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SICK BUILDING SYNDROME – A CASE STUDY IN ZAGREB

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Sick building syndrome was investigated in a newly built office building. Information about health complaints from the employees was obtained by means of a self-administered questionnaire. Measurements of microclimate conditions and air pollution levels confirmed that the employees' complaints were justified. Because of a high percentage of complaints, the questionnaire was evaluated by means of factor analysis. The results showed logical grouping of the complaints and/or symptoms, suggesting credibility of the answers. Factor analysis proved to be an appropriate tool for detecting and evaluating sick building syndrome.

Key terms
factor analysis, formaldehyde, indoor air pollution, microclimate, questionnaire evaluation

Sick building syndrome (SBS), i.e. the occurrence of frequent complaints and medical symptoms in occupants of large public buildings was first recognised in USA and Scandinavian countries. It has turned out to be an important health problem related to air pollution. In the average 30 per cent of buildings may be classified as sick, but the proportion varies among countries. Basic symptoms and common features of sick buildings are described by WHO experts working on this problem (1, 2). Building factors (physical, chemical, biological) as well as psychosocial ones (sex, education, age, job-related factors) contribute to the occurrence of SBS (3). *Molhave* (4) defined SBS by postulating five criteria: (a) occupant complaints must include eye, nose and throat irritation, (b) the symptoms of irritation must be predominant among complaints, (c) systemic symptoms should be infrequent, (d) no single cause should be identifiable in relation to either the indoor environment or the occupants, (e) the percentage of the occu-

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pants reacting with the symptoms must be so great that the reactions clearly are normal reactions to an abnormal environment and not related to special conditions of the occupants. WHO expert group (2) recommended three basic steps for practical investigations: (a) inspection of the building (architectural and engineering plans, discrepancies between the originally intended and actual use, maintenance and cleaning procedures, visual inspection of the building and the technical installations), (b) administration of a questionnaire for obtaining information about thermal comfort, noise, lighting etc., measurements of noise, lighting, ventilation, suspended particulate matter and formaldehyde; step (b) should be performed only if step (a) does not clearly indicate the problem, (c) administration of an extended questionnaire, objective testing of subjects, extended measurements of air pollution and ventilation.

Physical factors that contribute to the occurrence of SBS are primarily microclimate conditions like air temperature, solar irradiation, relative humidity, air velocity, noise, lighting and electric discharges. Determination of thermal comfort is usually the first and the most frequently performed step in a number of investigations. Solar heat gain could contribute a great deal to the occupants' thermal discomfort (5) and should be registered. Relative humidity is not a good indicator of dry air sensation, and although being in the optimal range (40–60%) it does not exclude complaints (6). *Madsen* (7) reported the importance of low and constant air velocities, showing that their peak variations were relevant for discomfort. Among air pollutants, formaldehyde (HCHO) concentrations are most often connected with SBS. *Konopinski* (8, 9) suggested that the control of HCHO concentrations should encompass those below 25 μgm^{-3}, since the concentrations in the range 30–60 μgm^{-3} can produce an adverse effect in sensitive persons. *Bach and co-workers* (10, 11) performed several tests showing that CNS functions measured as a short-time memory, ability to concentrate and to attend are impaired by formaldehyde exposure. *Molhave* (12) measured the difference in mucous membranes irritation with elevated concentrations of pollutants. He found no adaptation, and showed that the subjects were able to distinguish between irritation and odour intensity. Smoking habit turned to be one of the most common complaints, but no difference between smokers and non-smokers in the prevalence of SBS symptoms were found (13). According to *Ahlstrom and co-workers* (14) smokers were less sensitive to odours than non-smokers. Psychosocial factors were stressed as important in a number of investigations. *Waller* (15) claimed that people needed to feel that they could influence if not control their working environment. *Lenvik* (16) failed to find clear associations or interrelationships between job function, job satisfaction and job control and the prevalence of SBS symptoms. In a study performed under controlled and satisfactory microclimate conditions *Šverko and Vukmirović* (17) reported having received more complaints from women than from men, from the young than from the older, and more from the people with poorer education than from the highly educated ones. *Lauridsen and co-workers* (18) pointed out the importance of background odour, which was detected in 20 per cent of the investigated buildings, even while mechanical ventilation was operating. Questionnaires relating SBS complaints and symptoms proved to be a good and reliable tool (19). *Burge and co-workers* (20) compared self-administered questionnaires with medical opinions and found that they could produce a satisfactory estimate of work-related symptoms, removing the potential bias of the interviewer.

Frequent complaints about working environment and prevalence of adverse health symptoms in an office building in Zagreb initiated an investigation of possible causes of complaints in respect to the experience of other countries.

DESCRIPTION OF SITE AND METHODS

The investigation was performed in a three-year-old office building in Zagreb in which microclimate conditions were controlled by forced mechanical ventilation and air conditioning system. Complaints of occupants were related predominantly to thermal discomfort and therefore the study was performed during summertime. The building outer surface was glass covered (90%) and there was no possibility of opening the windows. Inner walls and furniture were predominantly made of chipboard with surfaces covered by a polyurethane layer. The floors were covered by wall-to-wall carpets. After the inspection of the building, microclimate measurements, including air temperature, relative air humidity, air velocity, and thermal irradiation contribution, were performed in 27 randomly selected rooms. By determination of the corrected effective temperature the expected percentage of people who would find the microclimate conditions to be satisfactory was calculated.

Although the results proved that the complaints were justified, the investigation was continued by taking into account the type of construction and furnishing materials i.e. by determining formaldehyde, phenols, respirable particles and carbon monoxide concentrations in indoor air.

Formaldehyde samples were collected over 24 h in bubblers containing 50 ml of redistilled water with the flow rate of 1 $Lmin^{-1}$. Prefilters were used for removing suspended particles. The samples were analysed by a colorimetric procedure based on Schryver's reaction. Eleven samples were collected over a period of two weeks in a room representative of the building. Concurrently, nine samples of phenol and its homologues were collected at a flow rate of 1.5 $Lmin^{-1}$ in bubblers containing 50 ml of 0.1 M NaOH, coupled with diazotized p-nitroaniline solution into an azo dye, whose extinction was measured at 530 μm.

Short-term measurements of respirable particle and carbon monoxide concentrations were carried out in 27 rooms by means of Piezobalance 5000 TSI and Ecolyzer 2600, respectively.

A self-administered questionnaire was distributed and answered by 285 employees out of a total of 301 (95%). The employees' personal data (age, sex, school degree, smoking habit) are shown in Tables 1–3.

Questions pertained to individual health characteristics (blood pressure, allergies, bronchitis, asthma, diabetes), complaints (thermal discomfort, air humidity, odours, dust, ventilation, smoking, bad air, noise, inadequate lighting) and the symptoms observed (eye, nose, throat irritation, cough, itching, headaches, dizziness, nausea, mental fatigue, vertigo, loss of concentration). Frequencies of answers stating complaints were determined for the entire sample, and for the subgroups formed according to sex.

Table 1 *Age distribution by sex*

Years	Male (%)	Female (%)	Total (%)
<=25	2 (1.1)	7 (6.5)	9 (3.2)
30	17 (9.6)	28 (25.9)	45 (15.8)
35	43 (24.3)	12 (11.1)	55 (19.4)
40	27 (15.3)	22 (20.4)	48 (16.9)
45	32 (18.1)	15 (13.9)	47 (16.5)
50	15 (8.5)	12 (11.1)	27 (9.5)
55	13 (7.3)	7 (6.5)	20 (7.0)
60	18 (10.2)	5 (4.6)	23 (8.1)
65	10 (5.6)	–	10 (3.5)
	177 (62.1)	**108 (37.9)**	**285**

Table 2 *Educational level by sex*

Educational level	Male (%)	Female (%)	Total (%)
Primary school	1 (5.6)	10 (9.2)	11 (3.9)
Secondary school	73 (41.2)	47 (43.5)	19 (42.1)
College	14 (7.9)	6 (5.6)	20 (7.0)
University degree	89 (50.3)	45 (41.7)	34 (47.0)

Table 3 *Smoking status by sex*

	Smokers (%)	Non-smokers (%)
Male	82 (46.3)	95 (53.7)
Female	48 (44.8)	60 (55.2)
Total	130 (45.6)	155 (54.4)

Interrelationships between complaints and symptoms were determined on the basis of the significant odds ratios.

For the validation of the questionnaire, to test the objectivity of the answers and logical grouping of the complaints and/or the symptoms, factor analysis was applied. Bartlett test showed that intercorrelation matrix containing unities at the main diagonal could be used in such a procedure. Principal components were extracted by means of iterative Hotteling's procedure. Only factors with eigenvalues larger than unity were used (Guttman-Kaiser criterion). Factor rotation was performed by Varimax method.

RESULTS AND DISCUSSION

Results of the microclimate measurements are shown in Table 4. Evidently, the air temperature as well as the average irradiation temperature of the surroundings were above the recommended value (21) and led, as a consequence, to the expression of the feeling of thermal discomfort. Relative air humidity was in the optimal range, whereas air velocities, although there is no prescribed lower limit, were rather low. The corrected effective temperature showed that only 67 per cent of the people if submitted to such conditions would find the thermal comfort satisfactory.

Table 4 *Results of microclimate investigation*

	Ta (°C)	Tir (°C)	RH (%)	W(ms^{-1})	%
N	27	11	27	27	11
Average	25.4	27.8	51.5	0.105	66.5
Standard deviation	0.8	2.9	1.8	0.075	24.0
Maximum	27.0	31.0	56.2	0.287	98
Minimum	23.5	21.5	48.0	0.008	20

Ta – Air temperature Tir – temperature of surrounding irradiation
RH – Relative air humidity W – Air velocity % – percent of people exposed

Table 5 *Air pollutant concentrations* (μgm^{-3})

	Formaldehyde	Phenol	R. particles	Carbon monoxide
N	11	99	27	27
Cavg	167.1	9.8	90.7	4070
Standard deviation	38.7	5.7	52.5	2530
Maximum	242	25	200	8800
Minimum	115	5	20	1112

Results of air pollutant measurements are summarized in Table 5. Formaldehyde concentrations were high, mostly exceeding the recommended upper guideline value of 120 μgm^{-3} (21). Although phenol and homologues were not expected to be found in indoor environment, the results demonstrated their presence but below the odour threshold (160 μgm^{-3}). Respirable particle concentrations were relatively high and showed large room to room variation. Carbon monoxide concentrations were low, and their possible health effects could be neglected.

Measurements of microclimate factors and air pollution levels confirmed that the complaints of the employees were justified.

The relative frequencies of the complaints (9 items) and the health symptoms observed (12 items) are shown in Tables 6 and 7. Comparison of these results with those from Tables 4 and 5 clearly speaks of the existence of SBS if the results are elaborated in the way suggested by *WHO* (1, 2) and *Molhave* (4).

Table 6 *Relative frequencies of complaints (%)*

Complaints	Rank	All (285)	Men (177)	Women (108)	By sex	
					OR	P
Bad air	1	83.9	80.2	89.8	0.46	0.0328
Dust	2	61.4	57.1	68.5		
Dry air	3	57.9	53.7	64.8		
Ventilation	4	50.2	48.6	52.8		
High temperature	5	46.3	42.4	52.8		
Noise	6	39.6	36.2	45.4		
Odours	7	39.6	33.9	49.1	0.53	0.0110
Smoking	8	33.7	31.6	37.0		
Lighting	9	33.3	27.7	42.6	0.52	0.0096
Low temperature	10	29.5	16.9	50.0	0.20	0.0000
Humid air	11	24.9	22.6	28.7		

OR – odds ratio

Table 7 *Relative frequencies (%) of symptoms at office (Off) and permanent (Perm)*

Symptoms	Rank	Men (177)			Women (108)			Off		Perm	
		Off	Perm	Ratio	Off	Perm	Ratio	OR	P	OR	P
Fatigue	1	77	24	0.31	92	32	0.35	0.31	0.002		
Eye	2	62	19	0.31	77	23	0.30	0.48	0.008		
Concentration	3	63	9	0.14	66	8	0.13				
Headache	4	50	10	0.19	76	15	0.19	0.30	0.000		
Throat	5	53	17	0.32	60	19	0.31				
Dizziness	6	37	10	0.26	62	9	0.15	0.36	0.000		
Nose	7	40	11	0.27	52	13	0.25	0.61	0.043		
Vertigo	8	28	5	0.18	60	12	0.20	0.26	0.000	0.39	0.033
Cough	9	32	11	0.36	34	11	0.32				
Hoarseness	10	28	9	0.31	33	8	0.25				
Nausea	11	24	5	0.22	37	6	0.15	0.53	0.016		
Itching	12	3	2	0.68	17	9	0.56	0.18	0.000	0.23	0.000

Table 8 *Complaint–symptom odds ratios (P<0.05)*

MEN	HT	LT	DA	HA	OD	DS	SM	VE	BA
Itching		5.3							
Cough					3.1	6.5	2.6		
Dry eyes		2.9		3.8	2.5	2.1		2.0	
Dry nose	2.5	2.3	3.4	2.3	4.1	3.8	3.3		3.2
Dry throat			2.0		2.3	3.6			
Nausea	4.3		3.1	3.3	2.8	2.6			4.0
Dizziness	3.7		2.6		2.3	2.1	2.7		2.8
Concentration	4.0		1.9		4.0	2.9	3.7		2.4
Hoarseness			2.2		3.1	7.0	2.6		
Headache	2.6		2.3		3.9	3.2	2.9		3.1
Fatigue	3.8		2.0			2.8	4.2		3.0
Vertigo	2.7		2.3		3.0		2.7		

WOMEN	HT	LT	DA	HA	OD	DS	SM	VE	BA
Itching						4.4			
Cough				2.3	3.2				
Dry eyes						2.6			
Dry nose					3.2	2.2			
Dry throat			2.3		2.2	2.6			
Nausea	3.8	2.7	3.2	2.4	4.8				
Dizziness	2.9	2.4	2.6		5.6	3.0			
Concentration	2.5	4.4		2.8	5.0	4.0			
Hoarseness				2.5	3.0				
Headache		2.6			3.2	3.2			
Fatigue									
Vertigo					2.6				

HT – high temperature LT – low temperature DA – dry air HA – humid air OD – odours DS – dust SM – smoking VE – ventilation BA – bad air

In Table 8 the significance of the interrelations between complaints and symptoms is expressed as odd ratios. Because of a high percentage of complaints and symptoms reported, and because the data provided by women (Table 8) tended to be less consistent, the questionnaire validation was performed by means of factor analysis, to test the credibility of answers. The results of extraction of the first 11 significant factors (62.2 per cent of variation) from the answers including 33 variables are presented in Table 9. Only the variable loadings larger than 0.3 are shown. The results demonstrate a logical grouping of the variables, suggesting credibility of the answers. The first five factors are strongly connected with SBS, while others represent individual characteristics like allergies, blood pressure, complaints against smoking etc. Obviously, the complaints with higher ranks are grouped together. The fact that they are not grouped with the symptoms of eye, nose and throat irritation leads to the conclusion that another latent factor

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Table 9 *Significant variable loadings in 11 first-order factors*

Factor	1st rank loadings	2nd rank loadings
1	cough, nose, throat irritation, hoarseness	eye irritation
2	high temperature, dry air, dust, bad air	lower education
3	odours, ventilation, noise, humid air, low temperature	lower education
4	eye irritation, headache, loss of concentration, fatigue	dizziness, itching, higher education
5	nausea, dizziness, vertigo	headache
6	pollen, house dust, asthma	itching
7	low blood pressure, females	low temperature
8	smoking, non-smokers	odours, dust
9	high blood pressure, age	non-smokers, odours
10	lighting, itching	humid air, noise
11	bronchitis	

might be responsible for them, very likely formaldehyde as measurements suggest. Results also suggest that nausea, dizziness and vertigo are more frequently reported by women and that they have to do with low blood pressure. Loss of concentration and headache are more closely linked with other environmental factors such as noise, light and job-related factors (higher education). The high rank of dry air sensation (58 per cent) could not be related to the level of air humidity, thus confirming the finding mentioned earlier (6). Results also suggest that the smoking problem should be treated separately from the SBS since its elimination would have no influence on the existence of SBS.

Factor analysis can be appropriately used for SBS detection and evaluation. Moreover, hypothetical models should be developed and used by formation of the target matrix of expectations. Prochrust transformations of the obtained data should prove their similarity with the target matrix i.e. the existence of SBS.

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Sažetak

SINDROM NEZDRAVIH ZGRADA – PRIMJER U ZAGREBU

Obrađen je slučaj sindroma nezdravih zgrada na primjeru novosagrađene poslovne zgrade u Zagrebu. Zbog učestalih pritužbi zaposlenih, nakon pregleda zgrade provedena su mjerenja mikroklimatskih činilaca i mjerenja koncentracije onečišćenja zraka u radnim prostorijama. Izmjerene temperature zraka, kao i temperature toplinskog zračenja bile su često iznad propisanih graničnih vrijednosti, što je rezultiralo relativno visokim postotkom (33%) osjećaja neudobnosti. Relativna vlažnost i brzina strujanja zraka kretale su se u zadovoljavajućim granicama. Koncentracije formaldehida i respirabilnih lebdećih čestica bile su više od preporučenih graničnih koncentracija, dok su koncentracije ugljik monoksida bile niske. Zabilježene su i mjerljive koncentracije fenola, koji se ne očekuje u takvoj okolini. Istodobno su s pomoću upitnika prikupljeni odgovori zaposlenih o njihovim pritužbama i zdravstvenim tegobama. Rezultati mjerenja potkrijepili su pritužbe zaposlenih. Zbog izrazito visokog postotka prigovora, kao i zbog razlike u odgovorima uvjetovane spolom, rezultati obrade odgovora dobivenih na postavljeni upitnik podvrgnuti su faktorskoj analizi te su pokazali logičko grupiranje što potvrđuje iskrenost odgovora i upotrebljivost navedene statističke metode pri detekciji i izučavanju problema sindroma nezdravih zgrada.

Ključne riječi:
formaldehid, faktorska analiza, mikroklima, onečišćenje zraka u prostorijama, vrednovanje upitnikom

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