due to a variety of possible biases in each study.

Bias from selection of buildings seems unlikely, as buildings in all studies were selected independently of worker complaints. Response bias among workers also seems unlikely, as response rates were high in all studies (see Appendix). Some selection bias due to cross-sectional study design

**J. Harrison, presented at Indoor Air Quality 89, San Diego, CA, April 17–20, 1989.

TABLE 3—Prevalence of Reported Work-related Symptoms among Office Workers by Building Ventilation Category

Study	Symptoms	Building Ventilation Categories I Natural (%)	II Simple Mechanical (%)	III Air-Conditioned No Humidification (%)	IV Air-Conditioned Steam Humidification (%)	V Air-Conditioned Water-Based Humidification (%)
	Central Nervous System					
1	headache	15.7	—	37.0	29.7	32.0
	Lethargy	13.8	—	45.2	29.7	41.3
2	Headache	20.7	—	39.3	—	35.6
	Lethargy	19.1	—	49.9	—	43.3
3*	Headache	39	33	45	48	47
	Lethargy	50	42	58	60	65
4*	Headache	20	36	—	—	40
5*	Headache	32	—	—	—	66
	Lethargy	62	—	—	—	86
6*	Headache, fatigue, or malaise	33	35	—	—	53
	Upper Respiratory/Mucus Membrane					
1	Nose symptoms	5.8	—	13.7	15.4	19.1
	Dry throat/blocked nose	8.1	—	17.8	16.5	29.9
	Eye symptoms	5.8	—	8.2	13.2	15.9
2	Nose symptoms	13.4	—	30.7	—	22.4
	Throat symptoms	15.5	—	31.6	—	30.8
	Eye symptoms	11.0	—	19.3	—	23.1
3*	Runny nose	19	16	24	25	26
	Blocked nose	40	32	48	48	55
	Dry throat	36	33	49	47	53
	Dry eyes	18	20	31	28	33
	Itching eyes	22	20	31	27	32
4*	Sore throat, coughs, colds	21	21	—	—	44
	Irritated/sore eyes	17	20	—	—	48
6*	Eye, nose or throat symptoms	27	26	—	—	42
	Lower Respiratory					
1	Tight chest	2.3	—	1.4	1.1	6.1
	Short of breath	1.5	—	0.0	0.0	1.9
	Wheeze	3.1	—	0.0	0.0	5.1
3*	Tight Chest	6	5	10	9	12
	Difficulty breathing	6	6	10	8	12
	Flu-like symptoms	15	14	27	27	27
	Skin					
1	Dry skin	5.7	—	5.5	9.9	10.8
	Rash	1.9	—	2.7	3.3	2.1
	Itching skin	2.9	—	2.7	4.4	5.5
2	Dry skin	6.4	—	10.5	—	12.5
6*	Dry skin or rash	6	7	—	—	13

*Prevalence data originally reported as integer values.

is possible as workers who left the workplace due to illness or discomfort were not included, but this would lead to underestimation of any real effects.

Because "negative" (non-significant) studies are generally less likely to be submitted or accepted for publication, reviews of the literature are likely to contain a disproportionate number of studies with positive findings, relative to all studies actually performed on that subject.[34,35] Publication bias may in this way have inflated the magnitude of associations in this review; however, larger studies are considered less prone to this bias,[35] and PORs for air-conditioned buildings were consistently elevated even in the largest studies reviewed. Furthermore, a consistent "negative" finding of this reanalysis was not subject to such bias: symptom prevalence in simply mechanically ventilated buildings was no greater than that in naturally ventilated buildings.

Possible information biases include reporting or interviewer bias and misclassification. Reporting or interviewer bias, due to increased worker or interviewer concerns about health in sealed, air-conditioned buildings, could have increased frequency of reported symptoms in such buildings and thus led to overestimation of odds ratios. This bias cannot be ruled out.

Awareness of the research hypothesis by interviewers or subjects could have had a similar effect. Interviewers were used only in study 1, so subjects in other studies could only have inferred hypotheses from the self-administered questionnaires. In study 1, with the highest PORs of all studies reviewed, interviewers conducted most interviews without knowledge of the buildings where subjects worked, and researchers had no prior hypotheses regarding ventilation type and symptoms other than lower respiratory.[12]

Misclassification bias could have occurred from crude classification of the very complex ventilation systems found

TABLE 4—Prevalence Odds Ratios (and 95% CIs) for Reported Work-related Symptoms among Office Workers in Different Building Ventilation Categories Relative to Naturally Ventilated Buildings

Study	Symptoms	Building Ventilation Categories I Natural POR (95% CI)	II Simple Mechanical POR (95% CI)	III Air-Conditioned No Humidification POR (95% CI)	IV Air-Conditioned Steam Humidification POR (95% CI)	V Air-Conditioned Water-Based Humidification POR (95% CI)
	Central Nervous System					
1	Headache	1.0	—	3.1 (1.7,5.7)	2.3 (1.3,4.0)	2.5 (1.6,3.8)
	Lethargy	1.0	—	5.1 (2.9,9.2)	2.6 (1.5,4.7)	4.2 (2.7,6.5)
2	Headache	1.0	—	2.5 (1.9,3.3)	—	2.1 (1.7,2.7)
	Lethargy	1.0	—	4.2 (3.2,5.5)	—	3.2 (2.6,4.0)
3	Headache	1.0	0.8 (0.6,1.0)	1.3 (1.0,1.6)	1.4 (1.1,1.9)	1.4 (1.1,1.7)
	Lethargy	1.0	0.7 (0.6,0.9)	1.4 (1.1,1.7)	1.5 (1.2,2.0)	1.9 (1.5,2.3)
4	Headache	1.0	2.2 (1.3,3.7)	—	—	2.7 (1.9,3.8)
5	Headache	1.0	—	—	—	4.2 (1.9,9.3)
	Lethargy	1.0	—	—	—	4.0 (1.6,9.9)
6	Headache, fatigue, or malaise	1.0	1.1 (0.9,1.3)	—	—	2.3 (1.7,3.1)
	Upper Respiratory/Mucus Membrane					
1	Nose Symptoms	1.0	—	2.6 (1.1,5.9)	3.0 (1.4,6.2)	3.8 (2.2,6.5)
	Dry throat/blocked nose	1.0	—	2.5 (1.2,5.1)	2.2 (1.1,4.5)	4.8 (3.1,7.6)
	Eye symptoms	1.0	—	1.5 (0.5,3.9)	2.5 (1.1,5.4)	3.1 (1.8,5.3)
2	Nose symptoms	1.0	—	2.9 (2.1,3.9)	—	1.2 (0.9,1.6)
	Throat symptoms	1.0	—	2.5 (1.9,3.4)	—	2.4 (1.9,3.1)
	Eye symptoms	1.0	—	1.9 (1.4,2.7)	—	2.4 (1.8,3.3)
3	Runny nose	1.0	0.8 (0.6,1.1)	1.3 (1.0,1.8)	1.4 (1.0,2.0)	1.5 (1.2,1.9)
	Blocked nose	1.0	0.7 (0.6,0.9)	1.4 (1.1,1.7)	1.4 (1.0,1.8)	1.8 (1.5,2.3)
	Dry throat	1.0	0.9 (0.7,1.1)	1.7 (1.4,2.1)	1.6 (1.2,2.1)	2.0 (1.6,2.5)
	Dry eyes	1.0	1.1 (0.8,1.5)	2.0 (1.5,2.7)	1.8 (1.3,2.4)	2.2 (1.7,2.9)
	Itching eyes	1.0	0.9 (0.7,1.2)	1.6 (1.2,2.1)	1.3 (1.0,1.8)	1.7 (1.3,2.1)
4	Sore throat, coughs, or colds	1.0	1.0 (0.6,1.8)	—	—	3.0 (2.1,4.2)
	Irritated/sore eyes	1.0	1.2 (0.7,2.2)	—	—	4.5 (3.2,6.5)
6	Eye, nose, or throat symptoms	1.0	1.0 (0.8,1.2)	—	—	2.0 (1.4,2.7)
	Lower Respiratory					
1	Tight chest	1.0	—	0.6 (0.1,4.8)	0.5 (0.1,3.8)	2.7 (1.2,6.4)
	Short of breath	1.0	—	0	0	1.2 (0.4,4.0)
	Wheeze	1.0	—	0	0	1.7 (0.8,3.7)
3	Tight chest	1.0	0.8 (0.5,1.3)	1.7 (1.1,2.6)	1.5 (0.9,2.5)	2.1 (1.4,3.2)
	Difficulty breathing	1.0	1.0 (0.6,1.6)	1.7 (1.1,2.6)	1.4 (0.8,2.3)	2.1 (1.4,3.2)
	Flu-like symptoms	1.0	0.9 (0.7,1.3)	2.1 (1.6,2.8)	2.1 (1.5,3.0)	2.1 (1.6,2.8)
	Skin					
1	Dry skin	1.0	—	1.0 (0.3,3.1)	1.8 (0.7,4.4)	1.8 (0.9,3.5)
	Rash	1.0	—	1.5 (0.3,8.0)	1.8 (0.4,7.9)	1.3 (0.4,4.3)
	Itching skin	1.0	—	1.0 (0.2,4.9)	1.6 (0.4,5.6)	1.9 (0.7,4.7)
2	Dry skin	1.0	—	1.7 (1.1,2.7)	—	2.1 (1.5,3.1)
6	Dry skin or rash	1.0	1.3 (0.9,1.7)	—	—	2.5 (1.6,4.1)

in large buildings. The resulting nondifferential misclassification, however, would have led to underestimation of any real effects.

A number of potential confounding factors could have affected results. Some non-building factors known to be related to symptom reporting[17,19,22]—such as particular social and work environments, gender, job types, workplace smoking, and season of measurement—could have introduced confounding if consistently associated with particular ventilation types. There is no evidence that these factors were related to building ventilation type in the buildings studied.

Studies 2, 4, and 5 reported no assessment of potential confounding factors.[16,20,21] Study 1 reported only that smoking prevalence was similar in all buildings studied.[12] For study 3, Hedge, *et al*,[19] performed a multivariate analysis examining simultaneous association of a number of factors with total number of symptoms reported by each individual. They reported that higher overall symptom prevalence was associated with air-conditioned buildings, independently of associations also found between symptom prevalence and various individual, psychological, occupational, and architectural factors.

For study 6, a multivariate analysis found that gender, job category, work activities, and psychosocial job factors were associated with work-related symptoms. Differences in symptom prevalence between buildings, however, remained substantially the same after multivariate adjustment, with symptom prevalence still highest in the single category V building.[23]

Some building-related factors may have caused confounding. Air-conditioned buildings, being on average newer than naturally or simply mechanically ventilated buildings, will be more likely to contain fluorescent lighting,[21,36] inner offices distant from windows, with no natural light,[21] "open-plan" office layouts,[20] newer synthetic materials which emit various organic compounds,[30] and materials with high absorptive surface area (such as carpets and cloth-covered partitions) capable of accumulating and re-releasing physical, chemical, or biological contaminants.[26,29,30,37] To produce spuriously the associations found, these factors would have to be strongly related to both symptom prevalence and ventilation type.[38] This possibility could not be evaluated in the studies reviewed here.

The patterns of association in this reanalysis suggest that symptom reporting is systematically related to still unidentified factors in sealed, air-conditioned buildings. If bias or confounding factors are not responsible for these patterns, these symptom increases may represent one or more as yet unidentified ventilation-related illness syndromes. Possible ventilation-related risk factors include inadequate fresh air ventilation, reduced thermal comfort, use of chemicals within ventilation systems to kill biologic agents,[27] and recirculation of infectious[39] or allergenic[30] biologic agents. Sufficient environmental data were not available from the studies reviewed to evaluate these factors (see Appendix).

Results of this reanalysis are consistent with increased exposure of workers to biologic aerosols from water within the ventilation system (i.e., on or under air-conditioning cooling coils, which dehumidify ventilation air, and in water-based humidification systems).[17,30] Inconsistent associations found between symptom prevalence and water-based humidification may reflect a dual effect of such systems: reduced risk of respiratory infections from humidification generally,[40] but increased risk of respiratory sensitization to biological contaminants (as in humidifier fever or hypersensitivity pneumonitis) from water-based humidification specifically.[41]

In conclusion, the reanalysis of epidemiologic studies presented here suggests that, at least in some countries, increases in building-related symptoms in offices may not be unusual events, but relatively common events not usually attributed to buildings. Future study of this problem, beyond investigation of complaint buildings, is advisable.

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APPENDIX

Summaries of Findings of Six Studies

Findings of the studies included in this reanalysis are summarized here; terms used to describe ventilation categories are from the studies themselves.

The first study,[12–15] involving eight buildings, found higher symptom prevalence associated with mechanical compared with natural ventilation, even higher symptom prevalence for buildings with air-conditioning, and the highest prevalence in buildings with air-conditioning and humidification. Whether air within air-conditioned buildings was recirculated did not markedly affect symptom prevalence.

The second study,[16] involving 27 buildings, reported higher symptom prevalence in both buildings with mechanical ventilation and those with air-conditioning and humidification, compared to buildings with natural ventilation. Increases in the two groups were similar. In this study, researchers included several buildings they suspected of having problems; they point out, though, that at that time the sick building syndrome was not known in the United Kingdom.*

The third and largest study,[17–19] involving 47 buildings, found lower symptom prevalence in buildings with mechanical ventilation relative to those with natural ventilation, higher prevalence in buildings with air-conditioning, and the highest prevalence in two subsets of buildings with air-conditioning: those with evaporative humidification,[18] and those with "water-based" air-conditioning systems (this refers to method of cooling the building[42,43] and is not related to type of humidification).

The fourth study,[20] involving five buildings, found prevalence of all symptoms measured to be higher in air-conditioned buildings relative to conventional (not defined in report), but prevalence of only one symptom higher in unconditioned buildings relative to conventional buildings.

The fifth study,[21] involving two buildings, found higher symptom prevalence in an air-conditioned, humidified building relative to a naturally ventilated one.

The sixth study,[22–26] involving 14 buildings (minimal data were reported on some additional buildings), found symptom prevalence in mechanically ventilated buildings higher, but not significantly so, than in naturally ventilated buildings. The oldest town halls had the lowest prevalence of symptoms.

The first two studies used physician-administered questionnaires, and defined work-related symptoms as those occurring more than twice in the previous year, and improving on days away from work;[12,16] symptoms were also required to have started or worsened since working in the current building, except for nose, throat, and eye symptoms in the second study.** All the other studies used self-administered questionnaires. Studies 3 and 5 defined work-related symptoms as those occurring more than twice in the previous year and also improving on days away from work.[17,21] Study 4 defined work-related symptoms as those reported to occur frequently at work.[20] Study 6 defined work-related symptoms as those occurring at least weekly and improving on days away from work.[22] Although individual symptoms were assessed in this study, data were reported only on groups of symptoms.

All studies achieved high response rates among workers in buildings studied—in study 1 from 75–97 percent;[12] in study 2 from 86 percent upward;[16] in study 3 from 67–100 percent, averaging 92 percent;[17] in study 5 averaging 97 percent;[21] and in study 6 from 61–93 percent, averaging 80 percent.[22]

No study reported outside air ventilation rates in buildings. In study 1, environmental measurements were taken in only two buildings, one with low and one with high symptom prevalence; no significant differences were found in the parameters measured—dry bulb temperature, globe temperature, relative humidity, air moisture content, air velocity, positive and negative ions, carbon monoxide, ozone, and formaldehyde.[14] In study 2, levels of airborne particles, as well as viable fungal and bacterial microorganisms, were measured in all buildings studied; no associations were found with symptom prevalence.[16] Study 6 reported that increased symptom prevalence was related to factors such as increased temperature and greater amounts of high surface area materials, open shelving, total floor dust, and potentially allergenic floor dust.[26]

Studies 1 through 5 assessed all buildings between November and March; study 6 between February and May.[22]

*Personal communication, J. Harrison.

**Personal communication, A. Robertson.

***Personal communication, A. Hedge.

Alfred Sommer Named Dean of Hopkins School of Public Health

Alfred Sommer, MD, MHS, a distinguished Hopkins ophthalmologist, epidemiologist and specialist in international health, has been named dean of the Johns Hopkins University School of Hygiene and Public Health, effective September 1, 1990. Sommer succeeds Donald A. Henderson, MD, MPH, who has served as dean for 13 years. The School of Public Health is the largest in the world, with more than 300 faculty members and 1,000 students from 75 countries and projects in nearly 40 nations.

Sommer is professor of ophthalmology at the School of Medicine and holds joint appointments in the departments of epidemiology and international health in the School of Public Health. He is internationally recognized for his pioneering work with vitamin A, in which he found that small, inexpensive doses can save the lives of millions of children around the world. Sommer's discovery came as a result of his work using vitamin A to prevent blindness in malnourished children in Indonesia and other developing nations.

A native of New York City, Sommer, 47, received his medical degree from Harvard in 1967 and his master of health science degree from the Hopkins School of Public Health in 1973.

Sommer is an adviser to numerous national and international groups, including the World Health Organization, the National Eye Institute, the Asian Foundation for the Prevention of Blindness, the International Agency for the Prevention of Blindness, Helen Keller International and the Royal Commonwealth Society for the Blind. He is president of the International Federation of Eye Banks and has published more than 180 papers, reviews or book chapters.