SICK BUILDING SYNDROME
Environmental Comparisons of Sick and Healthy Buildings

P. Sherwood Burge
Department of Occupational Lung Disease
East Birmingham Hospital, Birmingham, UK.

Phillip Jones
Welsh School of Architecture,
Cardiff, Wales.

A. S. Robertson
Institute of Occupational Health
University of Birmingham, UK.

Environmental measurements and plant surveys were made over two week periods in the winter heating season in six office buildings. The offices were chosen from a large group which had been selected without knowledge of health problems amongst the workforce. The original buildings were grouped according to ventilation category, buildings were studied with natural ventilation, air conditioning with induction units, and air conditioning with all air systems. Within each ventilation category two buildings were surveyed, one whose occupants had a high prevalence of symptoms suggestive of building sickness, and one with a lower prevalence. The environmental measurements of temperature, air change rate and humidity did not differentiate between the pairs of buildings with high and low building sickness prevalences, suggesting that these were not in themselves major causes of the sick building syndrome. There was a correlation between standards of maintenance, and of knowledge of the plant and the prevalence of building sickness suggesting that inadequate standards of maintenance are an important risk factor for the sick building syndrome.

INTRODUCTION

We have used the Building Symptom Index, the average number of work related symptoms per worker in a building, as an indicator of building sickness and have studied 47 office worker populations (l). This has shown that there is a continuous spectrum of buildings which cannot be easily separated into "sick" and "healthy" buildings (Figure 1). As the prevalence of symptoms varies depending on the sex and job status of the workers, we have corrected the crude building symptom index for these two factors by weighing the personal symptom index (the number of work related symptoms in an individual) with a factor to make all workers equivalent to male managers (the group with the least symptoms).

METHODS

From our original study of 47 office worker populations we selected three pairs of buildings, one of each pair to have a high building symptom index and one to have a low building symptom index (1). The three pairs were selected with different ventilating systems, one pair were naturally ventilated, one pair had all air systems (VAV, variable air volume) and one had local induction units. The building characteristics are shown in Table 1. Selection was unrelated to any known conditions of the ventilating system, the buildings were selected to be within reach of the survey team. A random sample of workers within each building completed the validated

Table 1 Characteristics of the buildings studied

Ventilation	Sealed	Humidifiers	Chillers	Deep plan	Single rooms %	Age of Building (yrs)	Floors	Smokers %	Building Symptom Index	Corr-ected BSI
Natural										
NVL	-	-	-	-	65	50	4	15	1.53	1.03
NVH	-	-	-	-	1	46	4	18	3.57	2.43
Air Conditioned										
Induction units										
AWL	+	+/-	+	+	4	2	7	25	2.79	2.01
AWH	+	+	+	-	1	12	10	14	4.25	3.09
Variable Air Volume										
AAL	-	-	+	+	29	2	3	12	2.25	1.73
AAH	+	+	+	+	0	4	5	25	3.59	2.48

NVL = Natural Ventilation Low
NVH = Natural Ventilation High
AWL = Air-water Low
AWH = Air-water High
AAL = All-air Low
AAH = All-air High

Selection was unrelated to any known conditions of the ventilating system, the buildings were selected to be within reach of the survey team. A random sample of workers within each building completed the validated self-administered questionnaire including questions on 10 common symptoms of sick building syndrome (dryness of the eyes, watering of the eyes, stuffy nose, runny nose, dry throat, lethargy and/or tiredness, headache, 'flu-like illness, difficulty with breathing, and chest tightness). Symptoms which occurred at least twice in each year and were improved on days away from work were classed as work related. The average number of work related symptoms per worker (the building symptom index) was calculated and compared with a separate random sample of workers within the building carried out during the initial survey 2 years earlier.

An area of the building containing at least 20 workers was selected for further study as being a typical area of the building. In this selected area face-to-face interviews were conducted with the workers and detailed environmental monitoring carried out. Monitoring equipment was installed to measure continuously a range of environmental parameters over a two week period. Sensors were mounted on a pole and the following environmental parameters were measured. Air temperature at three heights (0.3, 1.25 and 2.0 meters), globe temperatures at one height (1.25 meters), relative humidity (%), sound level (dBA), lighting level (lux) and carbon dioxide levels (ppm). The parameters were measured every 30 minutes using a computerised data logger. Air change rates were calculated from the carbon dioxide levels, the volume of the room being studied and the number of occupants.

The building plant was surveyed in a standardised manner. (a) An interview with the operations and maintenance personnel (b) An examination of service drawings, operating manuals and maintenance documentation. (c) An investigation of the plant, filters, humidifiers and plant rooms.

RESULTS

The building symptom index on each building determined from two separate random selections of the occupants two years apart showed consistent values suggesting that this was producing reproducible measures of the building occupants. Details of the environmental measurements made in the building studies are shown in Table II. Dry bulb air temperature was higher in the sicker naturally ventilated building but no higher in the two sicker air-conditioned buildings, compared with the paired controls. In only one was the mean air

Table II. Environmental Conditions

Office	Temperature Air (degC)	Globe	RH (%)	Ventilation Rate (l/s/p)	Air Speed (m/s)	Lighting Level (lux)	Sound Level (dbA)
Naturally Ventilated							
NVL	19.9	19.9	38(14)	4.4	0.12	500-850	NA
NVH	22.6	22.6	33(18)	3.7	0.17	200-650	54
Air-water							
AWL	23.4	23.4	34(28)	18.5	0.08	600-950	50
AWH	21.9	22.1	46(36)	22.5	0.07	700-950	46
All-air							
AAL	21.6	21.6	23(18)	11.6	0.08	520-560	52
AAH	21.6	21.6	37(29)	10.8	0.17	600-800	49

Table III. Operation and Maintenance standards

Office	Operated as designed	Controls Settings	Controls Understanding	Manuals
Air-water				
AWL	No	Poor	Poor	None
AWH	Yes	Poor	Fair	Fair
All-air				
AAL	Yes	Fair	Good	Good
AAH	Not Known	Fair	Poor	Not available

Office	Maintenance Procedures	Records kept	Cleanliness Plant	Cleanliness Filters
Air-water				
AWL	Poor	Some	Poor	Poor
AWH	Poor	No	Fair	Poor
All-air				
AAL	Good	Yes	Very good	Good
AAH	Poor	Some	Poor	Poor

The globe temperatures were low in each building as they were studied in the winter, and were generally measured some distance from the window. Both the air conditioned buildings with the low BSI's had lower humidity than their "sicker" pairs. The best air-conditioned building had a mean value of 23%, which is well below the recommended standard. The ventilation rates were substantially higher per person in the air conditioned compared with the naturally ventilated buildings. The building with the higher BSI with induction units had greater air changes per person than the building with the lower BSI. These results suggest that air change rates in themselves are not determinants of the building symptom index. Air flow rates did not differentiate between those with high and low BSI's and lighting levels were very similar in all buildings. These comparisons have failed to show a difference in common measures of the environment. In particular they have shown that the building with the lowest relative humidity had less symptomatic workers than the buildings with high humidity, and that symptoms did not relate to ventilation rates within the ranges found.

Table III shows the results of the environmental inspection of the plant for the air conditioned buildings. Only the healthiest air conditioned building had satisfactory standards, operation and maintenance. Two were operated incorrectly in terms of general mis-setting of the controls and in two cases the humidification was not operating. In only one case were there adequate manuals describing the operating procedures, in the other buildings in which manuals were not available or inadequate, there was usually a corresponding lack of understanding shown by the operation engineer on how the system worked. In some cases the air temperatures were allowed to drift upwards to save on cooling load. In only one building was the maintenance procedure considered to be a good standard. In most buildings filters were either dirty or inoperative and in some cases cooling tower ponds were found to be covered with layers of sediment.

DISCUSSION

The causes of building sickness are likely to relate to the building, the person, the job and the organisation. The strength of this study into building factors lies in the comparison of similarly ventilated pairs of buildings with one of each pair having a substantially higher prevalence of symptomatic workers than the other. The environmental conditions in terms of the CIBSE recommended standards were generally unsatisfactory in all buildings. The naturally ventilated buildings had the lowest estimated ventilation rate with the highest CO_2 levels (averaging 1152 and 1334 ppm over the working period). The air-conditioned buildings all had much higher ventilation rates per person compared with the naturally ventilated buildings, indicating that ventilation rates and CO_2 levels in themselves do not relate to building sickness and cannot differentiate substantially between sicker and healthier buildings.

Despite the "sicker" buildings having a higher prevalence of "dry" type symptoms the relative humidity measured in these buildings was higher than the healthier pair. Workers with medical complaints are often referred to the building services operators. Those with dry nose, or dry eyes often rate the environment to be too dry and the building service management may respond by showing that the humidity is satisfactory and often implying that the worker is therefore wrong. There is no correlation between environmental humidity as measured by hygienists and that assessed by a person (2). Workers complaining of dryness of the environment, a very common situation, are in fact reporting something apart from the water content in the air. Building Services Personnel should not be expected to interpret medical symptoms, which are the province of occupational health personnel .

There was no significant difference between air speeds, lighting levels or sound levels between the paired buildings. When all other factors are accounted for there is still a substantial difference between the building symptom index from different buildings implicating the building itself as one of the causes of building sickness. In general workers in air conditioned buildings have more symptoms than naturally or mechanically ventilated buildings. This may partly relate to lack of environmental control (1). Few air conditioned buildings have a high degree of personal environmental control; those that do are amongst the healthiest of air-conditioned buildings. The current surveys suggest that the main difference between the sicker and healthier of each pair of air conditioned buildings was in the standard of maintenance, the standard of record keeping and the availability of good manuals describing the system in each building. Many systems are substantially out of balance and inadequately maintained. There is clearly room for improvement in these factors. Building service management in the United Kingdom often has low status and often low priority. The measure of performance for many operatives is the amount of energy used. No building service manager used environmental complaints or sickness ratings of the occupants as a performance measure. The present study has not shown why one of the naturally ventilated buildings was healthier than the other. This is a situation where further research is needed.

Public sector buildings have more problems than private sector buildings. This may be because of organisational factors or due to the buildings themselves and their maintenance. We have studied one building with both a public sector and a private sector occupant, both groups had similar Building Symptom Indices (1). This limited survey would suggest that the building was the cause. The line of accountability for the running of building services and implementation of change is often less clear in public sector buildings, many of which are also "cheaper" buildings. Which factors relates to their higher rate of building symptom indices is as yet unclear.

Resolving building sickness requires a team approach involving occupational health to evaluate the symptoms of the workers, the building service management to manipulate and maintain the plant, and office managers to represent the work done within the office. Much can be done by explaining to workers the capabilities and limitations of particular ventilating systems and how to get the best out of each system.

REFERENCES

1. Burge P.S., Hedge A, Wilson S, Harris Bass J, Robertson A.S. Sick Building Syndrome: A Study of 4373 Office Workers, 1987 Ann. Occup. Hyg 31:493-504

2. Anderson I, Lundquist G.R, Proctor D.F. Human perception of humidity under four controlled conditions, 1973 Arch. Environ Health; 26:22-27

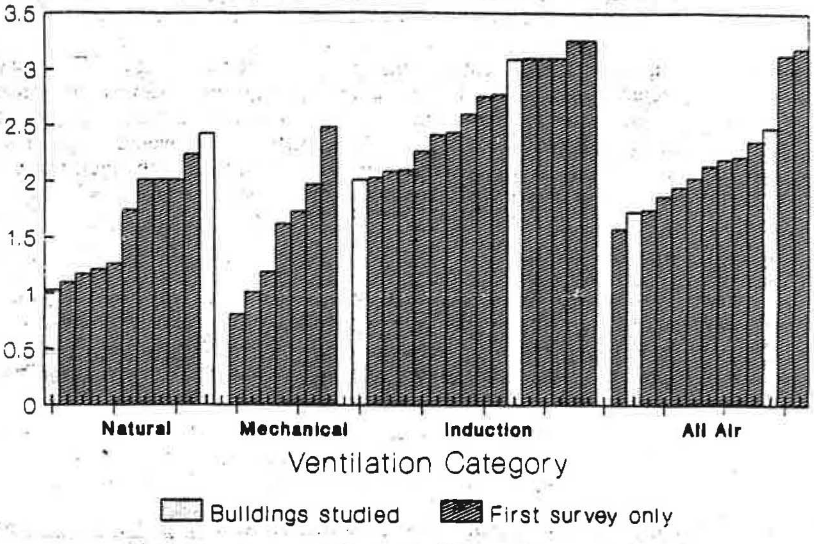

Fig.1 Building sickness indices - adjusted for job and sex, in the buildings originally studied.