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Indoor air quality-induced respiratory symptoms of a hospital staff in Iran

Rahmat Veysi · Behzad Heibati · Mehdi Jahangiri · Prashant Kumar · Mohd Talib Latif · Ali Karimi

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Abstract The ambient air of hospitals contains a wide range of biological and chemical pollutants. Exposure to these indoor pollutants can be hazardous to the health of hospital staff. This study aims to evaluate the factors affecting indoor air quality and their effect on the respiratory health of staff members in a busy Iranian hospital. We surveyed 226 hospital staff as a case group and 222 office staff as a control group. All the subjects were asked to fill in a standard respiratory questionnaire. Pulmonary function parameters were simultaneously measured via a spirometry test. Environmental measurements of bio-aerosols, particulate matter, and volatile organic compounds in the hospital and offices were conducted. *T*-tests, chi-square tests, and multivariable logistic regressions were used to analyze the data. The concentration of selected air pollutants measured in the hospital wards was more than those in the administrative wards. Parameters of pulmonary functions were not statistically significant ($p > 0.05$) between the two groups. However, respiratory symptoms such as coughs, phlegm, phlegmatic coughs, and wheezing were more prevalent among the hospital staff. Laboratory staff members were more at risk of respiratory symptoms compared to other occupational groups in the hospital. The prevalence of sputum among nurses was significant, and the odds ratio for the presence of phlegm among nurses was 4.61 times greater than office staff ($p = 0.002$). The accumulation of indoor pollutants in the hospital environment revealed the failure of hospital ventilation systems. Hence, the design and implementation of an improved ventilation system in the studied hospital is recommended.

Keywords Hospital · Pulmonary function · Respiratory disease

Introduction

Indoor air quality is an important factor affecting the health of staff and patients in hospitals. It is affected by the activities and processes of hospitals including the

R. Veysi · M. Jahangiri
Department of Occupational Health Engineering, School of Public Health, Shiraz University of Medical Sciences, Shiraz, Iran

B. Heibati
Air Pollution Research Center, Faculty of Health, Iran University of Medical Sciences, Tehran, Iran

P. Kumar
Global Centre for Clean Air Research (GCARE), Department of Civil and Environmental Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford GU2 7XH, UK

M. T. Latif
School of Environmental and Natural Resource Sciences, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

A. Karimi (✉)
Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
e-mail: a_karimi@sina.tums.ac.ir

use of anesthetic drugs, pharmaceutical products, laboratory chemicals, biological contaminants, cleaning compounds, sterilization, and dust (Hellgren and Reijula 2006). People in a hospital normally include hospital staff, patients, and visitors, who have different sensitivities to chemical and microbial materials. A variety of facilities and hospital workers have made the hospital a complicated building in comparison with commercial and industrial buildings. Poor indoor air quality in hospitals can cause an increment in the prevalence of sick building syndrome, a decrease in the resident's comfort and efficiency—this can consequently lead to hospital infections and occupational sicknesses (Leung and Chan 2006; Mohammadyan et al. 2017a, b; Ghozikali et al. 2016).

A study by Eickhoff (1994) showed that a major portion of respiratory infections is spread by personal contact. It was estimated that the air can transfer approximately 10% of all hospital infections. Later, Polk Jr and Christmas (2000) reported that about two million hospital infections are reported in the USA each year. These infections create a cost of about 5 to 10 billion dollars to the US economy and ~ 90,000 people lose their lives to them. Tuberculosis is one disease that can be transferred by air. Although the prevalence of tuberculosis in developed countries is decreasing, the risk to patients and healthcare workers still remains (Humphreys 2007). The prevalence of respiratory problems and sick building syndrome symptoms has been reported among hospital staff (Cox-Ganser et al. 2009; Husman et al. 2000; Kelland 1992; Nordström et al. 1995). In accordance with the study conducted on officially reported occupational asthma in the USA, hospital staff consisted 16% of the 1879 reported occupational asthma cases whereas only 8% were within the general US workforce (Pechter et al. 2005).

A study on 3811 hospital workers from ten large hospitals in Finland showed that the number of complaints from hospital staff about air dryness and tightness of chest as well as unpleasant odors was more than the number from office staff. The study found symptoms associated with poor indoor air quality such as nose, hand, skin, and eye irritations and fatigue were higher among the hospital staff than other employees (Hellgren and Reijula 2006). Another study on the prevalence of respiratory symptoms in hospitals affirmed that coughs are the most common complaint among the hospital staff. A relationship between environmental factors and nasal patency showed a decrease in nasal patency among nurses related to microbial amplification in the ventilation units caused by *Aspergillus fumigatus* (Smedbold et al. 2002). Numerous symptoms and diseases caused by poor indoor air quality in hospitals can lead to the low efficiency of workers, a reduction in effectiveness and increase in absenteeism. A recent study reported that the reasons for absenteeism among the hospital staff were respiratory diseases (31%), digestive diseases (17%), and musculoskeletal disorders (15%) (Donovan et al. 2008).

In this study, we carried out a quantitative study on indoor air quality to understand different factors affecting indoor air quality and its impact on a busy hospital staffs' respiratory function. A standard respiratory questionnaire and pulmonary function parameters have been used to determine the health condition of hospital staff working in different indoor air quality conditions. No previous studies have been published in the field of hospital staff respiratory health in Iran and thus this work is the first step to fill the research gap.

Materials and methods

This cross-sectional study was performed in a large teaching hospital. The study population included 228 hospital staff, including 86 nurses, 37 paramedics, 33 cleaning staff, 19 surgical technicians, 20 medical laboratory technicians, and 33 other personnel. The inclusion criteria of the hospital staff were work experience for at least 1 year. They should not have a history of respiratory, heart diseases, or thoracic surgery. The control group included 228 office staff having more than 1 year of work experience without a history of respiratory and heart disease or chemical exposure.

In order to survey the probable respiratory complications, the American Thoracic Society's standard respiratory questionnaire was used. The mentioned questionnaire evaluates the worker's respiratory conditions based on their phlegm, shortness of breath, acute cough symptoms, and wheezing. The questionnaire has been used in many countries, so its validity and reliability have been confirmed (Ferris 1978).

Pulmonary function tests

Pulmonary function tests included vital capacity (VC), forced vital capacity (FVC), and forced expiratory volume in the first second (FEV1). Tests were done following the American Thoracic Society method using a portable calibrated vitalograph (Model ST-150; Fukuda Sangyo Co. Ltd., Nagareyama-shi, Japan) to assess lung function parameters, including mean percentage predicted VC, FEV1, and FVC. Daily calibration was carried out after every 4 h in accordance with the manufacturer's guidelines. Each person was taught the correct spirometry technique.

Measurement of environmental factors

To evaluate the hospital indoor air quality, cross-sectional measurements were carried out for some environmental factors. All measurements except bio-aerosol concentration were performed using direct analysis equipment. All measurements took place in three rounds according to the worker's shifts (in the morning, afternoon, and evening) in different sections and units. Also, the same measurements were undertaken in office buildings adjacent to the hospital as a control. In order to measure the bio-aerosols, NIOSH method 0800 was used as well as an Andersen single-stage air sampler with a 28.3 L/min flow rate (following the noted standard) and a 10-min sampling period. To assess the bacterial and fungal cultures present, Trypticase soy agar and Sabouraud dextrose agar were used respectively. For the determination of VOC concentrations in hospital indoor air, a VOC detector model Phocheck Tiger made by Ion Science from England was used. This detector is equipped with a photoionization detector for monitoring at the parts per billion (ppb) level. Inhalable particulate matter (PM_{10}) was measured using an aerosol mass monitoring device model GT-331 made by SIBATA from Japan. This portable battery-operated device can gauge in standard mass concentrations at PM_{10}, PM_7, $PM_{2.5}$, PM_1, and TSP. The instrument operates on a 4-min cycle before it displays the result on its embedded Liquid Crystal Display (LCD), just enough time to do the spectra measurement.

Data analysis and statistical tests

First of all, data were surveyed in terms of their normal distribution. Independent sample *t* tests and chi-square tests were respectively used to compare the parameters of pulmonary function and respiratory symptoms prevalence among hospital staff and office staff. Multivariate logistic regression analysis was used to control confounding binary outcomes. Data were analyzed using SPSS 21 and at the 95% significance level.

Table 1 Demographic characteristics and smoking among case and control groups. *m*, SD, and *n* stands for mean, standard deviation, and number of participants, respectively

Variable		*p-value*	Control group (n = 228)	Case group (n = 228)
Age (year)		36.29± 8.25	6.65 ± 35.46	0.235*
Height (meter)		8.99 ± 165.82	8.62 ± 165.54	0.738*
Weight (kg)		14.39 ± 69.35	12.72 ± 69.61	0.836*
BMI (kg/m^2)		4.74 ± 25.17	3.6 ± 25.31	0.729*
Work experience (year)		7.47 ± 12.01	5.64 ± 8.93	0.001*
Number of smokers *n* (%)		24 (10.5%)	19 (8.3%)	0.423†
Smoking duration (year)		10.74 ± 16.46	8.97 ± 14	0.633*
Gender	Male	79 (34.6%)	77 (33.8%)	0.843†
	Female	149 (65.4%)	151 (66.2%)	
Marital status	Single	61 (26.8%)	72 (31.6%)	0.257†
	Married	167 (73.2%)	156 (68.4%)	
Educational level	Less than a high school diploma	33 (14.5%)	6 (2.6%)	0.001†
	Diploma or associate degree	78 (34.2%)	42 (18.4%)	
	Bachelor degree	102 (44.7%)	129 (56.6%)	
	Master degree and higher	15 (6.6%)	51 (22.4%)	

*Independent sample

† Chi-square or fisher exact test

Results

Demographic and smoking-related data are shown in Table 1. During the test results, variables such as age, height, weight, BMI, number of smokers, smoking duration, gender, and marital status were not significantly different between the two groups. However, work experience and educational level were significantly different between the two groups. Hospital staff had an average work experience of 3.01 years more than office staff. Table 2 shows the average measurement of environmental agents. As can be seen, mean concentrations of bioaerosols, particulate matter, and volatile organic compounds in the hospital are higher than those in office. Except for $PM_{2.5}$, the differences between concentrations of other environmental factors are statistically significant ($p < 0.05$).

Results of the pulmonary function tests among the two groups are presented in Table 3. As observed, all the pulmonary parameters, including VC, FVC, FEV_1, and FEV_1/FVC, are lower in the case group than in the control group. However, there are no statistically significant differences in any of the parameters measured between the two groups. Table 4 shows the results of surveying the respiratory symptoms between case and control groups. Results showed that all respiratory parameters were more frequent in the case group compared to the control group. The chi-square test confirmed that the prevalence of all symptoms, except tightness of chest, was significantly more in the case group than in the control group ($p < 0.05$). The odds ratios for symptoms such as coughing, phlegm, phlegmatic cough, wheezing, and shortness of breathing in the case group to the control group were 2.52, 3.83, 2.75, 4.51, and 1.97, respectively.

Table 5 shows the odds ratio of hospital staff respiratory symptoms as compared to office staff symptoms and was based on multivariate logistic regression. In order to control for confounders, dependent variables such as age, height, weight, gender, work experience, marital status, education, and smoking were entered into the model. Results showed that after controlling for confounders, symptoms such as coughs, phlegm, phlegmatic cough, and wheezing were significantly more prevalent among the hospital staff in comparison with the office staff. Table 6 shows the respiratory symptom odds ratios among different hospital occupational groups in comparison with the office group. Dependent variables such as age, height, weight, gender, work experience, marital status, education, and smoking were entered into the model as confounders. The prevalence of sputum among nurses was significant, and the odds ratio for phlegm among nurses was 4.61 times more than office staff ($p = 0.002$). The highest odds ratio was related to wheezing in the laboratory with an odds ratio of 13.82. Among the occupational groups, laboratory staff recorded the most significant complaints of coughs, phlegmatic cough, wheezing, and tightness of chest. In addition, complaints of chest tightness were only significant in this group ($p = 0.014$). Despite the prevalence of none of the respiratory symptoms, they were significant among surgical technicians but not office staff.

Discussion

The present study aimed to evaluate the respiratory health of hospital staff who are exposed to its indoor air pollution. No significant differences were observed in demographic characters such as age, height, weight, BMI, gender, and marital status between hospital and office staff (Table 1). The only difference was related to work experience and education; as confounder variables, these were controlled through the logistic

Table 2 Comparing means of environmental measurements

Pollutant		Hospital	Office	*p*-value*
Bio aerosols (cfu/m^3)	Bacteria	80.77 ± 169.48	19.35 ± 30.07	0.005
	Fungus	29.97 ± 55.15	11.09 ± 23.75	0.047
Particulate matter (μg/m^3)	PM_{10}	28.18 ± 38.7	10.02 ± 22.61	0.011
		2.65 ± 4.73	4.78 ± 5.1	0.422
Volatile organic compounds (ppb)		455 ± 389.5	38.7 ± 120.7	< 0.001

*Mann-Whitney U

Table 3 Comparison between case and control group pulmonary function parameters

Parameter	Case group (n = 228)	Case group (n = 228)	p-value*
VC	11.20 ± 86.24	10.39 ± 87.38	0.262
FVC	11.41 ± 90.79	10.83 ± 91.20	0.692
FEV1	11.50 ± 90.40	91 ± 10.50	0.855
FEV1/FVC	5.67 ± 99.76	6.15 ± 100	0.667

*Independent sample t test

regression. The number of smokers and duration of smoking were not significantly different between the two groups and smoking had a similar role in the prevalence of respiratory symptoms in both groups. Hence, the role of smoking was controlled through the logistic regression. All the studied people were from a united geographical region without having personal or family backgrounds related to chronic respiratory diseases, thoracic surgery, eye and ear surgery, or heart attack (Ferris 1978). The studied groups were not previously exposed to chemical pollutants in their previous jobs and they had at least 1 year of work experience in their current occupational position.

The spirometry test showed a decrease in lung capacities among hospital staff as compared to the office staff, although the differences were not statistically significant (Table 3). Few studies in this field have not resulted in a significant difference in the parameter of pulmonary function among hospital staff (Naserbakht and Sadeghniat 2011; Vyas et al. 2000) although the mentioned studies were carried out on a special group of hospital staff and pollutants such as endoscopy staff's exposure to the glutaraldehyde and laboratory staff's exposure to formaldehyde. The prevalence of coughs, phlegm, phlegmatic cough, wheezing, and shortness of breath among hospital staff was significantly more than that of the office staff (Table 4). Complaints of tightness in the chest were more prevalent in hospital staff in comparison with the office staff, although it was not statistically different.

Results showed that the odds ratios for symptoms such as coughing, phlegm, phlegmatic cough, wheezing, and shortness of breath for hospital subjects were 2.52, 3.83, 2.75, 4.51, and 1.97 times higher than those in control group, respectively. After controlling for confounders (such as work experience which was more in hospital staff) by logistic regression, respiratory symptoms such as coughing, sputum, phlegmatic cough, and wheezing still remained significant between the two groups. Also, the odds ratios decreased slightly so that for coughing, phlegm, phlegmatic cough, and wheezing in the case group were 2.34, 3.37, 2.65, and 3.31 times higher, respectively than those in control group (Table 5). There are some discussions about the prevalence of indoor air quality-related diseases. Most of the studies have surveyed the complaint about air quality and sick building syndrome. With regard to the study population, hospital building conditions, the number of residents, type of activity, and air quality, as well as the type and frequency of complaints, were different. Symptoms of sick building syndrome were frequent in almost all the previous studies (Hellgren et al. 2008; Hellgren and Reijula 2006; Mendes et al. n.d.; Nordström et al. 1995). Some studies have surveyed respiratory diseases such as asthma and tuberculosis. Previous research studies have discussed asthma as a prevalent disease among hospital personnel with symptoms of coughing, wheezing, and shortness of breath. Epidemiological studies have affirmed the prevalence of asthma among hospital

Table 4 Prevalence of respiratory symptoms in hospital staff to office staff

Symptoms	Case group (n = 228) Number (percentage)	Control group (n = 228) Number (percentage)	Odds ratio	CI (95%)	p-value†
Cough	54 (23.7%)	25 (11%)	2.52	1.51–4.22	< 0.001
Phlegm	40 (17.5%)	12 (5.3%)	3.83	1.95–7.52	< 0.001
Phlegmatic cough	37 (16.2%)	15 (6.6%)	2.75	1.46–5.17	0.001
Wheezing	17 (7.5%)	4 (1.8%)	4.51	1.49–13.63	0.004
Shortness of breath	71 (31.1%)	43 (18.9%)	1.97	1.26–3	0.002
Press in chest	18 (7.9%)	10 (4.4%)	1.87	0.84–4.14	0.119

†Chi-square or fisher exact test

Table 5 Odds ratio in case group as compared to the control group based on multivariate logistic regression analysis. Note that SE and β stands for standard error and regression coefficient, respectively

Symptoms	β	SE	Odds ratio	CI (95%)	p-value†
Cough	0.85	0.29	2.34	1.32–4.13	0.003
Phlegm	1.22	0.37	3.37	1.64–6.95	0.001
Phlegmatic cough	0.97	0.35	2.65	1.33–5.28	0.006
Wheezing	1.2	0.61	3.31	1.01–10.83	0.048
Shortness of breath	0.37	0.25	1.44	0.88–2.37	0.148
Press in chest	0.58	0.48	1.79	0.7–4.57	0.221

†Logistic regression

staff. Most complaints by personnel with asthma were due to contact with detergents, latex, and poor indoor air quality (Pechter et al. 2005). Kopferschmitt-Kubler et al. (2002) concluded that, after bakers, hospital staff was the people in most danger of asthma in France (Kopferschmitt-Kubler et al. 2002).

The high prevalence of respiratory symptoms was consistent with previous studies. In accordance with the presence of extensive biological and chemical pollutants in hospitals, having contact with such pollutants can result in respiratory diseases among hospital staff. Poor air quality in Hellgren et al. (2008), exposure to materials used in hospitals in Mirabelli et al. (2007), detergents and disinfectants in Arif and Delclos (2011), and exposure to glutaraldehyde in Vyas et al. (2000) are probable factors responsible for the prevalence of respiratory dysfunction.

According to the results of this study, most hospital staffs' complaints were about shortness of breath (31.1%) and cough (23.7%). Those results are consistent with studies conducted by Hellgren et al. (2008), although cough frequency in Hellgren et al. was 8% for hospital staff and 5% for office staff. Pulmonary function tests between the two groups were not significantly different due to (i) prevalence of respiratory symptoms was concluded through the questionnaire and interview but this is not reliable enough data; (ii) according to pollutant measurements, low lung capacity among hospital staff as compared to office staff was due to the high concentration of pollutants in hospitals as compared to that of the office (Table 2); and (iii) the quantity of pollutants in comparison with occupational standards was inconsiderable so that no significant differences were observed between the two groups. In a survey of obstructive lung diseases such as asthma, pulmonary function tests may either show obstructive symptoms or nothing abnormal.

Table 6 Odds ratio of respiratory symptoms among different hospital occupational groups compared with building staff based on logistic regression model

Symptoms Occupations		Cough	Phlegm	Phlegmatic cough	Wheezing	Shortness of breath	Press in chest
Nurse (n = 86)	Odds ratio	2.03	4.61	1.77	1.46	1.58	1.36
	CI (%95)	0.93–4.4	1.78–11.93	0.69–4.54	0.25–8.61	0.82–3.03	0.35–5.35
	p-value†	0.074	0.002	0.233	0.676	0.170	0.656
Paramedic (n = 37)	Odds ratio	2.11	3.06	3.71	5.82	1.46	1.98
	CI (%95)	0.79–5.64	8.91–1.05	11.21–1.23	26–1.3	3.76–0.56	9.54–0.41
	p-value†	0.135	0.041	0.020	0.021	0.438	0.396
Cleaning staff (n = 33)	Odds ratio	1.4	1.41	2.51	6.57	0.92	0.93
	CI (%95)	0.45–4.41	0.35–6	0.62–10.13	1.46–29.55	0.31–2.73	0.13–6.52
	p-value†	0.564	0.615	0.197	0.014	0.879	0.941
Surgery room (n = 19)	Odds ratio	1.02	0.97	0.85	2.06	1.69	1.3
	CI (%95)	0.21–5.05	0.11–8.22	0.1–6.98	0.16–26.52	0.55–5.23	0.14–11.95
	p-value†	0.976	0.976	0.877	0.578	0.362	0.820
Laboratory (n = 20)	Odds ratio	9.08	3.87	8.39	13.82	2.28	6.19
	CI (%95)	3.12–26.52	0.9–16.67	26.78–2.63	2.71–70.42	0.76–6.77	1.45–26.4
	p-value †	< 0.001	0.069	< 0.001	0.002	0.140	0.014

†Logistic regression

The prevalence of respiratory symptoms among occupational groups such as nurses, paramedics, cleaning staff, surgical technicians, medical laboratory technicians, and other hospital personnel were surveyed in comparison with office staff (the control group), and the role of confounders was controlled by logistic regression analysis (Table 6). Results of logistic regression analysis showed a difference between the prevalence of respiratory symptoms among different occupational groups. After controlling for confounders, the prevalence of phlegm among nurses was significant in comparison with office staff, and this result is in line with Smeldnold et al.'s study. In their study, nurses' nasal mucosal inflammation and nasal patency reduction were related to microbial amplification in the ventilation units caused by *Aspergillus fumigatu* (Smedbold et al. 2002). The prevalence of wheezing among cleaning staff was significant and the odds ratio for wheezing was 6.57 times more than that of the office staff. This result confirms Vizcaya et al.'s study. However, the prevalence of wheezing among cleaning staff w.as only 2.9 times more than in the control group in this study. In addition, Vizcaya et al. (2011) surveyed 37 cleaning corporations; the prevalence of asthma and its symptoms was only significant for hospital staff (Vizcaya et al. 2011). Laboratory technicians showed a prevalence of the most significant respiratory symptoms among hospital staff and this affirms the findings of Mirabelli et al. (2007). Other related studies have reported the prevalence of asthma and its symptoms differently. For example, Arif et al. (2009) and Pechter et al. (2005) studied nurses that were introduced as those individuals in the risk group for asthma and respiratory symptom prevalence.

Conclusion

Problems of hospital indoor air quality have affected health, comfort, and staff efficiency. This study showed that the mean concentrations of bio-aerosols, particulate matter, and volatile organic compounds in the hospital were higher than those in an office. Except for $PM_{2.5}$, the differences between concentrations of other environmental factors are statistically significant ($p < 0.05$). Based on the survey, most hospital staff complaints were related to shortness of breath (31.1%) and coughing (23.7%). Among the occupational groups, laboratory technicians are at more risk of respiratory diseases. The prevalence of sputum among nurses was significant, and the odds ratio for phlegm among nurses was 4.61 times more than office staff ($p = 0.002$). The exclusion of harmful substances or the use of low-risk materials can decrease the prevalence of respiratory symptoms. Medical examinations and occupational assessments seem necessary in helping vulnerable people. The accumulation of pollutants in hospital indoor environments has proved the insufficiency of hospital air conditioning and ventilation. Hence, the design and implementation of improved ventilation systems are advised in the studied hospital.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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