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AN INVESTIGATION OF THE RELATIONSHIP BETWEEN MICROBIAL AND PARTICULATE INDOOR AIR POLLUTION AND THE SICK BUILDING SYNDROME

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The sick building syndrome has been the subject of research for approximately 10 years. Although it is often suggested that symptoms in office workers are due to circulating micro-organisms or particles, epidemiological studies investigating the relationship between them have been lacking. This study has combined medical and aerobiological assessments of offices in Great Britain and has found that, although airborne particulates and micro-organisms are unlikely to be a major cause of the sick building syndrome, the interpretation of the findings was complex. The results suggest that certain symptoms may be related to circulating fungi.

INTRODUCTION - Both the existence and the composition of the sick building syndrome are well established [1-4], but the causes are unknown. In problem buildings the air inside is often perceived to be less clean than the external air and thus a cause of symptoms. In this study the indoor air of15 buildings has been sampled and analysed for its microbial and particulate content. Symptom prevalences have also been assessed. The aim of the study was to quantify the level of airborne contamination typical of buildings with heating, ventilation and airconditioning systems (H.V.A.C.) and to compare it with that of naturally ventilated buildings. The study also sought to identify possible relationships between this contamination and symptom prevalences.

METHODS - Buildings studied A total of15 office buildings were studied (table 1). The ventilation categories have been defined in a previous paper [1]. Recirculation of indoor air was a feature of all the H.V.A.C. buildings. Two of the mechanically ventilated buildings had local induction units. The naturally ventilated buildings were adjacent to the H.V.A.C. buildings and acted as control buildings.

Air sampling A six-stage Andersen sampler was used to sample the air for the presence of bacteria and fungi. Samples were cultured on plates containing2% malt extract agar with 0.5mg ml^{-1} chloramphenicol and nutrient agar containing 0.5mg ml^{-1} cycloheximide for the isolation of bacteria and fungi respectively - bacteria at 15°C and 37°C and fungi at 25°C and 37°C. The results quoted for bacteria are the maximum numbers obtained on either plate[5]. Gravimetric air sampling was performed using a cascade impactor and a quartz crystal sampler (QCM). The results of the sampling are expressed as means for each ventilation group. These are based on 27 sampling sites for microbial sampling, 26 for the QCM and 25 for the cascade impactor.

Statistical Analysis The significance of differences between mean symptom prevalence rates in the ventilation groups was tested by computing standardised z scores. The Mann-Whitney U-test was used to compare the results of air sampling as these data tended to have positively skewed distributions. Scattergrams were constructed to investigate the relationship between each symptom and the various air sample variables. Pearson correlation coefficients were computed, the interpretation of which was confirmed by fitting a series of models to the data, using the method of maximum likelihood and using the GLIM statistical computer package. Statistical significance was set at the conventional 5% level.

RESULTS - Details of the study populations are shown in Table 1. The response rate to the questionnaire was 88% and less than 2% of the sample were absent because of ill-health. It can be seen in Table 2 that the highest symptom prevalence rates, apart from the prevalence rate of eye irritation, were found in the mechanically ventilated group of buildings. Lowest symptom prevalence rates were found in the naturally ventilated group of buildings. For all symptoms except dry skin and eye irritation, the differences between the mean group prevalence rates were highly statistically significant. However, the results in Table 3 show that the highest levels of particles and micro-organisms were obtained in the naturally ventilated buildings. Apart from the results obtained with the QCM, the mean results for the other methods of air sampling in the non-naturally ventilated buildings were significantly lower than those obtained in the control group. The mean dry bulb temperatures and relative humidities for the three groups of buildings were not significantly different. (Table 4)

The relationship between building mean symptom prevalence rates and the results of air sampling was complex. The correlation between symptom prevalences and the results of both cascade impactor and QCM sampling tended to be negative. This occurred both within and between ventilation types. For the microbial sampling, in many instances the overall correlation across ventilation groups was negative

whilst the individual ventilation group coefficients were positive. More sophisticated statistical analyses confirmed that the underlying correlation between symptom prevalences and air pollutant levels, adjusting for the differences between building ventilation groups was : a) positive for bacterial and fungal counts in all instances; b) negative for particulate air sampling. There was also a significant positive relationship between measured levels of viable airborne fungi and blocked nose, dry throat and dry skin.

DISCUSSION - This study was very similar to that of Finnegan et al[1]. The questionnaire was changed slightly to distinguish between runny/itchy nose and blocked(stuffy) nose. The results obtained in this study demonstrate significantly higher symptom prevalence rates in the fully airconditioned and mechanically ventilated groups of buildings compared to the naturally ventilated group of buildings. Unlike the findings of Finnegan et al, however, the highest symptom prevalence rates were found within the mechanically ventilated group of buildings. In the study of Burge et al[2] it was found that the highest symptom prevalence rates, as expressed as a mean building sickness index, were in buildings with local induction units, followed closely by those with centrally supplied induction/fan coil units. Comparison between studies is difficult because of the use of different categories for types of ventilation system but only 2 out of 6 of the buildings with local induction units had humidity control and this group could be considered to comprise buildings with similar types of ventilation to those included in the mechanical ventilation group of this study. Burge et al also had a mechanical ventilation group but only 1 out of 7 buildings in this group was hermetically sealed, which might explain the low building symptom index that existed for this group.

The results of the air sampling show that there were low levels of particulates and micro-organisms in the indoor air in all 3 groups of buildings, but the highest levels were found in the naturally ventilated group of buildings. The levels were less than the1000 colony forming units (CFU) m^{-3} suggested as an indicator of problems related to excess moisture in an office building[6]. In an investigation of several buildings, each with a history of repeated flooding, a level of airborne fungi >94000 CFU m^{-3} has been recorded[7].

The relationship between the symptoms and the results of the air sampling is enigmatic. For airborne particulates the consistent negative correlations, both between and within ventilation groups, suggests that there is no causal relationship between them and the sick building syndrome. For airborne micro-organisms there was a strong negative correlation between levels of bacteria and fungi and symptom prevalence rates which tended to dominate the positive correlations found within each ventilation group. It is possible, therefore, that there is a link between symptom prevalence rates and levels of airborne

bacteria and fungi, but the effect is relatively minor compared to other effects associated with particular types of ventilation system.

The finding of this positive correlation is not evidence of a causal relationship. It is possible that levels of airborne bacteria and fungi merely reflect a more fundamental environmental parameter. In addition, the air samples, which were taken during a single visit to a building, have been taken as an estimate of the level of contamination of the indoor air for the preceding 12 months. However, where samples were taken on different days in a building the amount of variation in the results was small. In addition, the variation in results, taken at different times of the year from buildings within the same ventilation group was also small for sealed buildings (except the QCM results) suggesting that the air samples may be reasonably good unbiased estimates for these buildings. There was a larger variation in the results from the naturally ventilated because these results were influenced by the numbers of windows that were open at the time of sampling.

Links between symptoms and micro-organisms have been proposed. Burge et al[2] suggested that microbiological contamination of humidifiers, chillers or duct work could be responsible for symptoms by an allergic or endotoxin-related mechanism. Another possible explanation might be the production of bio-metabolites from fungi that have an irritant effect on the upper respiratory tract mucosa and the skin. Low levels of bio-metabolites may have been present in the air contributing to its "stuffiness". Such a concept has been proposed by Fanger in the definition of the olf[8]. It is unlikely that a particular species of fungus was implicated in causing the symptoms as a variety of species were isolated in low concentrations from each building, the respective concentrations reflecting the time of year of the sampling rather than the type of ventilation system in the buildings.

The finding of a positive relationship between the symptom prevalence rates of sick building syndrome and airborne micro-organisms within the 3 ventilation groups is interesting and merits further investigation. However, the main finding of this study is that the indoor air of the hermetically sealed buildings studied was much cleaner than that of the naturally ventilated buildings whereas the occupants of the latter group of buildings had the lowest mean symptom prevalence rates. It is concluded that airborne particulates and micro-organisms are unlikely to be a major cause of the sick building syndrome.

REFERENCES

(1) Finnegan MJ, Pickering CAC, Burge PS. 1984. The sick building syndrome: prevalence studies. BMJ ;289 (Dec 8th):1573-1575.

(2) Burge PS, Hedge A, et al. 1987. Sick Building Syndrome: a study of 4373 office workers. Ann. Occup. Hyg.; 31(4A):493-504.

(3) Harrison J, Pickering CAC, et al. 1987.The sick building syndrome: further prevalence studies and investigation of possible causes. IN: Vol 2, Indoor Air '87: Proc 4th International Conference on Indoor Air Quality and Climate, West Berlin, 487-491.

(4) Skov P, Valbjorn O. 1987 The "sick" building syndrome in the office environment (The Danish Town Hall study). IN: Vol 2, Indoor Air '87:Proc 4th International Conference on Indoor Air Quality and Climate, West Berlin, 439-443.

(5) Austwick PKC, et al. 1989 Microbiology of Sick Buildings. IN: Airborne Deteriogen and Pathogens: Proc. of the spring meeting of the Biodeterioration Society, Edinburgh (Ed. Flannagan) .

(6) Morey PR. 1984 Case presentations: problems caused by moisture in occupied spaces of office buildings. IN: Evaluating Office Environmental Problems", ACGIH:10:121-127.

(7) Morey PR, et al. 1984 Environmental studies in moldy office buildings: biological agents, sources and preventive measures. IN: "Evaluating Office Environmental Problems", ACGIH:10:21-35.

(8) Fanger PO. 1987. A solution to the sick building mystery. IN: Vol 1, Indoor Air '87: Proc 4th International Conference on Indoor Air Quality and Climate, West Berlin, 49-53.

Table 1. Details of buildings in air sampling study.

	Full a/c	M. Vent.	Nat. Vent.
Number of buildings	5	6	4
Total population	1331	3033	246
People sampled	588	764	169
People interviewed	525	661	153
% Current smokers	24	24	23

Table 2. Prevalence (% sample) of work-related symptoms in buildings with different types of ventilation system.

MEAN VALUES (SD)

Symptom	Full a/c	M.Vent.	Nat. Vent.
Runny/itchy nose	18.2 (3.3)	28.9 (6.2)	9.7 (9.4)
Blocked nose	15.9 (5.2)	27.8 (5.9)	10.6 (6.9)
Dry throat	24.0 (8.4)	37.2 (8.6)	19.5 (13)
Eye Irritation	25.6 (8.3)	24.5 (6.8)	16.6 (6.3)
Headache	34.1 (7.9)	41.3 (8.5)	23.2 (5.9)
Lethargy	33.5 (9.4)	50.5 (7.8)	24.1 (5.9)
Dry skin	7.6 (2.0)	10.7 (5.0)	7.2 (4.6)

Table 3. Results of air sampling.

Sampling method	Full a/c	M. Vent.	Nat. Vent.	
Cascade Impactor				
Median	21.15	23.65	56.7	} No. particles.
Range	11.1-39.9	1.4-41.4	31.4-88.7	$}10^4 .m^{-3}$
Q.C.M.				
Median	29.79	20.71	43.02	$\}\ \mu g.m^{-3}$
Range	5.6-54.9	6.0-103.8	20.4-110.1	}
Bacterial Counts				
Median	200	232.5	686.5	} C.F.U. m^{-3}
Range	60-361	80-374	234-961	}
Fungal Counts				
Median	25.5	36	277	} C.F.U. m^{-3}
Range	2-103	2-167	35-978	}

Table 4. Microbial air sampling - mean temperature and humidity (SD).

	Full a/c	M. Vent.	Nat. Vent.
Temperature ^oC	21.6 (1.4)	24.3 (2.7)	22.7 (1.3)
Relative Humidity (% RH)	44.2 (5.2)	38.5 (7.3)	38.8 (5.5)

key
Full a/c = Full air conditioning
M. Vent. = Mechanical ventilation
Nat. Vent. = Natural ventilation