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31 OCT 1985

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Comparison of health problems related to work and environmental measurements in two office buildings with different ventilation systems

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Abstract

A cross sectional survey investigating "building sickness" was carried out in two buildings with similar populations of office workers but differing ventilation systems, one being fully air conditioned with humidification and the other naturally ventilated. The prevalence of symptoms related to work was assessed by a questionnaire administered by a doctor. A stratified, randomly selected sample of workers was seen (84% response).

Building sickness includes several distinct syndromes related to work, most of which were significantly more common in the air conditioned building than the naturally ventilated building—namely, rhinitis (28% v 5%), nasal blockage and dry throat (35% v 9%), lethargy (38% v 13%), and headache (31% v 15%). The prevalence of

work related asthma and humidifier fever was low and did not differ significantly between the two buildings.

An environmental assessment of the offices was performed to attempt to identify possible factors responsible for the differences in the prevalence of disease. Globe temperature, dry bulb temperature, relative humidity, moisture content, air velocity, positive and negative ions, and carbon monoxide, ozone, and formaldehyde concentrations were all measured. None of these factors differed between the buildings, suggesting that building sickness is caused by other factors.

Introduction

The typical modern office building is a sealed structure ventilated by a mechanical heating, ventilation, and air conditioning system and lit primarily by fluorescent lamps. In such buildings ambient conditions are controlled so that they are within the range considered to give optimal comfort throughout the working day. Despite this widespread complaints of ill health in such offices have recently been documented.¹⁻⁴ The pattern of symptoms reported usually includes headaches, lethargy and fatigue, sore eyes, and irritation of the upper respiratory tract and is commonly referred to as "building sickness"; this has reportedly reached large proportions in some North American offices. The causal agent has so far not been found.

Turiel *et al* conducted an extensive study comparing an air conditioned office building in San Francisco where occupants reported health problems with a non-problematic building.¹ Many different variables were measured, including 28 organic contaminants and odour, but none exceeded the recommended threshold limit. Carbon dioxide, fine particulates, hydrocarbons, and formaldehyde were, however, detected at higher concentrations indoors than outdoors. Indoor concentrations increased when the air conditioning system recirculated a greater proportion of the return air. Several questionnaire surveys of building sickness in the United Kingdom have shown the prevalence of complaints to be independent of smoking,^{5,6} to correlate with negative views on the adequacy of the ventilation

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and lighting systems, to be higher among women, and to be lower in naturally ventilated cellular offices⁴; but again causal factors have not been identified. Sterling and Sterling showed that complaints and symptoms of building sickness can be decreased by changing from sunlight simulating to standard cool white fluorescent lamps and by increasing the intake of fresh air from 25% to 87%.³ Subsequent complaints of eye irritation decreased by 31% and of headaches by 19%. Either change alone produced only a 6-8% decrease in complaints, but the reasons for this remain unclear.

The symptoms of workers with building sickness are non-specific. It is therefore important to differentiate between symptoms that are related to work and those that are not, and to compare the prevalence of symptoms with that in control populations. Such measurements have yet to be performed. This study aimed to rectify these limitations by investigating the prevalences of health problems related to work in two office buildings, one air conditioned and the other naturally ventilated, and to correlate these with environmental measurements.

Subjects and methods

A cross sectional study was conducted on office workers performing similar clerical and managerial tasks in two adjacent office buildings. One building was heated by radiators with open window ventilation, the other was fully air conditioned with sealed windows. The air conditioner included preheaters and humidification by water spray followed by chiller and heater baffles. Unlike other buildings that have been studied there was no recirculation of return air. A total of 288 workers were randomly selected from rooms in both buildings after initial stratification of the rooms according to floor level and aspect (north east, north west, south east, south west) so that a representative sample was obtained.

A questionnaire administered by an interviewer was given to each worker without the interviewer having knowledge of which building the worker worked in. Interviewing took place in a hall that was communal to workers from both buildings and sited adjacent to a corridor connecting the buildings. Workers were called from both buildings simultaneously. Each worker completed a numbered sheet with details of name, office, building, etc, and handed this to a clerk before the interview; the sheet was matched with the questionnaire only after the interview. No such details were requested during the interview, which was therefore performed blind. The questions were designed to cover a wide range of symptoms and symptom complexes, both specific and non-specific, that may be related to different characteristics of the office environment.⁶ The questionnaire also investigated the relation between these symptoms and work (date of onset and whether they improved on rest days).

Questions were classified into general groups, each characterised by a possible environmental mechanism, which was then investigated further: (1) Symptoms originally thought to be caused by low humidity: (a) dry throat or stuffy nose, or both; (b) dry skin; (c) difficulty with wearing contact lenses. (2) Symptoms of possible "allergic" reaction in nose and eyes: (a) itching and irritation or watering of the eyes; (b) itchy or runny nose. (3) Symptoms of possible humidifier fever: (a) fever; (b) lassitude; (c) joint aches and pains; (d) muscle pains; (e) headache. Humidifier fever was diagnosed when at least four of these symptoms were present, occurred repeatedly, and lasted one to two days, particularly on the first day of work after a break. (4) Symptoms suggestive of asthma: (a) chest tightness; (b) wheeze; (c) breathlessness. (5) Symptoms whose cause was unclear: (a) lethargy or tiredness; (b) headache.

Symptoms were regarded as related to work if they improved away from work and had started for the first time, or become more severe, after the subject had started to work in the building in question. Results are given only for symptoms related to work.

After the initial study of the prevalence of symptoms we carried out a survey of occupational hygiene in the buildings to identify environmental factors that might have caused the symptoms. The survey was performed over three separate weeks in January, April, and June, as we thought that external environmental conditions might be important.

Seven rooms that were each occupied by several workers in the air-conditioned building and three such rooms in the naturally ventilated building were selectively sampled for further study. Five of the air conditioned rooms and the three naturally ventilated rooms were selected from the initial survey because of a high prevalence of symp-

toms among the workers. The remaining two rooms in the air conditioned building had a low prevalence of symptoms.

Hygiene measurements were taken in all the sampled rooms. Globe temperature (using a 150 mm diameter globe thermometer was measured at head height for a seated person. A whirling hygrometer was used to find wet and dry bulb temperatures, and with these readings relative humidity and moisture content were calculated from a psychrometric chart. Air velocity was calculated using Bedford's equation⁹ with readings from a katathermometer. Positive and negative ions were measured using a Medion air ion analyser equilibrated for 20 minutes. Concentrations of the pollutants carbon monoxide, ozone, and formaldehyde were measured. Carbon monoxide was measured for 30 seconds at desk level using a carbon monoxide indicator (Dupont CO 2000). Ozone was detected by passing office air sampled at a rate of 3 litres/min through a solution of ethylene oxide. The resulting reaction emitted light, which was measured by a photomultiplier (Analytical Instrument Co model 560 portable ozone monitor) in parts per million. Similarly, formaldehyde was assayed by passing air through a sodium bisulphite solution,¹⁰ which was analysed with a Pye SP 30 spectrophotometer set at 580 nm.¹¹ The analysis could detect concentrations as low as 0.025 ppm.

Results

The questionnaire was completed by 241 workers (an 84% response), 129 (89%) from the air conditioned building and 112 (78%) from the naturally ventilated building. Table I compares the prevalences of the various symptoms in the two buildings. There were considerable differences between the two groups, particularly in the number of workers with "dry" symptoms and nasal and eye symptoms suggesting allergy. Symptoms of lethargy and headache related to work were also common, affecting about a third of the workers in the air conditioned building and 14% of those in the naturally ventilated building. There was a higher percentage of workers with symptoms suggestive of work related asthma in the air conditioned building, although the difference did not achieve significance. Humidifier fever was uncommon, with only two workers, both from the air conditioned building, thought probably to have the condition.

TABLE I—Prevalence of symptoms related to work in naturally ventilated building compared with air conditioned building. (Figures are numbers (%) of subjects)

Symptoms	Ventilation system		p Value
	Natural (n = 112)	Air conditioned (n = 129)	
"Dry" symptoms:			
Stuffy nose or dry throat, or both	10 (9)	45 (35)	<0.001
Dry skin		7 (5)	<0.05
Difficulty wearing contact lenses	1/7 (14)	4/9 (44)	NS
Symptoms suggestive of allergic reaction:			
Blocked, runny or itchy nose	6 (5)	35 (27)	<0.001
Watering or itching of eyes	8 (7)	28 (22)	<0.01
Symptoms suggestive of asthma:			
Chest tightness	4 (4)	9 (7)	NS
Wheeze	5 (5)	11 (9)	NS
Shortness of breath	2 (2)	4 (3)	NS
Symptoms with uncertain cause:			
Lethargy	15 (13)	47 (36)	<0.001
Headache	17 (15)	40 (31)	<0.01

The hygiene surveys were performed during one week in January, April, and June when the mean external temperatures during working hours were 7.1°C, 8.2°C, and 12.2°C respectively. There were no significant differences in any of the environmental variables measured between the two buildings (table II). The conditions were mostly within the ranges recommended for office buildings.¹² Relative humidity occasionally fell below 40%, mainly in January, when external temperatures were lower, but there was no significant difference in the frequency with which this occurred between the two buildings. Air velocity was generally lower than is thought comfortable,^{9,12} although again there were no significant differences between the buildings. Ozone readings ranged from 0.0 to 1.6 parts per billion (recommended maximum indoor concentration 50 parts per billion) and carbon monoxide concentrations from one to seven parts per million (threshold limit 50 parts per million). All the formaldehyde readings were below 0.025 parts per million.

TABLE II—Environmental measurements made in January, April, and June in naturally ventilated and air conditioned buildings (mean external temperatures 7.1°C, 8.2°C, and 12.2°C respectively)

Building	No of readings	Globe temperature (°C)	Dry bulb temperature (°C)	Relative humidity (%)	Moisture content (kg/kg)	Air velocity (m/s)	Positive ions (ions/cm ³)	Negative ions (ions/cm ³)
<i>January</i>								
Naturally ventilated:								
Mean (SD)	18	24.2 (3.1)	22.8 (0.86)	44.7 (5.7)	0.00786 (0.00077)	0.052 (0.05)	185* (13.2)	177* (25.2)
Range		22.5-35.0	21.5-25.0	33.0-48.0	0.0064-0.0094	0.00-0.16	175-200	150-200
Air conditioned:								
Mean (SD)	45	22.7 (1.29)	22.8 (1.20)	43.2 (6.1)	0.00748 (0.00073)	0.069 (0.04)	342† (123)	256† (104)
Range		20.5-27.0	20.5-25.0	30.0-58.0	0.0058-0.0088	0.00-0.21	175-500	150-350
<i>April</i>								
Naturally ventilated:								
Mean (SD)	12	22.5 (1.3)	21.8 (1.4)	42.3 (1.8)	0.00628 (0.00056)	0.053 (0.04)		
Range		20.0-23.5	19.0-23.0	39.0-44.0	0.0056-0.0072	0.00-0.13		
Air conditioned:								
Mean (SD)	30	23.0 (1.47)	22.7 (1.35)	43.5 (2.6)	0.00747 (0.00053)	0.062 (0.032)		
Range		20.0-26.0	20.0-25.0	38.0-50.0	0.0066-0.0084	0.00-0.18		
<i>June</i>								
Naturally ventilated:								
Mean (SD)	20	23.6 (1.02)	22.9 (1.1)	46.8 (4.3)	0.00748 (0.00089)	0.093 (0.010)		
Range		21.5-25.5	21.3-24.1	42.0-53.0	0.0058-0.0084	0.036-0.270		
Air conditioned:								
Mean (SD)	22	22.9 (1.02)	22.9 (1.0)	49.9 (5.9)	0.00877 (0.00077)	0.070 (0.004)		
Range		21.0-24.0	20.8-24.0	38.0-58.0	0.0074-0.0098	0.008-0.170		

*Mean of only three readings.

†Mean of only seven readings.

Discussion

In this study randomly selected groups of similar office workers were interviewed with the interviewer blind as to which office the worker worked in. Over 80% of the sampled workers were seen. The significant excess of symptoms found in the workers in the air conditioned building compared with those in the naturally ventilated building can therefore confidently be attributed to the building in which they worked.

Humidifier fever is the best recognised non-infective disease related to air conditioning systems and occurs mainly in industrial buildings, particularly in printing works.¹³ The disease often results from exposure to humidifiers that are contaminated with a wide range of micro-organisms.¹⁴ None of the workers in this study had unequivocal humidifier fever, although two workers with probable humidifier fever were identified in the air conditioned building. The lack of humidifier fever in our study probably relates to the cleanliness of the humidifiers, which was due to the lack of recirculated air passing through them and perhaps also to the use of biocides.

Asthma from exposure to contaminated humidifiers was first recognised by Solomon in 1974¹⁵ and was more recently identified in a printing works.¹⁴ Cleaning of the humidifier without any other change in work practice resulted in a substantial improvement in the affected workers, showing that the humidifier was the source of the asthma. A study of nine buildings with different types of ventilation showed that symptoms suggestive of asthma were related to air conditioned buildings with humidification rather than without humidification, again suggesting that the humidifier was the source of the symptoms.⁶ In our study symptoms suggestive of occupational asthma were uncommon; although they were twice as prevalent in the air conditioned building, the difference was not significant. There was probably a low prevalence of genuine occupational asthma in the air conditioned building.

Watering and irritation of the nose and eyes, clinically similar to that seen in allergic reactions, were largely confined to the air conditioned building. Previous work has shown that these symptoms are related to sealed buildings whether or not humidifiers have been installed, raising some doubt about whether they are due to allergy to the humidifier organisms or to other factors related to air conditioning systems.⁴

Dry throat, a stuffy nose, dry eyes, and dry skin have in the past been attributed to working in an atmosphere with low relative humidity or moisture content. Our study clearly showed an excess of these symptoms in the air conditioned building. The hygiene study, however, showed that the relative humidity tended to remain within the suggested range for comfort of 40-50%. More readings below 40% occurred in the air conditioned building than in the naturally ventilated building

during the week in January, but the excess was not significant. All readings of moisture content exceeded the recommended minimum of 0.0055 kg/kg. Although previous work has shown symptoms of dryness to be particularly related to buildings with a humidifier and therefore to material derived from the humidifier rather than the lack of humidity, the symptoms are also more prevalent in sealed buildings without humidifiers than in naturally ventilated buildings,⁶ which raises considerable doubt about their aetiology.

Work related lethargy or headache, or both, has been recognised only recently as a problem in sealed buildings and is the symptom complex colloquially called "building sickness."^{2,4,5} The prevalence of these symptoms in our study was similar to that found in other sealed buildings⁶: they occurred in 15% of those working in the naturally ventilated building and 30% of those in the air conditioned building. The significant excess in the air conditioned building was probably not caused by the humidifier itself as the symptoms were also present in the naturally ventilated building. This is borne out by a prevalence of lethargy related to work of 45% found previously in a mechanically ventilated building without humidification.⁶ Many causes have been suggested for these symptoms.

No single environmental variable tested explained the difference in the prevalence of symptoms. The temperature remained within the World Health Organisation's recommended range of 18-24°C. Mean values were similar to Fanger's predicted temperature for optimal thermal comfort of 22.6°C,¹⁶ and although small variations from this can produce many complaints there were no significant differences in temperature between the two buildings. Air velocity was generally below the 0.075 m/s recommended to prevent a sense of stagnant atmosphere⁹ but did not differ between the two buildings.

A build up of indoor pollutants has been suggested as a possible cause of many of the symptoms of building sickness. Similar symptoms have been reported in "tight" homes insulated with ureaformaldehyde.¹⁷ Our study showed undetectable formaldehyde concentrations in both buildings, making it improbable that formaldehyde was a cause. Ozone and carbon monoxide could also cause many of the symptoms, but ozone readings were lower in the offices than outdoors and carbon monoxide was well within acceptable limits. Whether a certain concentration of ozone is required for a feeling of "freshness" is unknown. Lack of negative ions has also been suggested as a cause of non-specific symptoms in air conditioned buildings.¹⁸ The buildings in our study had ion concentrations below those thought to be optimal, but the concentrations were similar in both buildings, making it improbable that they were the sole cause of the symptoms. They may possibly contribute to the symptoms in naturally ventilated buildings, although Hedge and

Eleftherakis showed no improvement in performance tests when the concentrations of negative ions were increased.¹⁹ Other possible causes for the symptoms have been suggested, including the spectral quality of light from fluorescent lamps and photochemical smog catalysed by fluorescent lighting systems.²

The possibility that group suggestion may explain the increased prevalence of symptoms in the sealed building must be considered. Such suggestion could come from other workers or from the media in view of the current concern about these problems. This could give rise either to a "mass hysteria" effect or simply to heightened awareness in one particular group of people. Symptoms due to mass hysteria are usually vague, often neurological, and often associated with nausea, dizziness, and fainting. Hyperventilation may occur with these symptoms, which are mostly transient and resolve rapidly.²⁰ None of these features were present in the workers that we saw.

The possibility of increased awareness in one particular group was minimised in our study by the management and unions from both buildings participating simultaneously throughout. The reason for the "medical survey" was not explained to the office workers. The prevalences of the various symptoms related to work have been found to differ consistently with different ventilating systems.⁶ Similarly, the prevalences of symptoms have been found to decrease after a change in ventilation and lighting systems.² Both of these facts suggest that the cause is physical rather than psychological.

In conclusion, we believe that most of the respiratory, eye, and nasal symptoms in air conditioned buildings are related to the ventilation system. On current evidence lethargy and headache are probably related to factors other than the ventilation system. Factors that need investigating include the stability of the environment in sealed buildings, the effects of different types of work practice, and the removal of control of lighting and

ventilation from the individual worker, as well as more extensive study of the quality of indoor atmosphere.

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(Accepted 9 May 1985)