Indoor Air 1994, 4: 83–94
Printed in Denmark · all rights reserved

ISSN 0905-6947

Sick Building Syndrome (SBS) in Office Workers and Facial Skin Symptoms among VDT-Workers in relation to Building and Room Characteristics: Two case-referent studies

Jan Sundell[1,2], Thomas Lindvall[1], Bernt Stenberg[3], Stig Wall[4]

Abstract

In two case-referent studies the associations between questionnaire symptom reports, expressed as SBS (Sick Building Syndrome) in office workers or facial skin symptoms among VDT-workers, and physical data from offices in 160 buildings were investigated. The results show that low outdoor airflow rate and presence of certain pollution sources, such as copying machines, tended to be associated with an elevated prevalence of SBS. Buildings built or remodelled between 1977 and 1986, low-rise buildings with a horizontal roof and a foundation of the type "concrete slab on the ground", as well as rooms with flourescent tube lighting with metal shields were also associated with higher SBS risks. A number of factors were associated with an overrepresentation of skin symptoms among VDT-workers such as type of foundation (concrete slab on the ground and crawlspace), the frequency of floor cleaning and type of lighting (fluorescent tubes with glass/plastic shields). It has not been possible to establish conclusive explanations for these associations. The difference in associations between building factors and SBS, and between building factors and skin symptoms among VDT-workers points to different etiologies.

KEY WORDS:
SBS, VDT, Epidemiology, Ventilation, Building age, Photocopying machine

Manuscript received: 10 March 1993
Accepted for publication: 23 November 1993

[1] Institute of Environmental Medicine, Karolinska Institute, P.O. Box 60208, S-10401 Stockholm, Sweden
[2] Mailing address: Lignells väg 21, S-83142 Östersund, Sweden (Fax 46-63-114550)
[3] Department of Dermatology, University of Umeå, Sweden
[4] Department of Epidemiology and Health Care Research, University of Umeå, Sweden

Introduction

Building, room and ventilation factors are believed to influence the prevalence of symptoms and complaints often referred to as the Sick Building Syndrome (SBS). However, the basis for such statements is weak. Most reported studies deal with one or a few buildings only, and the results cannot be used for general conclusions regarding causes of SBS. Results from a few larger studies have been published, e.g. the Danish "Town Hall Study" (Skov et al., 1989; 1990) and the British "The Office Environment Survey" (Wilson and Hedge, 1987; Hedge et al., 1989). In the Danish study the importance of room characteristics such as temperature, fleece-factor (area of fleecy material in m^2 per m^3 room volume) and shelf-factor (length of open shelves in m per m^3 of room volume) were pointed out. In both the Danish and the British studies the type of ventilation and the size of the office were associated with the prevalence of SBS-symptoms. Although inadequate ventilation is a common denominator of buildings with SBS-problems (NIOSH, 1987) there has been no large multibuilding study of SBS where ventilation rates have been measured.

Skin symptoms (mainly facial) among VDT-workers have proved another problem of concern during the last decade (Nielsen, 1982; Knave et al., 1985; Lidén and Wahlberg, 1985; Berg et al., 1990; Stenberg et al., 1993). The etiology is not known. Apart from psychosocial factors, electric and magnetic fields from the video display terminal (VDT) as well as particulate matter have been discussed as potential risk factors (Sandström et al., 1991). The skin symptoms reported are similar to those reported in connection with SBS (Stenberg et al., 1990). There has been no multibuilding study of skin symptoms among VDT-workers which has included a thorough study of the office environment.

The aim of the present studies is to assess the association between building, room and ventilation characteristics, and the occurrence of perceived symptoms of SBS in office workers and of facial skin symptoms among VDT-workers, respectively.

Materials and Methods

A questionnaire study of office workers in three cities in a county in northern Sweden was carried out during October–December 1988. A proportional stratified sample of offices was drawn from the three cities. The study included 5,986 persons from all places of work with more than ten office workers, constituting approximately one third of all office employees in the county. The questionnaire included questions on demographic factors, work and building characteristics, perceptions of physical climate and psychosocial conditions and perceived symptoms. The questionnaire return rate was 95.7%. After exclusion of 13% of the respondents due to their spending less than half their working hours in the office, and because of absence from work during the study period etc., 4,943 office workers in approximately 210 buildings remained in the study. For further information on the total study design, the questionnaire and its reliability see Stenberg et al. (1993), and Sundell et al. (1993).

The questionnaire covered the following perceived symptoms:

1. "General" symptoms including "fatigue", "feeling heavy-headed", "headache", "nausea/dizziness" and "difficulties concentrating".
2. Mucous membrane symptoms including "itching, burning or irritation of the eyes", "irritated, stuffy or runny nose", "hoarse or dry throat" and "cough".
3. Skin symptoms including "dry facial skin", "flushed facial skin" and "itchy, stinging, tight or burning sensations in facial skin".

Answers were to be given in one of three categories: "Yes, often (every week)", "Yes, sometimes" and "No, never". The recall period was three months.

The questionnaire study was used as the screening base for two case-referent studies: one on the Sick Building Syndrome (SBS) and the other on facial skin symptoms among VDT-workers. Only respondents spending more than half their working hours in a specific room were included in the studies. Cases for the SBS-study were defined as persons reporting less than one hour daily work at a VDT and reporting the presence of symptoms from all three symptom groups: at least one mucous membrane as well as one skin symptom "Yes, often (every week)" and at least one general symptom "Yes, sometimes". Originally the same criterion "Yes, often" was used also for general symptoms, but the number of cases was then too small. We chose to enlarge the criterion for general symptoms as we assumed such symptoms to be the least specific with regard to associations with the indoor climate. In the VDT study cases were persons reporting more than one hour daily work at a VDT and reporting both sensory skin symptoms (itching, pricking or burning sensation in facial skin) and flushed and/or dry facial skin weekly. In both studies referents were chosen among those who fulfilled the same criterion as cases regarding VDT work. Referents were matched for city, sex and age.

The reason for not including VDT-workers in the SBS-study was 1) that we knew from the questionnaire study (Stenberg et al., 1993) that VDT work was associated with SBS and 2) that we wanted, in the actual studies, to analyse whether the possible associations between building and room factors and SBS on the one hand, and skin symptoms among VDT-workers on the other, were the same.

Originally, an equal number of cases and referents were chosen (2·225, 2·75). Some individuals were excluded since their place of work had undergone important physical changes between the questionnaire and the physical measurement periods (e.g. improved ventilation, new carpets, etc.). After exclusions and replacements (when practically possible), selected in the same way, the study groups consisted of 414 persons (SBS-group) and 156 persons (VDT-group), making a total of 570 persons. Neither the field investigators nor the persons included in the study knew whether a respondent was classified as a case or a referent.

Measurements and inspections were made on site in the 160 buildings in which the respondents worked. A "building" is defined as a whole building or a uniform part of a building served by one ventilation system. Basic facts regarding the type of building, its age, whether and when it had been rebuilt, type of ventilation and heating, occurrence of water- and mould problems etc. were gathered from the occupational health engineer working with the building. Data were assembled during January–April in 1989.

In 540 rooms the outdoor airflow rate was measured as specified by the Nordic Ventilation Group (1982) using either a calibrated hot-wire-instrument for measurement of airflow or an IR-instrument (Miran 1A) for measurement of air change rate, with nitrous oxide as tracer gas (decay method). For supply airflow the bag method was also used. Doors and windows were closed during measurements. In buildings with recirculation of air or with risk for leakage of exhaust air into the supply air the return airflow rate was measured with the tracer gas. Temperature and humidity were measured in each room at three heights at the place of work (0.1 m and 1.1 m above the floor, and 0.1 m below the ceiling) as well as in the supply air to the room (hot wire instruments: Rotronic Hygroscopic DV-2 with probe SA-100C). The mean outdoor temperature was +1.9°C (SD 3.0, range −10 and +12°C). Measured indoor humidity was standardized to the same outdoor air humidity (4.5 g/m^3) (Sundell and Lindvall, 1993). For further information on the indoor climate study see Sundell et al. (1991).

Parallel to the physical measurements, observations were made as to room size, surface materials, fleece- and shelf-factors, age of furniture, smoking habits, cleaning routines and presence of humidifiers, copying machines and laserprinters. All observations were assessed at room level and not related to the specific surroundings of an individual person.

Different samples of the total study groups have been used in the analysis. For subsamples we have, besides data on symptoms and buildings, also data from a psychosocial study (Eriksson and Höög, 1991) as well as from a clinical study of skin symptoms (Stenberg et al., 1990). For these groups multivariate analyses have been made, besides bivariate analyses, in order to adjust for the influence of psychosocial and personal factors. The SBS-groups have also been stratified into persons working in offices for 1–2 persons and persons working in other types of offices. The reason for this stratification is that the group "other types of rooms" is very heterogeneous with regard to type of room (i.e. lobbies, libraries, open-plan offices) and type of work, which introduces difficulties in an analysis of the importance of room factors. The group "offices for 1–2 persons" is more homogeneous in these aspects. In Table 1 some characteristics of the different samples are given.

Risk indicators under study are building and room factors as indicators of chemical, microbiological and other exposures.

Table 1 Some characteristics of the samples of cases and referents used in the analysis of SBS, and of skin symptoms among VDT-workers. Figures within brackets refer to respondents on whom psychsocial and clinical information is available and who are included in multivariate analysis (adjusted OR.)

Respondent characterisic	All rooms	Rooms for 1–2 persons	Other rooms
SBS-study			
Number of respondents	347–414 (266)	232–280 (197)	115–128 (69)
Cases %	50 (46)	47 (44)	55 (52)
Women %	83 (80)	78 (77)	93 (90)
Smokers %	25 (24)	26 (25)	21 (22)
VDT-study			
Number of respondents	126–156 (105)		
Cases %	49 (49)		
Women %	72 (74)		
Smokers %	31 (31)		

"Other rooms" are of type open-plan offices, lobbies, and libraries

It is assumed implicitly that certain building characteristics involve a greater degree of microbiological exposures (due to more frequent water damages and resulting microbiological growth) and that certain room characteristics (new surfaces, copying machines, tobacco smoking) imply a higher exposure to chemical contaminants in the air. Personal and work characteristics which might be important for the symptoms of a single individual are in this study dealt with as aspects not interfering with the group response (in the bivariate analysis), or as background information (which is adjusted for) in a multivariate analysis.

Statistical Methods

In the analysis, cases and referents are compared with regard to exposure to different environmental factors. As a measure of the strength and direction of the association between health outcome and exposure factors, the Odds Ratio (OR) is used. The Odds Ratios are given as point estimates with a 95% confidence interval within brackets (95% CI).

The results are initially presented as a crude, bivariate, partly stratified (postfactum) analysis. Results are also given of a multivariate logistic regression analysis in which a number of potential confounding factors have been controlled.

Three multivariate models have been used. The first one used in the SBS-study includes personal and work-related factors. The personal factors are reported asthma and skin sensitivity to sunlight (easily burned or eczematisized by sunlight). The work-related factors used are the reported amount of paperwork (Stenberg et al., 1990) and work satisfaction (Eriksson and Höög, 1991). The second model for SBS includes, in addition to the abovementioned factors, the outdoor airflow rate and the presence of copying machines in the office room. With regard to skin symptoms among VDT-workers, a third model was used including reported asthma, skin sensitivity to sunlight, amount of paperwork, work satisfaction and number of working hours in front of a VDT. In the logistic analysis, measured values are dichotomized and, when appropriate, the median value is used as the cut-point.

The data were analysed using Epi Info version 3 (Center for Disease Control, Atlanta) and SPSS/PC+ (SPSS Inc., Chicago) statistical packages.

Results

Characteristics of Building and Rooms

The mean age of the 160 buildings was 26 yrs, median 21. Approximately 50% had been remodelled as to construction and/or installations. The mean number of years since construction or remodelling, "virtual age", was 12 yrs, median 8.

Physically, the 160 buildings were characterized by having 1–12 floors, median 3. There was a "horizontal" roof on 55% of the buildings, 72% had a foundation type basement and 80% had a "heavy" construction of stone or concrete. With respect to ventilation, most buildings (93%) had a mechanical exhaust and supply ventilation system, a majority some kind of heat exchanger (typically rotary heat exchanger), 29% had recirculation of air and most systems (79%) were shut off during nights or weekends.

Room characteristics are given as percentile values in Table 2. With regard to type of room, 68% of the 570 respondents worked in rooms for 1–2 persons, 21% in "open-plan offices" and 11% in lobbies, libraries etc. The outdoor airflow rates in the measured 540 rooms had a mean value of 16.9 *l*/s,p (SD 13.0), median 13.6 *l*/s,p. Office rooms for 1–2 persons had a median value of 12.8 *l*/s,p, open plan offices 17.4 *l*/s,p, and rooms of the type lobbies and libraries 16.8 *l*/s,p. Three percent of the rooms were illuminated by electric bulbs, the rest by fluorescent tubes (1% open, 72% with metal shields, 24% with shields of glass or plastic). A great majority (70%) worked in rooms with furniture older than 5 yrs. As a mean value the floors in the rooms investigated were cleaned 2.75 times/week, median 2. In 21% of the rooms the floor was cleaned only once per week. With an assumed activity level of 1.2 met and a clothing of 0.9 clo, and assumimg only marginal heat loss by thermal radiation, the measured mean and median room temperature values are close to an optimal thermal comfort according to Fanger (1984).

Copying machines were present in 1% of rooms for 1–2 persons but in 31% of open-plan offices and in 27% of lobbies, libraries etc. In total, 10% of the respondents were working in rooms with a copying machine, 5% in rooms with a laserprinter and 8% in rooms that were humidified (almost exclusively by small room devices).

Among the respondents of the initial screening study, 19.8% of the men and 29.6% of the women reported themselves to be smokers. Smoking was generally allowed in 17% of the office rooms investigated. In 6% of the buildings containing 12% of the rooms investigated, smoking was prohibited. In general, smoking was allowed in specially designated "smoking-rooms".

Risk Analysis of Building Characteristics

In Table 3 the crude Odds Ratios, regarding SBS, for buildings of different age categories are given.

Table 2 Percentile values for selected factors in 540 office rooms in Swedish office buildings

	Percentile values %								
	10	20	30	40	50	60	70	80	90
Ceiling height, m	2.39	2.49	2.57	2.62	2.67	2.70	2.75	2.80	2.97
Room volume per person m^3	17.4	22.0	24.0	26.0	28.6	32.0	35.0	39.0	45.0
Shelf-factor m/m^3	0.09	0.14	0.18	0.22	0.27	0.33	0.42	0.53	0.76
Fleece-factor m^2/m^3	0.09	0.14	0.16	0.18	0.20	0.23	0.28	0.35	0.52
Temperature °C	21.6	22.1	22.5	22.7	22.9	23.1	23.4	23.8	24.1
Relative humidity %	17.3	19.8	21.3	22.6	23.8	25.1	26.4	28.0	30.0
Outdoor air flow *l*/s,p	5.0	7.8	9.2	11.1	13.6	15.8	19.4	24.8	33.3

Table 3 Number of buildings and respondents (cases and referents) and crude Odds Ratios (OR) and confidence intervals (CI) for cases of "Sick Building Syndrome" (SBS) when working in buildings of different years of construction and of different years of construction or remodelling

	Number of buildings n = 160	Number of respondents n = 414	OR	CI(95%)
Year of construction				
< 1950	20	46	1	
1950–1964	40	90	1.09	0.5–2.4
1965–1976	58	156	1.40	0.69–2.9
1977–1986	39	111	1.37	0.65–2.9
1987–1989	3	11	1.56	0.4–7.1
Year of construction or remodelling				
< 1977	55	145	1	
1977–1986	85	211	1.76	1,12–2,8
1987–1989	20	58	1.32	0,69–2,6

The category boundaries were selected before the data analysis and represent historically important changes in compulsory building codes and/or changes in building technology. With regard to year of construction there is a tendency, although not statistically significant, towards an elevated prevalence of SBS in "new" buildings (see also Tables 4 and 5). The "virtual" age of the buildings, i.e. from the year of construction or remodelling, tends to be related to the risk of SBS. In buildings of age-category 1977–1986, workers have a significantly raised "risk" in the crude analysis (Table 3). The adjusted Odds Ratios display the same trend (Tables 4 and 5).

The risk of skin symptoms among VDT-workers is not associated with building age but the trend is towards lower prevalences in buildings constructed after 1965 (Table 6).

Stratified analysis of combinations of different building characteristics shows that high rise buildings (3–12 floors) erected or rebuilt during 1965–1976 ("virtual age"), having a heavy construction and a "horizontal" roof, had low prevalences of SBS. Compared to this group of relatively "healthy" buildings, the trend is towards higher prevalences of SBS in high-rise buildings erected or rebuilt after 1977, having a leaning roof, as well as in low-rise buildings (1–2 floors) (Odds Ratios 1.49, CI 0.93–2.4 and 1.48 CI 0.8[illegible]–2.7 respectively). Among the low-rise buildings the elevated "risk" tends to be associated with a light construc-

Table 4 Crude and adjusted odds ratios for "SBS" when working in rooms and buildings with different characteristics [illegible] indicators). OR1 means adjusted for reported asthma (crude OR 2.1*), "skin sensitivity to sunlight" (crude OR 1.8*), "amount of paper work" ("Large amount" crude OR 1.7*) and "work satisfaction" ("Low satisfaction", crude OR 2.1*). OR2 means adjusted for the above mentioned factors (OR1) plus for the outdoor airflow rate and the presence of copying machines in the office room. OR = 1 for [illegible] working in rooms or buildings with the contrary characteristic. * means that the association is significant with $p < 0.05$

Risk indicators	All respondents (n = 347-414) % of respondents	All respondents Crude OR	Respondents with psychosocial/clinical data (n = 266) % of respondents	Crude OR	Adjusted OR1	Adjusted OR2
Building factors						
Built > 1965	67	1.3	68	1.5	[illegible]	1.7
Built or remodelled > 1977	65	1.6*	62	1.4	[illegible]	1.6
Buildings ≤2 floors	17	1.2	17	1.0	[illegible]	1.4
≤2 floors + horizontal roof + concrete slab on the ground	3	6.4*	5	6.2*	[illegible]	11.3*
Room factors						
Room for 1–2 persons	70	0.7	74	0.7	[illegible]	1.1
Plastic floor	30	1.4	26	1.1	[illegible]	0.9
Fluorescent tubes, glass/plastic shields	30	0.7	30	0.4*	[illegible]	0.3*
Furniture ≤5 years	28	1.0	26	1.1	[illegible]	1.3
Copying machine	11	1.9	8	3.4*	[illegible]	4.9*
Humidifier	7	2.2	6	1.8	[illegible]	2.1
Outdoor airflow rate < 13.6 l/s,p#	52	1.3	55	1.7*	[illegible]	2.1*
Room air temperature < 22.9°C#	49	1.1	49	1.4	[illegible]	1.4
Room air relative humidity < 23.8%#	50	1.2	49	0.9	[illegible]	1.0
Shelf-factor > 0.27 m/m³#	50	0.9	50	1.1	[illegible]	1.1
Fleece-factor > 0.20 m²/m³#	51	1.0	50	0.8	[illegible]	0.9
Floor cleaning ≤2 times/week	58	1.1	58	1.1	[illegible]	1.2
Water/mould problems	35	1.2	36	1.3	[illegible]	1.4

\# median value of the total study population

Table 5 Crude and adjusted odds ratios for SBS for persons working in rooms for 1–2 persons as a function of building and room characteristics (risk indicators). OR1 means adjusted for reported asthma (crude OR 2.0), "skin sensitivity to sunlight" (crude OR 2.1*), "amount of paper work" ("Large amount", crude OR 1.4) and "work satisfaction" ("Low satisfaction", crude OR 3.1*). OR2 means adjusted for the above-mentioned factors (OR1) plus for the outdoor airflow rate and the presence of copying machines in the office room. OR = 1 for persons working in rooms or buildings with the contrary characteristic. * means that the association is significant with $p < 0.05$

Risk indicators	All respondents (n = 232–286)		Respondents with psychosocial/clinical data (n = 197)			
	% of respondents	Crude OR	% of respondents	Crude OR	Adjusted	
					OR1	OR
Building factors						
Built > 1965	68	0.9	69	1.2	1.3	1.2
Built or remodelled > 1977	62	1.5	63	1.3	1.7	1.5
Buildings ≤ 2 floors	18	1.4	17	1.2	1.2	1.4
Room factors						
Plastic floor	20	1.4	19	1.3	1.1	1.3
Fluorescent tubes, glass/plastic shields	28	0.6	28	0.4*	0.3*	0.3*
Furniture ≤ 5 years	27	0.9	25	1.0	1.1	1.3
Outdoor air flow rate < 13.6 l/s,p#	57	1.7*	58	2.3*	2.4*	2.4*
Room air temperature < 22.9°C#	52	0.9	51	1.2	1.2	1.0
Room air relative humidity < 23.8% RH#	47	1.0	49	0.7	0.7	0.9
Shelf-factor > 0.27 m/m^3#	53	0.9	51	1.3	1.3	1.3
Fleece-factor > 0.20 m^2/m^3#	54	0.9	52	0.8	0.9	0.9
Floor cleaning ≤ 2 times/week	67	1.4	65	1.6	1.9	1.7
Water/mould problems	36	1.6	38	1.7	1.6	1.8

% median value of the total study population

Table 6 Crude and adjusted Odds Ratios for skin symptoms among VDT-workers when working in rooms and buildings with different characteristics (risk indicators). OR1 means adjusted for reported asthma (crude OR 1.7), "skin sensitivity to sunlight" (crude OR 1.7), "amount of paper work" ("Large amount", crude OR 2.1), "number of hours/day at a VDT" (> 4h/day, crude OR 1.8) and "work satisfaction" ("Low satisfaction", crude OR 2.2). OR = 1 for persons working in rooms or buildings with another characteristic. * means that the association is significant with $p < 0.05$

Risk indicators	All respondents (n = 126–156)		Respondents with psychosocial/clinical data (n = 105)		
	% of respondents	Crude OR	% of respondents	Crude OR	Adjusted OR1
Building factors					
Built > 1965	74	0.6	79	0.7	0.8
Built or remodelled > 1977	69	0.9	77	1.0	1.2
Buildings ≤ 2	29	2.0	28	1.7	1.6
Concrete slab on the ground/crawlspace	26	3.4*	25	3.5*	2.9*
Room factors					
Room for 1–2 persons	67	0.9	73	0.6	1.2
Plastic floor	27	1.2	26	1.4	1.6
Fluoroscent tubes, glass/plastic shields	22	2.7*	19	4.1*	4.3*
Furniture ≤ 5 years	41	1.7	37	1.8	1.6
Copier	11	1.3	8	2.4	1.5
Humidifier	10	2.5	10	5.6*	4.6
Outdoor air flow rate < 13.6 l/s,p#	46	0.7	48	0.6	0.6
Room temperature < 22.9°C#	50	0.8	50	0.8	0.9
Room air relative humidity < 23.8%RH#	52	0.9	51	1.2	1.5
Shelf-factor > 0.27 m/m^3	50	0.7	46	0.8	0.7
Fleece-factor > 0.20 m^2/m^3#	48	1.0	49	1.2	1.4
Floor cleaning ≤ 2 times/week	63	1.8	70	2.5*	3.1*
Water/mould problems	37	0.6	33	0.6	0.6

median value of the total study population

tion, OR 1.99 (CI 0.84–4.7), a light construction plus a horizontal roof, OR 4.0 (CI 1.27–13) and combinations of a light construction, a horizontal roof and a foundation type "concrete slab on the ground", OR 9.3 (CI 1.92–61). The latter group of high-risk buildings (9 buildings) was to a great extent erected between 1965 and 1976, had been remodelled later and had more often been subject to water and mould problems. These trends and differences remain even after adjusting for personal and work-related factors as well as for outdoor airflow rates and presence of copying machines (Table 4).

Skin problems among VDT-workers tended to be more frequent in low-rise buildings (OR 2.6, CI 0.97–6.9) compared to high-rise buildings with a combination of a heavy construction and a horizontal roof. Low-rise buildings with a heavy construction and a foundation type "concrete slab on the ground" had the highest risk of skin problems (OR 3.8, CI 1.22–12).

In low-rise buildings with reported water/mould damages, SBS tended to be more frequent (OR 1.67, CI 0.78–3.6), compared to low-rise buildings without such damages. There was no association between SBS and water/mould damages in high-rise buildings or between skin symptoms among VDT-workers and water/mould damages at all.

Neither SBS nor skin symptoms among VDT-workers were associated with type of ventilation. There was a tendency, although not statistically significant, towards an elevated risk of SBS in buildings with natural ventilation (OR 1.61, CI 0.4–7.0) or with mechanical exhaust ventilation (OR 1.93, CI 0.57–6.9). Adjusting for personal and work-related factors did not change these results. Regarding skin symptoms among VDT-users the material was too limited for further analysis.

Type of heat exchanger, recirculation of air or ventilation shut-off during nights or weekends were not associated with SBS or with skin symptoms among VDT-workers. However, ventilation running time less than 9–12 hours was associated with an elevated risk of SBS (OR 2.7, CI 1,52–5.0).

Risk Analysis of Room Characteristics

In a crude analysis of the rooms in the SBS-study, the risk tended to be elevated when outdoor airflow rates were below the median value. Considering only rooms for 1–2 persons, this crude OR was 1.67 (CI 1.00–2.8). Adjusting for personal factors, work characteristics and the presence of copying machines strengthened this association (Tables 4 and 5). The association between SBS and outdoor airflow rate was most pronounced when using the median (13.6 *l*/s,p) as cut-point as compared to other values between 8 and 25 *l*/s,p. Using 3 or 4 levels of outdoor airflow rates revealed a tendency towards a dose-response relationship.

Skin problems among VDT-workers tended to be inversely related to outdoor airflow rates in a crude analysis (OR 0.70, CI 0.35–1.40), as well as after adjustment (Table 6).

In the crude analysis there was a small tendency, not statistically significant, towards higher prevalences of SBS in "open-plan offices" (OR 1.23, 0.73–2.1) and "lobbies, libraries" (OR 1.62, 0.81–3.2) compared to rooms for 1–2 persons. When adjusting for personal and work-related factors, this trend was less pronounced. After adjusting for outdoor airflow rates, and especially for the presence of copying machines, the trend disappeared (Table 4). With respect to the risk of skin symptoms among VDT-users, there was no obvious difference in symptom prevalences in different types of rooms.

Illumination by fluorescent tubes with shields of glass/plastic tended to be associated with a low prevalence of SBS, a tendency that was strengthened, and statistically significant after adjustment (Tables 4 and 5). On the contrary, with regard to skin symptoms among VDT-workers, there was a significantly elevated risk associated with the same type of lighting (Table 6).

There was no association between the prevalence of SBS and the age of furniture. There was, however, a tendency, in both the crude and the adjusted analysis, towards an elevated prevalence of skin symptoms among VDT-users working in rooms with furniture less than 5 yrs of age. The Odds Ratios in a crude analysis were 1.51 (CI 0.7–3.2) for furniture 1–5 yrs, and 2.9 (CI 0.6–15) for furniture of <1 yr of age respectively, compared to furniture older than 5 yrs.

The presence of copying machines in the office room tended, in a crude analysis, to be associated with an elevated risk of SBS. After adjusting for personal and work-related factors and for outdoor airflow rate, this association was pronounced (Table 4). With regard to skin symptoms among VDT-users there was the same trend, though not significant (Table 6).

Humidifying of room air tended to be associated with an elevated prevalence of both SBS and skin symptoms among VDT-workers (Tables 4 and 6).

Plastic floor covering tended, in a crude analysis, to be associated with an elevated risk of SBS compared to linoleum and wall-to-wall carpets (OR 1.42, CI 0.93–2.2). However, after adjusting for personal and work-related factors, there was no such trend (Tables 4 and 5). With regard to skin symptoms among VDT-users, there was a tendency towards an elevated risk in rooms with plastic floor coverings in an adjusted analysis.

In rooms for 1–2 persons a low cleaning frequency, here defined as ≤2 times/week, tended to be associated with an elevated risk of SBS (Table 5). For all types of rooms skin symptoms among VDT-workers tended to be associated with a low cleaning frequency; this association became statistically significant after adjustment (Table 6).

There were no general associations between SBS or skin symptoms among VDT-workers, and room air temperature. There was, however, a tendency towards an elevated prevalence of SBS and a lowered prevalence of skin symptoms among VDT-workers when the temperature was below the median value (Tables 4, 5 and 6). There was no general association between relative humidity and variations in risks of SBS or skin symptoms among VDT-workers. The use of 3 or 4 levels of room air temperature or relative humidity, instead of 2 levels, did not change the general "no association" picture with regard to SBS or skin symptoms among VDT-workers.

There were no associations between SBS or skin symptoms in VDT-workers with fleece- and shelf-factors, ceiling height, room volume per person, type of interior ceiling, wall surface materials, type of sunshading or access to openable windows (12% had not).

Risk Analysis of Smoking

Smokers tended to have a slightly elevated risk of SBS (OR 1.32, CI 0.82–2.1) compared to nonsmokers in both a crude and an adjusted analysis. For skin symptoms among VDT-users this Odds Ratio was close to 1. In buildings with or without smoking there were small and insignificant differences in the risks of SBS, and of skin symptoms among VDT-users. Smokers did have a tendency towards elevated prevalences of both SBS and of skin symptoms among VDT-users in those buildings where smoking was prohibited or only allowed in specially designated "smoking rooms". However, nonsmokers had a tendency towards slightly lowered prevalences in such buildings.

Discussion

Buildings

In comparison with most other studies of building-related health and comfort problems, the case-referent studies presented involve a large sample of buildings (160). The initial screening questionnaire study involved a stratified random sample of approximately 210 buildings representative of the whole stock of office buildings in the county and including about 1/3 of all office workers in the county. The selection of the 160 buildings investigated was governed by the selection of an equal amount of cases and referents. Thus "problem" buildings might have been overrepresented in the final group of buildings. However, for no single symptom or group of symptoms, was there a difference in the frequency of answers "Yes, often (every week)" of more than 3%, neither for women nor for men, when comparing the investigated and non-investigated groups of buildings. Women had slightly more mucous membrane symptoms but slightly less general and skin symptoms in the investigated buildings. Men had slightly less of all symptom groups in the buildings studied. In total, the prevalence of persons having at least one symptom "Yes, often (every week)" was 46.6% in the buildings investigated compared to 46.9% in the rest. With regard to symptom reports, therefore, the buildings investigated seem to be representative of a typical population of office buildings in northern Sweden.

Questionnaire

As shown in Sundell et al. (1993) the test-retest reliability of the questionaire for single symptoms or groups of symptoms is fair to good (kappa values between 0.30 and 0.60). Although the intraindividual consistency between symptom reports, three to six months apart, seems low, the intragroup consistency seems high (ibid). The mean response of a large group of occupants seems fairly stable in spite of the fact that the individuals of the group may have partly changed. Thus, the questionnaire works well in studies of associations between building factors and symptom reports of the group.

Measurements

A problem with the study design is that inspections and measurements in buildings took place 3–6 months after the time of the questionnaire study. As we wanted to analyse health-data *vis-à-vis* building data, the data on buildings and rooms should be representative for the questionnaire period. Buildings or rooms which had been subject to changes, potentially influencing the indoor air quality, were excluded from the study. The data on building and room characteristics such as surface materials should therefore be relevant. With regard to airflow rates, the data should also be relevant as both the questionnaire and the physical measurement studies are from the same climate season (winter) meaning that the setting of the ventilation system has been the same.

Validity in the data on room temperature and indoor air humidity is more questionable. Measurements have been made only once in each room. Point measurements do not reflect daily or weekly variations. The humidity indoors is a function of the humidity outdoors, the outdoor airflow rate and factors within the room such as humidity sources and sinks. The measured humidity values have been adjusted with regard to the outdoor absolute humidity. Thus the humidity data used in the analysis are normalized to increase comparability. Measured high temperature values are correlated with complaints of "Too high temperature", ($p < 0.001$). Any misclassification as to indoor climate conditions would not be systematic but would underestimate a possible association with symptom reports, i.e. the Odds Ratio would go towards 1.

Water/mould Problems

The ways of obtaining the information on water/mould problems, i.e. reports from a health officer and from a walk-through inspection, implies underreporting. By "problem" is meant any type of damage whether there has been a risk of exposure for the persons under study, or not. Therefore, there may be both underreporting of damages and overreporting of damages with regard to risk of exposure. In conclusion, this means a potential misclassification when analysing the association between water/mould damages and symptoms. A possible association might be unrecognized or underrated.

Gender

Female gender is in the questionnaire study highly associated with elevated prevalences of both SBS and skin symptoms among VDT-workers as shown by Stenberg et al. (1993). In the present studies, cases and referents were matched for sex but a confounding effect of sex may still remain. However, an analysis of the influence of sex both through stratification and via multivariate techniques has shown that the remaining confounding effect of gender is negligible.

Risk Indicators for SBS

In Tables 4, 5 and 6 a summary of Odds Ratios from the crude bivariate analysis, the stratified analysis and the multivariate logistic regression analyses is given. The large covariation between exposure variables introduces large risks of confounding. The results from the bivariate analysis must therefore be assessed against the results from the multivariate analysis. Generally, the results from the crude and the multivariate analyses are consistent.

Besides personal and work-related factors (see Stenberg et al., 1993) only type of building, outdoor airflow rate, presence of copying machine in the office room and type of lighting act as essential "risk" indicators of SBS in an analysis of all rooms. For rooms for 1–2 persons, a low floor cleaning frequency and water/mould problems are also associated with SBS. Other, but not as important, "risk" indicators are the age of the building and the use of humidifiers. The association between symptoms and humidifiers may be due to the fact that room humidifiers sometimes are used to compensate for the sensation of "dry air" that commonly follows SBS. Surface materials, temperature, indoor air humidity, fleece- and shelf-factors did not seem to be important "risk" indicators of SBS. The associations between symptom reports, indoor air humidity and the sensation of "dryness" are further analysed in a separate report (Sundell and Lindvall, 1993).

This study is the first large multibuilding SBS-study that includes a thorough measurement of ventilation rates. Earlier we have reported an association between outdoor airflow rates and reports of different groups of symptoms (Sundell et al., 1991). That report, as well as the present one in which we have demonstrated an association between the prevalence of SBS and outdoor airflow rate, supports the general assumption that indoor air quality is important for the occurrence of SBS. Further, the analysis shows that the influence of outdoor airflow rates and photocopying machines are stronger after adjusting for each other. Most photocopiers are in rooms (open-plan offices) with a relatively high outdoor airflow rate. In a crude, non-stratified, analysis of ventilation rates, photocopiers act as confounders, hiding the impact of ventilation rates or vice versa.

The negative influence of type of building refers to low-rise buildings with a horizontal roof and a foundation of the type concrete slab on the ground, i.e. a type of building that in a Swedish climate is prone to get water and mould problems. However, in most cases these buildings were also low-budget buildings, including the choice of "cheap" surface materials and a low cleaning frequency.

The unexpected association between SBS and the type of lighting may be due to chance or to some factor or factors that in this study covary with the type of lighting: water/mould problems, airflow rate, "virtual" age, surface materials and age of furniture. Adjusting for such factors, however, changes the strength of the association only to a minor degree. Another possible explanation is that type of lighting is associated with the heat load in the room. The point estimates of room temperature do not favour such an explanation. In favour of regarding the result as a chance outcome is the fact that so far there is no simple explanation of the mechanism behind an effect of type of lighting.

The role of copying machines as "risk" elevators of SBS is most likely due to the emission of air pollutants. Another possible explanation is that copying machines are often handled by more "sensitive" persons such as women, or persons with a low work satisfaction. However, this theory is not supported by our results as the associations between SBS and copying machines are stronger in the adjusted than in the crude data.

Type or age of surface materials or furniture in the rooms are not strongly associated with SBS. This is a surprising finding since a great deal of the debate on SBS has been focusing on the role of off-gassing from surface materials. It should be noted, however, that the classification of materials has been coarse. For instance, all plastic floor materials are grouped together as are all wall-to-wall carpets. A more refined classification with regard to type and age of materials might have given other results. The importance of building materials may be part of the reason for the association between SBS and buildings built or rebuilt during 1977–1986, a period not only of energy conservation but also of the introduction of many new materials and building techniques.

Comparison with Other SBS-Studies

The results of the present SBS-study correspond in some respects with the results presented in both the Danish "Town Hall Study" (Skov et al., 1989; 1990) and the British "The Office Environment Survey" (Wilson and Hedge, 1987; Hedge et al., 1989) despite essential differences in the measure of effects. In the Danish study, general symptoms and mucous membrane symptoms were studied separately, whereas in the British study all symptoms were summarized. However, skin symptoms were not included in their studies. In the present study we have used a definition of a "full" SBS-case, being a person who reports having at least one general symptom ("Sometimes"), one mucous membrane symptom ("Often") and one skin symptom ("Often"). All three studies used a period prevalence but in the Danish and the present studies this period was 3 months compared to one year in the British study. Finally, in the British and the Danish studies they asked for "Work-related symptoms" while we have asked for "Symptoms" with no specification of work relation.

The Danish, British and the present studies gave similar results with regard to the importance of sex gender, psychosocial and work-related factors. Working in open-plan offices seems to be associated with an increased risk for SBS. This risk, however, is in our study essentially removed when adjusting for personal and work-related factors and the presence of copying machines. In the British, the Danish as well as in other studies, modern ventilation systems with mechanical supply and extract air have been looked upon as a risk factor for SBS. Especially air-conditioning systems with cooling and humidifying are reported to be associated with elevated prevalences of SBS. Such systems are uncommon in northern Sweden. In our material there is a rather strong tendency towards an increased risk associated with natural ventilation and mechanical extract-only systems.

Essential conclusions from the Danish "Town Hall Study" were that high fleece- or shelf-factors were associated with high prevalences of SBS. These results have not been verified in our study. With regard to the fleece-factor, type and age of wall-to-wall carpets may influence the different results of the two studies. The colder climate in northern Sweden means that the humidity indoors is lower and this may influence e.g. the microbial growth in the carpets. In Sweden such carpets are also less common than in Denmark. The importance of floor cleaning was pointed out in the Danish study. To some extent their results are supported by ours.

The description of SBS given by WHO (1986) states that the problems are primarily found in new and remodelled buildings. The prevalences were also shown in the "Town Hall Study" to be relatively lower in old buildings. We see the same tendency in our data. In our crude analysis, the "virtual" age of the buildings, i.e. the year of erection or remodelling, has a greater impact.

SBS?

The different criteria of SBS, used in different studies, point towards a fundamental problem. We have no generally accepted definition of SBS and we do not know whether there is one syndrome, "SBS", or if different symptoms or groups of symptoms that persons percieve in non-industrial buildings have different causes. If there are a number of different symptoms or syndromes with different causes then a simple total summary of symptoms (that happens to be included in the questionnaires) or even a summary of symptoms within groups of symptoms might conceal true associations. If, for instance, one symptom or syndrome is associated with "too much" of a factor and another symptom or syndrome is associated with "too little" of the same factor then an analysis of a "summary of symptoms" will lead to an underestimation of "true" associations. Further studies are needed to shed light upon this topic. In the planning of this study of SBS we thought that using a very strict criterion for cases would give us most information, but we do not know if that is true. Still, factors that are strong risk "indicators" of SBS in this study are probably important for those who perceive significant health problems from non-industrial indoor environments.

Risk Indicators for Skin Symptoms among VDT-Workers

The assumption that building and room factors influence the prevalence of skin symptoms among VDT-workers is supported by our results (Table 6). The "risk" indicators are not the same as in the study of SBS. Besides the floor cleaning frequency, the "risk" elevators of the prevalence of skin symptoms (i.e. type of lighting, type of foundation) are not commonly associated with the pollution load in rooms. They might influence the electric background field in the room, a factor that has been shown to be associated with symptom prevalence (Sandström et al., 1991). The mechanism behind such a possible effect is still hidden. The role of chance cannot be disregarded.

SBS versus Skin Symptoms among VDT-Workers

The associations between building factors and SBS, and between building factors and skin symptoms among VDT-workers are generally different. This difference points towards different etiologies of SBS and VDT-related skin symptoms.

Acknowledgement

This research was sponsored by the Swedish Council for Building Research, the Swedish Work Environment Fund and the FOLKSAM Insurance Group.

References

Berg, M., Lidén, C. and Axelson, O. (1990) "Facial skin complaints and work at video display units; an epidemiologic study of office employees", *Journal of the American Academy of Dermatology* 22, 621–625.

Fanger, P.O. (1984) "The philosophy behind a comfort standard". In: Berglund, B., Lindvall, T. and Sundell, J. (eds.) *Proceedings of Indor Air '84*, Stockholm, Swedish Council for Building Research, Vol. 1, pp. 91–98.

Hedge, A., Burge, P.S., Robertson, A.S., Wilson, S. and Harris-Bass, J. (1989) "Work-related illness in offices: A proposed model of the "sick building syndrome", *Environment International*, 15, 143–158.

Eriksson, N. and Höög, J. (1991) *The Office Illness Project in Northern Sweden. The Importance of Psychosocial Factors for Prevalences of Sick Building Syndrome (SBS) and of Skin Symptoms among VDT Workers*, Umeå, National Institute of Occupational Health (Undersökningsrapport 1991:13) (in Swedish with English summary).

Knave, B.G., Wibom, R.I., Voss, M., Hedström, L.D. and Bergqvist, U.O.V. (1985) "Work with video display terminals among office employees. I. Subjective symptoms and discomfort", *Scandinavian Journal of Work, Environment and Health*, 11, 457–466.

Lidén, C. and Wahlberg, J.E. (1985) "Work with video display terminals among office employees. V. Dermatologic factors", *Scandinavian Journal of Work, Environment and Health*, 11, 489–493.

Nielsen, A. (1982) "Facial rash in video display unit operators", *Contact Dermatitis*, 8, 25–28.

NIOSH (1987) *Guidance for Indoor Air Quality Investigations*, Cincinnati, NIOSH.

Nordic Ventilation Group (1982) *Methods for Measuring Air Flows in Ventilation Installations, T32:1982*, Stockholm, Swedish Council for Building Research (in Swedish).

Sandström M., Hansson-Mild, K., Lönnberg, G., Stenberg, B. and Wall, S. (1991) *Indoor Environment and Health in Northern Sweden. Electric and Magnetic Fields: a Case Referent Study of VDT Workers*, Umeå, National Institute of Occupational Health (Undersökningsrapport 1991:12) (in Swedish with English summary).

Skov, P., Valbjörn, O., Pedersen, B.V. and the Danish Indoor Study Group (1989) "Influence of personal characteristics, job-related factors and psychosocial factors on the sick building syndrome", *Scandinavian Journal of Work, Environment and Health,* 15, 266–295.

Skov, P., Valbjörn, O., Pedersen, B.V. and the Danish Indoor Study Group (1990) "Influence of indoor climate on the sick building syndrome". *Scandinavian Journal of Work, Environment and Health,* 16, 363–371.

Stenberg, B., Lönnberg, G. and Wall, S. (1990) "The office illness project in northern Sweden, Part II: Case referent study on Sick Building Syndrome (SBS) and VDT related skin symptoms – clinical characteristics of cases and predisposing factors". In: Walkinshaw, D. (ed.) *Proceedings of Indoor Air '90*, Ottawa, Canada Morgage and Housing Corporation, Vol. 4, pp. 683–688.

Stenberg, B., Hansson Mild, K., Sandström, M., Sundell, J. and Wall, S. (1993) "A prevalence study on Sick Building Syndrome (SBS) and facial skin symptoms in office workers", *Indoor Air,* 3 (2), 71–81.

Sundell, J., Andersson, B., Andersson, K. and Lindvall, T. (1993) "Volatile organic compounds in ventilating air in buildings at different sampling points in the buildings and their relationship with the prevalence of occupant symptoms", *Indoor Air 3* (2), 82–93.

Sundell, J., Lindvall, T. and Stenberg, B. (1991) "Influence of type of ventilation and outdoor air flow rate on the prevalence of SBS symptoms". In: *Proceedings of IAQ 91, Healthy Buildings*, Atlanta, ASHRAE, pp. 85–89.

Sundell, J. and Lindvall, T. (1993) "Indoor air humidity and the sensation of dryness as risk indicators of SBS", *Indoor Air* (submitted).

World Health Organization (1986) *Indoor Air Quality Research,* Copenhagen, WHO Regional Office for Europe (EURO Reports and Studies 103).

Wilson, S. and Hedge, A. (1987) *The Office Environment Survey*, London, Building Use Studies Ltd.