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TANAFFOS

Association of Sick Building Syndrome with Indoor Air Parameters

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Background: Energy crisis in 1973 led to smaller residential and office buildings with lower air changes. This resulted in development of Sick Building Syndrome (SBS). The objective of this study was to assess the association of SBS with individual factors and indoor air pollutants among employees in two office buildings of Petroleum Industry Health Organization in Tehran city.
Materials and Methods: The association between personal and environmental factors and SBS symptoms was examined by a reliable and valid combined questionnaire. Environmental parameters were measured using calibrated instruments.
Results: The results suggested that SBS symptoms were more common in women than men. Malaise and headache were the most common symptoms in women and men. Throat dryness, cough, sputum, and wheezing were less prevalent among employees in both offices. Light-intensity was significantly associated with some symptoms such as skin dryness (P = 0.049), eye pain (P = 0.026), and malaise (P = 0.043). There were no significant differences in prevalence of SBS symptoms between female workers of the two offices (P>0.05)
Conclusion: The main causes of SBS among the employees were recycling of air in rooms using fan coils, traffic noise, poor lighting, and buildings located in a polluted metropolitan area.

Key words: Sick Building Syndrome, Offices, Indoor air, Parameters

INTRODUCTION

In industrialized countries, people spend about 90% of their life indoors (office, home, sport centers, transportation vehicles, etc.) (1). Energy crisis in 1973 led to less air changes in offices and homes. Number of air changes per hour decreased from 2 to 0.2 or 0.3. The fresh air for each person also decreased from 20 – 30 ft^3/person to 5 ft^3/person. This led to lower ventilation capacities, indoor accumulation of air pollutants, increased exposure of occupants and resultantly compromised health (2). Application of double glazing to save energy minimized natural ventilation. On the other hand, indoor air pollution sources also increased due to the use of new office equipment, decoration and facilities. Modern office equipment such as laser printers, fax machines, copiers, etc. also produce air pollutants (2,3). Studies have shown that exposure of occupants to indoor air pollutants is 100 times higher than their exposure to outdoor air pollutants. Concentration of indoor air pollutions was found to be 2-4 times higher than that of outdoor air pollutants. In 1983, the world health organization (WHO) used the term “Sick Building Syndrome” for the first time to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to the time spent in a building, but no specific illness or cause can be identified (4). Many, including the WHO, believe that SBS is the main cause of absence from work and low efficiency of staffs and employees.

According to Rohles et al (1989), if ≥ 20% of employees suffer from symptoms that are relieved when they leave work at the end of the day, SBS needs to be considered for further investigations (5). The United States National Institute of Occupational Safety and Health (US NIOSH) calls improper air quality, insufficient ventilation, outdoor air pollutants, biological agent, indoor pollutant, building materials, noise, lighting, and other unknown factors as possible reasons for SBS (6). The targeted subsidies plan in Iran in 2010 and increase in prices of energy carriers are believed to be the initiation point for SBS in Iran. To date, there has been little discussion about SBS in Iran. Only three studies on SBS were found that investigated the related symptoms in Tehran and Mashhad (7-9). The purpose of this study was to assess the symptoms of SBS and their correlation with employees' personal characteristics and indoor environmental parameters in two office buildings of Petroleum Industry Health Organization in Tehran.

MATERIALS AND METHODS

All 170 employees of the two office buildings of Petroleum Industry Health Organization in Tehran city participated in this cross- sectional study. To determine the prevalence of SBS among office employees in two office buildings, HSE questionnaire (1995) was combined with Skov’s (1987) and Fanger’s (2000) questionnaires (10-13). The questionnaire included demographic information (including age, weight, height, work experience and BMI), job information**,** workplace conditions, and SBS symptoms such as mucosal and skin symptoms, headache, and nausea. Experts reviewed the questionnaire and the validity and reliability of the questionnaire were tested on 30 participants in a pilot study (Cronbach's alpha: 0.75). There were four answer choices: "always", "often", "sometimes" and "never" for questions. If the answer to a question was "always" or "often", symptoms were considered to be present in participant and if the answer to a question was "sometimes" or "never", symptoms were considered absent in the subject. Indoor environmental parameters of the buildings were measured using proper equipment. Carbon dioxide concentration was measured using CO_2 direct-reading METER- 1370 (14, 15); CEL-440 sound level meter with ±0.05 dB accuracy equipped with octave frequency analysis (16) was used to measure the noise level in the offices and the noise levels were compared using the American Society of Heating, Refrigerating and Air-conditioning Engineer’s (ASHRAE) recommended noise criteria for offices (17). Light intensity was assessed with Deutsches Institut für Normung (DIN) 5035 method and Hong Kong Labor Department principles for lighting assessment in workplaces (18) using Hagner digital luxmeter EC1 with ±0.05 lux accuracy (18,19). Humidity, temperature and air velocity were measured with standard devices for two weeks in January (18). Health effects of electromagnetic fields were also evaluated as a new aspect of environmental factors affecting SBS in our study. Electromagnetic field was measured by HI-3603 (18,20) based on the method of measuring electromagnetic field developed by Swedish Standards Institute (18, 21). Statistical analysis was performed using chi-square and independent-sample t-test with SPSS 16 for windows (Microsoft, Chicago, IL, USA). Independent sample t- test was used to compare the personal characteristics of employees in the two offices.

RESULTS

Demographic Characteristics

Of the study population, 170 subjects completed and returned the questionnaires. The response rate was 94.3%

in both offices. Comparison of the demographic characteristics of employees in the two offices is presented in Table 1. There were significant differences in demographic characteristics such as height and weight of the male and female employees between the two offices. There were no significant differences in demographic features between male and female employees in each office except for the height of male workers.

Indoor Environmental Parameters

The results obtained from measuring indoor environmental parameters in the two offices are shown in Table 2. Significant differences were reported in some environmental parameters such as lighting, air velocity, relative humidity, and noise levels ($P<0.001$) between the two offices. No significant differences were found in air temperature and CO_2 concentration between the two offices.

The results of measuring electromagnetic field at 30, 50 and 60 cm distances from computer monitors in both offices indicated that the exposure level of employees to electromagnetic field based on distance was higher than the exposure limit values. Also, there were significant differences in exposure to the electric field at 30 cm distance between workers of the two offices ($P=0.006$). Recommended limit values for exposure to electric and magnetic fields are 10 volts per meter (22); and 80 amperes per meter (23), respectively (Table 3).

The prevalence of sick building symptoms

In office No.1, malaise had the highest prevalence among symptoms with a prevalence of rate of 71.4% and 84.8% among men and women, respectively (Table 4). Dry throat and dyspnea had the lowest prevalence among men and women (18.2% each). In building No. 2, headache (72%) and malaise (62%) were the most common symptoms. While wheezing and cough with phlegm had the lowest prevalence (15%) among women. Cough with phlegm had the lowest prevalence (15%) among men.

Women presented more sick building symptoms than men in both offices. Statistical analysis of sick building symptoms showed a significant association between headache and the prevalence of SBS among men and women in office No. 2 ($P = 0.05$). In general, results showed a greater prevalence of headache among women than men. Table 4 illustrates the incidence and statistical relationship of SBS among women and men in the two office buildings. Comparison of the prevalence of SBS between men and women of the two offices revealed significant relationships between sneezing, nasal irritation, and headache among men in the two offices ($P<0.05$) and the prevalence of these symptoms among men in office No. 1 was greater than that in office No. 2. There were no significant differences in prevalence of symptoms between female workers of the two offices ($P>0.05$).

Sick building symptoms and environmental parameters

The results of investigating the relationships between sick building symptoms and indoor environmental parameters indicated that some sick building symptoms such as nausea, headache, nasal irritation, dyspnea, and throat dryness significantly increased with increasing CO_2 concentration. The statistical test results also showed that exposure to high noise levels was associated with increases in prevalence of some symptoms such as headache ($P = 0.036$) and dizziness ($P = 0.048$) (Table 5). There was a significant relationship between light intensity and symptoms such as skin dryness, eye pain, and malaise. In some areas of both offices with temperatures higher than 20-24 °C, headache, skin redness, itchy eyes and sneezing were also observed. Eye and skin symptoms decreased, although cough significantly increased by an increase in relative humidity from 40-50% to 50-60%. The results also showed the significant effect of air velocity on some symptoms like cough and wheezing. Tables 5 and 6 show the association between the prevalence of sick building syndrome and indoor environmental parameters in office No. 1 and 2, respectively.

Table 1. Comparison of demographic characteristics of employees between the two offices

Individual characteristics	Office No.1 (n=68) Men (33) μ±σ	Women (35) μ±σ	P-value	Office No.2 (n=102) Men (60) μ±σ	Women (42) μ±σ	P-value	P-value for comparison of the two offices Men	Women
Age (year)	40±9	33±5.7	0.393	38±9	32±6.3	0.397	0.308	0.471
Weight (kg)	76.5±8.3	61.5±8.6	<0.05	79±9	64±6.3	<0.05	0.191	0.146
Height (cm)	179.5±5.7	160±18.4	0.001	174±6.3	164±9	<0.05	<0.001	0.246
Job experience (year)	7±5.21	6.3±3.7	0.150	6.4±3.6	6±3.1	0.464	0.559	0.700

Table 2. The results of measuring indoor environmental parameters in the two offices

Parameter	Office No.1 (n=68) Range	μ±σ	Office No.2 (n=102) Range	μ±σ	Exposure limits	P-value
Lighting (lux)	189-815	402±135	102-740	301±140	300-600	<0.001
Air velocity (m/s)	0.45-0.7	0.52±0.049	0.09-0.35	0.17±0.01	0.05-0.2	<0.001
Temperature (^{o}C)	19-26.3	23±1.3	20-26.7	23±2.4	20-24	>0.90
Relative humidity (%)	45-75	51±4.51	25-66	53.9±5.19	40-60	<0.001
CO_2 concentration (ppm)	389-1160	701±163	501-1060	741±124	450-675	0.088
Noise level (dBA)	23-59	40±5.5	37-51	42.73±2.93	40-45	<0.001

Table 3. The results of electromagnetic field measurements in both offices

Parameter	Distance from the source, cm	Office No.1 (n=62) μ±σ	Range	Office No.2 (n=90) μ±σ	Range	Exposure limits	P-value
	30	63.90±5	6-275	52.60±37.60	3-194		0.006
Electric fields	50	48.12±3	5-153	42.89±32.80	3-153	10	0.136
	60	34.37±26.80	3-106	42.76±27.17	3-106		0.062
	30	89.42±53.05	5-153	96.49±37.6	13-194		0.368
Magnetic fields	50	83.85±48.70	3-106	93.95±48.70	11-153	80	0.211
	60	77.11±47.89	4-96	84.18±56.12	9-106		0.420

Table 4. The prevalence (%) of sick building syndrome among men and women

Symptoms	Office No.1 Men	Women	P-value	Office No.2 Men	Women	P-value	P-value for comparing the two offices Men	Women
Sneezing	62.9	54.5	0.486	28.6	45	0.097	0.003	0.548
Itchy nose	45.7	51.5	0.632	30.4	35	0.631	0.213	0.220
Nasal irritation	42.4	48.4	0.611	19.6	25	0.531	0.035	0.058
Nasal congestion	51.4	45.5	0.622	32.1	32.5	0.971	0.109	0.351
Dyspnea	18.2	34.3	0.132	26.8	27.5	0.405	0.498	0.692
Wheezing	28.6	24.2	0.686	14.3	15	0.696	0.163	0.465
Cough	34.1	37.3	0.7	17.9	17.5	0.694	0.133	0.089
Cough with phlegm	28.6	33.3	0.584	10.7	15	0.393	0.056	0.105
Dizziness	40	48.5	0.481	35.7	50	0.162	0.852	0.922
Headache	54.3	57.6	0.758	30.6	72.5	0.05	0.043	0.258
Nausea	37.1	42.4	0.656	19.6	22.5	0.734	0.110	0.104
Malaise	71.4	84.8	0.182	62.5	70	0.164	0.524	0.208
Throat dryness	31.4	18.2	0.207	25	40	0.118	0.675	0.068
Skin dryness	48.6	57.6	0.457	37.5	57.5	0.053	0.412	0.824
Itchy skin	48.6	48.5	0.994	39.4	40	0.697	0.523	0.605
Skin redness	34.3	45.5	0.347	33.9	32.5	0.884	0.849	0.351
Eye pain	54.3	60.6	0.546	42.9	70	0.09	0.403	0.532
Eye redness	57.1	51.5	0.553	50	52.5	0.809	0.661	0.887
Itchy eyes	62.9	54.5	0.327	52.5	47.5	0.246	0.337	0.560

Table 5. The association between symptoms and environmental parameters in office No. 1 (p-value)

Symptoms	Noise	Light	Temperature	Humidity	Co_2 concentration
Nasal irritation	0.242	0.317	0.627	0.594	0.008
Cough	0.3	0.146	0.823	0.021	0.734
Dizziness	0.048	0.88	0.46	0.721	0.0312
Headache	0.036	0.046	0.005	0.186	0.0315
Nausea	0.67	0.642	0.350	0.697	0.049
Malaise	0.1	0.780	0.173	0.202	0.023
Skin dryness	0.472	0.049	0.459	0.332	0.113
Skin redness	0.306	0.642	0.632	0.013	0.081
Eye pain	0.684	0.036	0.183	0.044	0.805

Table 6. The association between symptoms and environmental parameters in office No. 2 (p-value)

Symptoms	Noise	Light	Temperature	Humidity	Co_2 concentration	Air Velocity
Sneezing	0.542	0.71	0.045	0.331	0.678	0.266
Dyspnea	0.378	0.6	0.12	0.43	0.028	0.41
Wheezing	0.248	0.395	0.102	0.707	0.188	0.025
Cough	0.495	0.843	0.338	0.048	0.494	0.027
Dizziness	0.032	0.242	0.469	0.280	0.392	0.218
Headache	0.541	0.278	0.021	0.336	0.523	0.238
Malaise	0.222	0.0431	0.524	0.551	0.351	0.093
Throat dryness	0.587	0.710	0.122	0.331	0.028	0.579
Skin redness	0.542	0.90	0.014	0.187	0.453	0.527
Eye pain	0.178	0.026	0.307	0.141	0.382	0.425
Itchy eyes	0.339	0.323	0.008	0.447	0.351	0.509

DISCUSSION

The association of sick building syndrome with indoor air parameters was evaluated in the current study. The prevalence of sick building symptoms in both office buildings of Petroleum Industry Health Organization was high. The results were consistent with those of Bourbeau et al. (24). Our results showed that the prevalence of most sick building symptoms among men and women in office No.1 was higher than that in office building No.2.

Malaise was the most common symptom among men and women. The results of this study showed that poor lighting was the leading cause of malaise in the offices. The results also showed the higher prevalence of symptoms among women than men. This finding is in agreement with the results of Skov who showed that symptoms of fatigue and headache were more common among women than men (25). Some risk factors for gender-related symptoms included equipment of work place, job characteristics, job satisfaction, self reported allergy, number of individuals per room, and smoking cigarettes (26). Stenberg and Wall found that women in all age groups under the same conditions suffered discomfort and health problems more than men. Home responsibilities and participation in social activities were found to be the main reasons (27).

The main causes of SBS were recycling of air in rooms using fan coils, traffic noise, poor lighting, and buildings located in a polluted metropolitan area. Some symptoms such as dizziness and headache were associated with high level of noise exposure (Tables 5 and 6). This study produced results which corroborated the findings of other previous works in this field including the study by Pathak and Tripathi (28).

There was a significant correlation between light intensity and some symptoms like skin conditions, eye pain and malaise. These results were in accord with those of some observations including the one by Kholasezadeh et al. who showed that poor lighting can cause fatigue, headache, tiredness, depression, loss in productivity, and general discomfort (29).

A correlation was found between the office temperature and some of sick building symptoms (sneezing, skin redness, itchy eyes, and headache). Skov and Valbjørn also showed that there was a significant association between indoor temperatures and mucosal symptoms such as sneezing, itching, and pain of the eyes (11).

Exposure to CO_2 may cause dizziness, headache, nausea, nasal irritation, throat dryness, dyspnea, and malaise. However, these findings do not support those of Fanger et al. who showed no significant differences between CO_2 concentration and sick building symptoms (13). These results are consistent with those of Norback et al. who showed that an increase in concentration of CO_2 might worsen some symptoms like malaise and headache (30).

Relative humidity showed a significant association with sneezing, skin redness, and pain of the eyes. The findings of Wang confirm that relative humidity in indoor environments is associated with some sick building symptoms (31). The results of laboratory experiments carried out by Reinikainen in Finland indicated that lower prevalence of symptoms such as skin, nasal, and throat dryness and nasal congestion was expected at relative humidity in the range of 30- 40% than relative humidity in the range of 20- 30% (32). The findings of the current study may not be comparable to those of Reinikainen et al. because of the differences in the relative humidity range in the two studies (32).

Mahmodi et al. indicated that magnetic fields around 20% of the computer monitors were higher than the exposure limit values while electric fields around 52% of computer monitors were higher than the considered standard levels at 30 cm distance from the monitors (33).

The current study showed that the magnetic fields around 13% of computer monitors in office No. 1 and 16% of computer monitors in office No. 2 were higher than the exposure limit values. These results are consistent with those of Mahmodi et al. The results also indicated that electric fields around 95% and 80% of computer monitors in offices No. 1 and 2 were higher than standard levels which are much higher than those reported by Mahmodi et al.

Exposure to electromagnetic fields from the computer monitors was evaluated as a new aspect of SBS in the current study, but unfortunately the amount of occupational exposure to the electromagnetic fields at 30 and 60 cm distance from the computer monitors could not be measured exactly because there were great changes in these fields at 30 and 60 cm distance and thus, a relationship between the SBS and the electromagnetic field could not be established.

CONCLUSION

The present study was designed to determine the association of SBS with indoor air parameters. These findings suggested that in general, malaise was the most common symptom among men and women. The results indicated that there was a higher prevalence of some sick building symptoms among women than men in the two offices. Indoor environmental parameters and indoor air quality influence the prevalence of sick building symptoms in office environments. The main causes of SBS among the employees were recycling of air in rooms using fan coils, traffic noise, poor lighting, and buildings located in a polluted metropolitan area.

Conflict of interest

The authors declare no conflict of interest.

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