SICK BUILDING SYNDROME (SBS) AMONG SCHOOL EMPLOYEES IN THE COUNTY OF UPPSALA, SWEDEN

B Sahlberg*, G Smedje and D Norbäck

Department of Occupational and Environmental Medicine, University Hospital and Uppsala University, Uppsala, Sweden

ABSTRACT

Sick building syndrome (SBS) in school employees was investigated in 38 randomly selected schools in mid-Sweden. A questionnaire was mailed in 1993, with follow-up questionnaires in 1995 and 1997. Exposure was measured in 98 classrooms in 1993, and 101 in 1995. In 1993, 1410 employees participated (85%). The prevalence of weekly ocular, dermal, upper-respiratory, and general symptoms in 1993 was 8%, 13%, 26%, 28%, respectively. General symptoms were more prevalent at higher temperature. Eye symptoms and tiredness were more common at lower lightning effect. Tiredness was more common at lower illuminance. Headache was more common at less daylight. Eye symptoms were related to total air concentration of bacteria. A relationship between observed building dampness and SBS-symptoms was found, but only in schools with an air exchange rate below the median value (<1.8 ach). The study indicates that bacteria, building dampness, temperature and illumination in schools, are associated with SBS.

INDEX TERMS

Building dampness, Illumination, School environment, Room temperature, Sick Building Syndrome (SBS)

INTRODUCTION

The school environment has been paid an increased attention. Poor ventilation, lack of maintenance and unsatisfactory cleaning are though to be common. Studies have shown that the air exchange rate is low, resulting in high concentrations of carbon dioxide (CO_2) and dust (Lee and Chang, 1999; Norbäck et al., 1990; Ruotsalainen et al., 1995; Smedje et al., 1997). Disorders that have been associated with indoor air pollution include asthma, allergies, and non-specific symptoms from eyes, upper airways and facial skin. These non-specific symptoms are sometimes referred to as the sick building syndrome (SBS) (Hodgson, 1995; Apter et al., 1995). Most studies on SBS have been dealing with office workers, and there are few studies on SBS in relation to different aspects of the school environment (Cooley et al., 1998; Norbäck et al., 1990, Lander et al., 2001). In the Swedish School Environment Project we have undertaken a number of studies of health effects and on the subjective perception of the indoor environment, among school personnel and pupils. The aim of the study was to investigate the prevalence and incidence of SBS, and frequent respiratory infections, in relation to the school environment. The following hypotheses were tested. SBS is related to different characteristics of the school building, fittings and furniture, and pollutants in the classroom air.

* Contact author email: bo.sahlberg@arbmed.uas.lul.se

METHODS

In Sweden, the compulsory school comprise 9 forms and the vast majority of Swedish children attend public schools. In the county of Uppsala, there were in 1992 approximately 130 such schools, from which we randomly selected 40, 38 participated. All employees in the 38 schools received a postal questionnaire in 1993, 1410 participated (85%). In total, 49 subjects (3%) that filled in the questionnaire, but had not been working during the latest 3 months were excluded. The questionnaire also requested information on personal factors including smoking habits, and atopy, and some questions about domestic exposures. There were also questions on different aspects of the psychosocial climate at work, consisting of analogue rating scales measuring from 0 (minimum) to 100 (maximum). In addition, there was also one yes/no question about frequent respiratory infections. The questionnaire contained 16 questions on SBS-symptoms during the latest 3 months period. They were classified as ocular, respiratory symptoms (nasal or throat symptoms), skin symptoms, and general symptoms (headache, fatigue, sensation of getting a cold, and nausea. In the multiple logistic regression analysis, weekly or daily symptoms were classified as “1”, and absence of the symptom, or symptoms less than once a week were classified as “0”.

Between March-May 1993 exposure measurements were performed in the schools. In each school we chose 2-5 classrooms so that the different buildings were represented. Measurements and inspections were performed in 98 classrooms in 1993, and 101 in 1995. Experienced occupational hygienists inspected the buildings and noted details on construction, materials, type of ventilation system, room size, amount of open shelves and fabrics, smells and signs of dampness in the construction. In each classroom we measured the temperature, relative humidity, air exchange rate, and the concentration in the air of carbon dioxide (CO_2), nitrogen dioxide (NO_2), formaldehyde, other volatile organic compounds (VOC), volatile organic compounds (VOC) of possible microbial origin (MVOC), respirable dust, moulds and bacteria. Temperature and humidity were recorded by a psychrometer and air exchange rate by a tracer gas decay method. Respirable dust and CO_2 were recorded by direct reading instruments. Formaldehyde was sampled on glassfiber filters, impregnated with 2,4 dinitrophenylhydrazine, with the sampling rate of 0.2L/min, during 4 h. Specific VOC and MVOC were sampled on beaded charcoal sorbent tubes (0.2 L/min; 4h), and total microorganisms on nucleopore filters with a pore size of 0.4 μm (1.5 L/min; 4 h). A diffusion-sampling badge were used for NO_2 with a 7 days sampling time. Settled dust was collected from desks, chairs and floor using a vacuum cleaner and was analysed concerning its content of cat and dog allergen using enzyme immunoassays, mite allergen using the ACAREX-test and endotoxin using a Limulus test. Methodological details have been previously published (Smedje et al., 1997).

Multiple logistic regression was used for the statistical analyses of relationships between weekly SBS symptoms or frequent respiratory infections, and observed building factors and measured exposures. As a first step, all personal factors and domestic exposures were forced into the model. Secondly, non-significant factors were excluded. Thirdly, all school building characteristics were forced into the model one by one. In all the statistical analyses, two tailed tests and a significance level of 5 % were used.

RESULTS

Personal factors and domestic exposure

In 1993, the mean age was 45 years (16-64 y). On the analogous rating scale, general satisfaction with work was rated 0.67 (SD=0.18) on average, .stress at work 0.55 (SD=0.22), and climate of cooperation as 0.66 (SD=0.21). Data on personal factors and domestic exposure is given in table 1. The prevalence of weekly ocular, respiratory symptoms, dermal symptoms, and general symptoms in females were 8%, 12%, 26% and 25%, respectively. The corresponding figures were 8%, 13%, 26% and 29% in males.

Table 1. Personal and occupational factors, and domestic exposures

Female	76%
Teacher	54%
A history of atopy	29%
Nickel allergy	22%
Doctors' diagnosed asthma	8%
Current smoker	19%
Detached/semidetached domestic house	64%
Indoor painting latest 12 months	24%
Signs of building dampness	15%
Environmental tobacco smoke at home	34%
House pets	42%

Building characteristics
In 1993, the mean age of the school buildings was 33 years; the oldest was built in 1900 and the newest in 1992. Mechanical supply and exhaust air systems, without air conditioning, were found in 61%, while 27% had natural ventilation only. The mean air exchange rate in the classrooms was 5.5 l/s p, with a range from 0.1 to 22.4 l/s p. All the classrooms had hard floor coverings, almost all of PVC or linoleum. In 19 % of the classrooms there were visible signs of dampness, mould growth or a mouldy odour. In about 70% of the schools there were daily floor cleaning. The desks were usually wiped once a week. In nearly half of the schools, there were no routines for washing the curtains, while in the others they were usually washed once a year. The epidemiological study on illumination and daylight in relation to SBS was performed in 1995. All classrooms had fluorescence strip lighting, and in 1995 with an average effect of 14.8 W/m2 (range 7.5 – 29.8).

Exposure measurements
In 1993, a quarter of the measurements the room temperature was 25 ºC or more. The concentration of CO_2 was above the recommended limit of 1 000 ppm in 41 % of the measurements. In two thirds of the classrooms the concentration of formaldehyde was below the detection limit of 5 $\mu g/m^3$. The highest concentrations of VOC were of alfa-pinen, delta-karen, limonene, toluene, xylen, n-decane, and n-undecane. The highest concentrations of NO_2 (11 µg/m3) and CO (0.9 µg/m3) were found in schools in the city of Uppsala. The most common indoor microorganisms were Cladosporium sp., *Penicillium sp*., *Mycelia sterilia*, Yeasts, and *Pseudomonas sp*. Traces of house dust mites allergens (Der p 1 or Der f 1), were found in three classrooms. Cat allergen (Fel d 1) and dog allergen (Can f 1) were found in all schools but one. Data on school exposure is given in table 2.

Weekly SBS and frequent respiratory infections in relation to the school environment
In the cross-sectional data from 1993, general symptoms were more prevalent at higher temperature. Eye symptoms were more prevalent at higher total air concentration of bacteria. A relationship between observed building dampness and SBS-symptoms was found, but only when combined with an air exchange rate below the median value (<1.8 ach). Frequent respiratory infections were more common in schools with lower air exchange rate, higher

concentration of respiratory dust, and more settled dust in the classrooms. The cross-sectional data from 1995 was used to analyse associations between illumination and ocular symptoms, headache and fatigue. Eye symptoms and tiredness were more common at lower lightning effect. Tiredness was more common at lower illuminance. Headache was more common in schools with less daylight. Data on significant relations are given in table 3.

Table 2 Exposures in 96 classrooms, measured in 1993.

Exposure factor	*Arithmetic mean*	*Min-max*
Temperature (ºC)	23.5	19.5-27.5
Relative humidity (%)	38	16-75
Carbon dioxide (ppm)	990	425-2800
Formaldehyde (µg/m^3)	6	<5-72
Sum of VOC (µg/m^3)#	35	2-302
Nitrogen dioxide (µg/m^3)	6	1-11
Carbon monoxide (µg/m^3)	0.2	<0.1-0.9
Respirable dust(µg/m^3)	19	6-60
Total bacteria (number/m^3)	52 000	8000-290 000
Viable bacteria (number/m^3)	900	100-18 000
Total moulds (number/m^3)	40 000	7 000-360 000
Viable moulds (number/m^3)	500	100-4 500
Sum of MVOC (µg/m^3)†	0.38	0.01-10
Settled dust (mg/classroom)	172	26-370
Cat allergen (ng/g fine dust)	133	<16-391
Dog allergen (ng/g fine dust)	643	<60-3990

#Sum of 14 identified VOC †Sum of 16 identified MVOC

Table 3 Associations between SBS, respiratory infections, and the school environment

Exposure	*Health outcome*	*Adjusted OR*	*95% CI*	*2-tailed p-value*
Nitrogen dioxide	Ocular symptoms	1.10	1.02-1.20a	<0.05
Total bacteria	Ocular symptoms	2.50	1.30-4.90[b]	<0.01
Damp building[c]	Ocular symptoms	1.94	1.04-3.62[d]	<0.01
Room temperature	General symptoms	1.10	1.01-1.20[e]	<0.05
Low air exchange rate	Respiratory infections	1.43	1.01-2.02[f]	<0.05
Respiratory dust	Respiratory infections	1.31	1.06-1.58[g]	<0.05
Settled dust	Respiratory infections	1.65	1.22-2.45[h]	<0.05
Illumination	Fatigue	0.90[i]	0.84-0.99	<0.05
Lighting effect	Eye symptoms	0.43[j]	0.21-0.90	<0.05
Lighting effect	Fatigue	0.59[j]	0.38-0.90	<0.05
Day light factor	Headache	0.62[k]	0.39-0.99	<0.05

a Change of coefficient per 1 μg/m^3.
c Combination of building dampness and ventilation below the median (1.8 ach)
b Change of coefficient per 10-fold increase.
d Both textile factor and damp building simultaneously in the regression model
e Change of coefficient per °C room temperature
f Dichotomised variable, personal outdoor air flow below 7 L/s (yes/no)
g Change of coefficient per 10 μg/m^3.
h Change of coefficient per 100 mg sampled settled dust
i Change of coefficient per 100 lux
j Change of coefficient per 10 W/m2
k Change of coefficient per 10% change of the day light factor
(m2 window area/m2 floor surface)

DISCUSSION

Prevalence of weekly eye symptoms, headache, fatigue and frequent respiratory infections were related to exposures in the school environment, including low air exchange rate, respiratory dust, settled dust, airborne bacteria, and observed signs of building dampness in the classrooms. Illumination, total lighting effect of the fluorescence tubes, and degree of daylight were also important factors for ocular symptoms, headache and fatigue. The response rate was high, and the exposure measurements were made after that the participants had answered the questionnaire. Moreover, signs of building dampness were observed independently of the questionnaire response, by an experienced occupational hygienist.

The significance of high room temperature (>22 °C) for SBS has been pointed out previously, but mainly in the office environment (e.g. Reinikainen and Jaakkola, 2001). In a recent Danish school study, schools with more SBS-symptoms had significantly higher mean room temperature (22.0 C), as compared to the room temperature (20.9 C) in schools with a low prevalence of SBS. (Meyer, 2000). The significance of low ventilation rate (< 10 L/s and person) has been associated with an increase of SBS-symptoms, mainly in office workers, and a few studies have found effects of poor ventilation on respiratory infections (Godish and Spengler, 1996; Seppänen et al., 1999). The relationship between airborne bacteria and eye symptoms is a new finding, to our knowledge. An association between total bacteria in dwellings, measured by the same method as in our study, and asthmatic symptoms have previously been demonstrated (Björnsson et al., 1995). Moreover, the Danish school study found an association between presence of visible mouldy surfaces (>0.25 m2) and an increased prevalence of SBS (Meyer, 2000). In another Danish school study, there were indications of an association between building related symptoms and indications of IgE mediated mould allergy (Lander et al., 2001). Our finding consenting illumination in schools, and symptoms is a new finding, to our knowledge. There are only a few studies on SBS in relation to illumination (Robertson et al., 1989; Wallace et al., 1993), Both these studies were from offices. They found an association between SBS and self-reported glare, but did not report any measurements of illumination factors.

CONCLUSION AND IMPLICATIONS

Many of the schools does not fulfil the current ventilation standards, requiring a minimum ventilation flow of 8 L/s and person, and a CO_2 concentration below 1000 ppm The study indicate that bacteria, building dampness, temperature and illumination are important factors in schools, associated with an increase of SBS and respiratory infections. Preventive measures should include to ensure adequate air exchange rate, lowering of the room temperature, elimination of building dampness and microbial growth, and sufficient cleaning.

ACKNOWLEDGEMENTS

This study was supported by grants from the Swedish Council for Work Life Research, the County Council of Uppsala, the Swedish Society of Medicine and the Swedish Association against Asthma and Allergy.

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