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EVALUATION OF HOSPITAL WARDS INDOOR AIR QUALITY: THE PARTICLES CONCENTRATION

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ABSTRACT:

Introduction: Indoor air quality in hospitals plays an important role in prevention of infectious disease and inhibits the transmission of infections to staff and patients. The aim of this study is to evaluate the indoor air quality and its relation with environmental air in one of the public hospitals in Qazvin. This cross-sectional study was carried out in a densely occupied educational hospital affiliated with Qazvin University of Medical Sciences.

Materials and methods: In this study, several factors those affect the air quality (including carbon dioxide, temperature, relative humidity, and particulate matters sized PM_{10}, $PM_{2.5}$, and $PM_{0.3}$) were measured using direct measurement data logger tools in different wards of hospital in various weather conditions. All data obtained was analyzed by SPSS 20.

Results: The collected data was analyzed using SPSS with a confidence interval of 95% and α=0.05. The mean 24 h concentrations of PM_{10}, $PM_{2.5}$ and $PM_{0.3}$ were 83.09, 21.47 and 1.6 μg/m^3 at indoor parts of the hospital, respectively. The highest concentrations were observed in men cardiac, women internal, and women cardiac wards. The mean 8 h concentration of carbon dioxide, temperature, and relative humidity were significantly associated with American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) standards.

Conclusions: The highest Indoor to outdoor air quality ratio for particulate matters was PM_{10}=3.75 in men cardiac ward, $PM_{2.5}$=2.6 in women internal ward and $PM_{0.3}$=1.31 at women cardiac ward. According to the World Health Organization (WHO) and the Environmental Protection Agency (EPA) standards, the air quality is divided in several categories based on the concentration of particulate matters, and in this study the level of air quality was moderate. Air quality can be improved to optimal levels and pollutants can be reduced through corrective measures such as suitable and efficient ventilation system and further measurements.

INTRODUCTION

Nowadays, most occupational activities are being performed indoors due to the specific conditions. Working in indoor environments may lead to the production and transmission of pollutants from diverse sources. The concentration of these pollutants can be exacerbated in the indoor environment, especially when they are combined

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with the outdoor pollutions [1-3]. Thus, in recent years, Indoor Air Quality (IAQ) and its effect on the human health has been taken into consideration by different researches. Nowadays, the indoor air quality is considered to be desirable in two conditions: it does not have any negative effects on the human health and more than 80 percent of exposed people feel satisfied within it [4]. Poor air quality in the work environment, not only reduces the comfort and efficiency of the staff, but also can lead to occupational diseases 5-9]]. According to the previous research, there is a strong association between people's health and the environmental conditions in which they work, live, or are treated [10]. IAQ is of great importance in hospitals. It is necessary to utilize the highest quality standards for clean air in hospitals in order to provide the medical services to patients and protect the health of patients and medical staff against infectious diseases, especially airborne infectious diseases. According to the World Health Organization (WHO), the recommended amount of particulate matters in indoor and outdoor environments is 25 $\mu g/m^3$ for $PM_{2.5}$ and 50$\mu g/m^3$for PM_{10} [11]. According to Environmental Protection Agency (EPA), the recommended amount of particulate matters in indoor and outdoor environments is 35 $\mu g/m^3$ for $PM_{2.5}$ and 150 $\mu g/m^3$ for PM_{10} [12].

According to American Society of Heating, Refrigerating and Air-conditioning Engineers organization (ASHRAE), the recommended level of 8 h of continuous exposure to carbon dioxide is 1000 ppm, the thermal comfort indexes of dry and wet temperature are 25.5–22.5 °C, respectively and the relative humidity is less than 70%. IAQ of hospitals is affected by a range of chemical and infectious contaminants which may emerge due to different factors including the diversity of services and activities, the presence of patients with various diseases especially infectious diseases, and using various chemicals such as anesthetic drugs, pharmaceutical products, laboratory chemicals, cleaning agents and disinfectants. The mentioned factors can affect the duration of the patients treatment and the safety and health of healthcare providers [13]. The efficiency of a hospital, as an economic firm, depends on the delivery of healthcare services to patients with the highest quality with the lowest costs. As a result, it is of great importance to observe the highest quality standards for the air quality. In USA, two million patients are affected by nosocomial infections attributed to air pollutions annually, of which 90 thousand people die due to the infections. Thus, the financial burden of 5 to 10 billion dollars is being imposed to the economy of this country at each year [14]. Death rate from indoor air pollution in Iran imposes a financial burden of 200 million dollars on the economy of the country, annually [15].

In a study, it was reported that the indoor air quality in a hospital is affected by the outdoor air [16]. Some researchers examined the air quality in hospital operating rooms in Taiwan. According to their results, indoor air quality depends on the people quantity present in the operating room. In addition, they concluded that a decrease in the concentration of particulate matters was associated with the reduced bacterial contamination (i.e. nosocomial infections) [17, 18].

Since several cities in Iran have been exposed to the severe dense dusts in recent years, the human life has been affected by this phenomenon in Qazvin, specially. Considering this dust attack, the spread of diseases has been increased with different types among people. Hospitals, as one of the institutions that are presenting health services to the patients, should be in appropriate air quality conditions to guarantee the clients health. . The concentrations of particulate matters with different sizes and their effects on air quality were investigated at BoAli-Sina hospital in Qazvin. The reasons for selecting the mentioned hospital were that it has been located in down-town near one of the city streets which suffers from heavy-traffic, usually. So, the air quality in different wards of hospital has significant effect on presenting suitable health services which improves the patient treatment process. Towards this goal, in this study, the relationship between the concentrations of outdoor particles compared with the concentration of indoor particles indicated that the outdoor particles can transfer into the hospital. Thus, the free air can affect air quality inside the hospital.

MATERIALS AND METHODS

Study area

This cross-sectional study was conducted in an educational hospital affiliated with Qazvin University of Medical Sciences from October 2015 to December 2015. In this study, some of the factors affecting air quality (carbon dioxide, temperature, relative humidity, concentration of particulate matters sized PM_{10}, $PM_{2.5}$, and $PM_{0.3}$) were measured in various parts of the hospital. Air samples from indoor hospital environment were collected two days a week. The air samples were collected from infectious ward, emergency ward, men and women internal ward, men and women cardiac ward, and Coronary Care Unit (CCU). During the course of the study, a total of 28 samples were collected from each ward and 56 samples from ambient air, overall, a total of 252 samples were collected. In order to evaluate the effects of weather conditions on indoor air quality, sampling was performed in sunny and rainy conditions and also when a dust mass from Iraq entered to the country due to several years of drought and war in Iraq, wetlands have dried up.

Monitoring method and measurement equipment

Sampling and determining the concentration of PM_{10}, $PM_{2.5}$, and $PM_{0.3}$ were carried out using a laser counter, model HAT200. HAT200 handheld detector with USB is designed to measure air PM_{10}, $PM_{2.5}$, and $PM_{0.3}$ special detection equipment values. It was developed a set of aerodynamics at high sensitivity miniature laser sensor technology on the basis of absorbing foreign advanced digital signal processing, optical and electrical integration of high-tech. The HAT200 handheld PM_{10}, $PM_{2.5}$ and $PM_{0.3}$ detector with USB has high precision, stable performance, versatility, simple and convenient operation can be widely applied to the determination of environmental and atmospheric public spaces, and the air cleaner can also be used to analyze the efficiency of the evaluation.

Indoor air quality meter used to measure carbon dioxide (CO_2), relative humidity and temperature in indoor and outdoor air. Thermal comfort can be achieved only when air temperature, humidity and air movement are within a specified range. In order to meet the requirements of sampling, recommended by EPA and WHO, the measurement of particulate matters was performed at a height of 1.3 m above the ground, in the patients respiratory level in the indoor environment, and at a height of more than 20 m from the street, trees, and sources of infection in the outdoor environment [19]. Indoor air quality index was determined using air quality index calculator software [20].

Statistical analysis

The data were analyzed using SPSS within the confidence interval of 95% and α=0.05 [21]. The statistical t-test was incorporated to assess the indoor air quality in treatment wards. Also, the regression analysis was used to examine the relationship between parameters and their effects on the concentration of particulate matters in different weather conditions.

RESULTS AND DISCUSSION

Table 1 represents the results of the comparison between the mean 24 h concentrations of particulate matters (PM_{10}, $PM_{2.5}$, and $PM_{0.3}$) and mean 8 h concentrations of carbon dioxide, temperature, and relative humidity of air in different indoor and outdoor parts of the hospital in different weather conditions.

The mean 24 h concentrations of PM_{10}, $PM_{2.5}$, and $PM_{0.3}$ in indoor parts of the hospital, in different weather conditions were as 83.09, 21.47 and 1.6 $\mu g/m^3$, respectively. The highest concentrations were observed in men cardiac ward, women internal ward, and women cardiac ward.

Table1. Mean concentration of airborne particles (PM_{10}, $PM_{2.5}$, and $PM_{0.3}$), temperature, relative humidity, and carbon dioxide in different indoor and outdoor parts of the hospital

Sampling site	weather conditions	PM_{10} (µg/m^3) SD±mean	$PM_{2.5}$ (µg/m^3) SD±mean	$PM_{0.3}$ (µg/m^3) SD±mean	Concentration of carbon dioxide(ppm) SD±mean	temperature (°C) SD±mean	Relative humidity (%) SD±mean
Infectious ward	Sunny	18.68±2.54	6.14±2.25	0.93±0.38	528.67±89.77	24.61±1.56	23.58±6.99
	Cloudy - Rain	40.00±23.36	13.37±6.09	1.61±0.39	513.25±100.33	25.83±3.01	18.51±6.98
	Dust	100.00±20.79	38.88±24.56	1.78±0.22	459.00±112.42	25.50±3.05	17.50±3.32
Men cardiac ward	Sunny	111.28±50.59	8.44±5.19	0.72±0.29	728.45±163.45	24.47±1.12	26.34±4.96
	Cloudy - Rain	67.71±43.64	18.72±9.23	1.41±0.55	519.00±63.32	23.30±3.49	22.21±3.96
	Dust	70.28±51.26	19.82±9.93	1.82±0.92	520.00±189.71	23.20±3.81	22.30±3.31
Women cardiac ward	Sunny	34.00±33.10	12.78±11.87	0.99±0.52	568.71±106.49	23.79±1.40	27.48±6.17
	Cloudy - Rain	58.16±25.45	16.38±7.08	1.97±0.32	591.00±182.28	24.18±0.81	22.74±24
	Dust	79.44±17.22	29.66±12.82	1.84±0.96	546.71±71.05	24.60±0.71	21.33±2.09
Men internal ward	Sunny	14.46±2.46	6.58±2.52	0.93±0.42	533.71±89.74	23.78±1.18	28.04±5.90
	Cloudy - Rain	48.33±32.95	11.97±5.46	1.14±0.32	570.33±86.67	23.10±0.11	21.93±2.26
	Dust	91.66±11.93	41.93±14.92	1.71±0.03	510.32±73.07	25.66±0.57	21.33±2.08
Women internal ward	Sunny	23.33±18.64	7.67±2.86	1.16±0.43	549.414±115.87	23.80±1.06	28.58±7.51
	Cloudy - Rain	72.14±46.25	19.82±16.63	1.22±0.32	554.80±119.26	23.20±2.16	24.68±3.11
	Dust	99.50±14.84	36.93±15.76	1.84±0.09	546.71±71.05	24.60±0.71	21.33±2.09
CCU	Sunny	21.93±16.26	7.77±5.57	0.93±0.402	627.51±176.10	23.38±1.41	28.82±7.02
	Cloudy - Rain	73.00±23.45	17.96±10.88	1.2±0.35	597.14±311.82	24.42±1.48	24.52±3.16
	Dust	85.46±27.71	37.32±11.32	1.58±0.33	600.00±315.88	25.41±1.51	24.57±1.02
Emergency ward	Sunny	28.22±13.74	7.83±3.76	0.99±0.357	597.23±83.81	24.60±1.8	28.90±7.82
	Cloudy - Rain	38.66±5.50	17.61±9.62	1.28±0.46	586.50±69.04	24.90±2.20	21.46±4.81
	Dust	13.65±84.33	13.51±20.60	0.22±1.76	459.00±112.49	1.57±25.50	21.60±0.8
The roof of the hospital	Sunny	13.59±1.06	3.42±1.11	1.20±0.97	440.09±89.66	23.61±0.91	26.71±0.91
	Cloudy - Rain	27.00±11.31	7.10±3.44	1.30±0.46	342.00±12.76	19.00±2.00	31.83±5.34
	Dust	74.50±31.26	24.27±8.48	1.50±0.19	526.50±86.69	25.16±0.75	19.83±2.98

The mean 24 h concentration of PM_{10}, $PM_{2.5}$, and $PM_{0.3}$were as follows in the various wards of hospital. Fig.1 represents the comparison between the concentrations of the particulate matters sized PM_{10}, $PM_{2.5}$ and $PM_{0.3}$ in different wards of hospitals. The concentration of PM_{10}, $PM_{2.5}$ and $PM_{0.3}$ particulate matters is affected by a number of factors like proximity to traffic, the number of people and hospital beds, gardens and etc. In this study the most important reasons were the type of ward, the number of hospitalized patients, proximity to street. As shown in Fig.1 the highest concentration of PM_{10} was in men cardiac ward which can be due to the low area of ward, the large number of patients and their families and proximity to road. The high density of PM_{10} related to the mentioned factors can be reasons of the high concentration of it compared with $PM_{2.5}$ and $PM_{0.3}$.

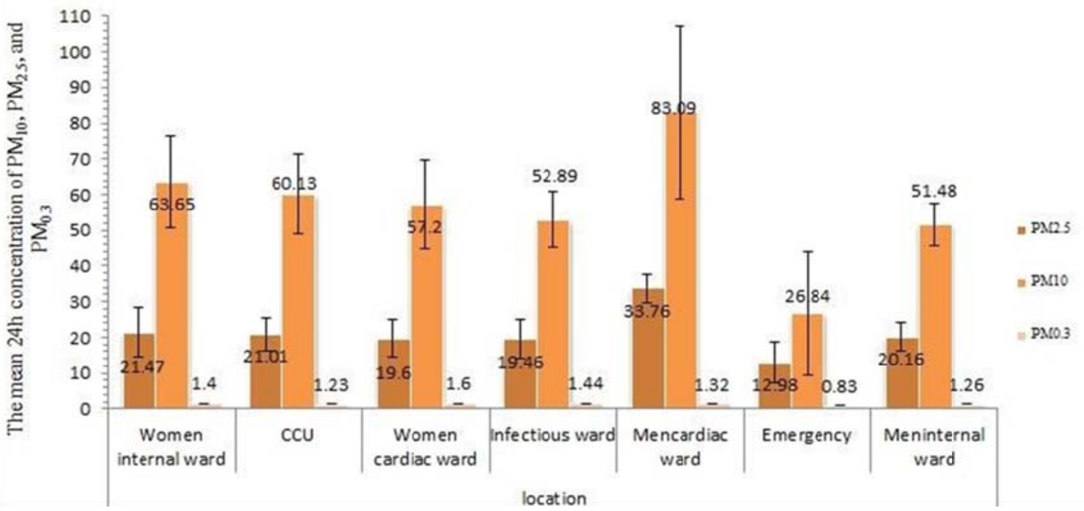

Fig.1. Comparison between the concentrations of the particulate matters sized PM_{10}, $PM_{2.5}$, and $PM_{0.3}$in different wards of hospital

Table 2 represents the relationship between air quality variables (temperature, relative humidity, and carbon dioxide) with the concentration of particulate matters in air.

Table 3 represents the results of comparison between indoor and outdoor mean concentration of particulate matters (PM_{10}, $PM_{2.5}$, and $PM_{0.3}$), temperature, relative humidity, and carbon dioxide and the ratio of indoor to outdoor concentrations in hospital (I/O).

Mean 24 h concentration of PM_{10} particulate matters in all internal wards of the hospital were higher than WHO standard and no significant relationship was observed to model this behavior. In addition, mean 24 h concentration of $PM_{2.5}$ in all internal wards had no significant relationship with the standard ($P>0.05$). Significant relationship (in this section) between two parameters means that these parameters increase and decrease together. But considering US EPA standard (according to US EPA standard, the mean 24 h concentration of PM_{10} should be 50 μg/m^3), the values obtained in this study were less than the US EPA standard and a significant relationship was observed ($P<0.001$). Concerning $PM_{2.5}$ particulate matters in hospital indoor environments, there were statistically a sensible relationship between the two standards and the $PM_{2.5}$ level. The concentration of $PM_{2.5}$ in all wards was less than the WHO (less than 25 μg/m^3) and US EPA standards (less than 35 μg/m^3) [11, 12]. The mean 8 h concentration of carbon dioxide, temperature, and relative hu-

Table 2. The relationship between the air quality variables (temperature, relative humidity, and carbon dioxide) with the concentration of particulate matters in different weather conditions

Sampling site	Statistical Index	PM_{10} and RH	PM_{10} and temperature	PM_{10} and CO_2	PM_{10} and weather conditions	$PM_{2.5}$ and RH	$PM_{2.5}$ and temperature	$PM_{2.5}$ andCO_2	$PM_{2.5}$ and weather conditions	$PM_{0.3}$ and RH	$PM_{0.3}$ and temperature	$PM_{0.3}$ andCO_2	$PM_{0.3}$ and weather conditions
Infectious ward	R^2	0.772	0.730	0.112	0.613	0.101	0.721	0.547	0.640	0.011	0.210	0.014	0.116
	P_{value}	0.044	0.001	0.079	0.001	0.778	0.007	0.014	0.001	0.572	0.072	0.256	0.219
Men cardiac ward	R^2	0.240	0.085	0.046	0.233	0.087	0.101	0.065	0.171	0.014	0.041	0.177	0.014
	P_{value}	0.049	0.221	0.281	0.022	0.721	0.286	0.441	0.037	0.734	0.943	0.163	0.999
Women cardiac ward	R^2	0.112	0.110	0.230	0.348	0.030	0.025	0.098	0.199	0.089	0.110	0.188	0.166
	P_{value}	0.358	0.327	0.091	0.018	0.856	0.540	0.534	0.029	0.518	0.205	0.011	0.044
Men internal ward	R^2	0.054	0.089	0.221	0.311	0.101	0.025	0.013	0.114	0.511	0.065	0.058	0.210
	P_{value}	0.861	0.942	0.004	0.003	0.296	0.330	0.239	0.049	0.009	0.071	0.916	0.029
Women internal ward	R^2	0.110	0.014	0.230	0.240	0.041	0.401	0.251	0.374	0.019	0.031	0.040	0.112
	P_{value}	0.961	0.942	0.004	0.003	0.128	0.023	0.003	0.001	0.176	0.640	0.198	0.589
CCU	R^2	0.141	0.210	0.210	0.301	0.112	0.210	0.112	0.241	0.141	0.120	0.100	0.057
	P_{value}	0.231	0.317	0.048	0.009	0.661	0.494	0.090	0.058	0.132	0.214	0.293	0.941
Emergency ward	R^2	0.112	0.016	0.054	0.225	0.057	0.105	0.064	0.096	0.087	0.168	0.110	0.104
	P_{value}	0.063	0.275	0.156	0.010	0.693	0.152	0.721	0.217	0.125	0.221	0.406	0.317

Table 3. Ratio of hospital mean indoor to outdoor air quality (I/O) and the concentration of particulate matters (PM_{10}, $PM_{2.5}$, and $PM_{0.3}$), temperature, relative humidity and carbon dioxide

Sampling site	Weather conditions	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	$PM_{0.3}$ ($\mu g/m^3$)	Concentration of carbon dioxide (ppm)	Temperature (°C)	Relative humidity (%)
Infectious ward	Sunny	1.37	1.79	0.77	1.20	1.04	0.88
	Cloudy - Rain	1.48	1.88	1.23	1.50	1.35	0.58
	Dust	1.34	1.55	1.18	0.87	1.01	0.88
Men cardiac ward	Sunny	8.18	2.46	0.60	1.65	1.03	0.98
	Cloudy - Rain	2.50	1.44	1.33	1.51	1.22	0.60
	Dust	0.94	0.80	1.21	0.98	0.92	1.12
Women cardiac ward	Sunny	2.50	3.73	1.20	1.29	1.00	1.02
	Cloudy - Rain	2.15	2.30	1.51	2.44	1.27	0.72
	Dust	1.06	1.21	1.22	1.03	0.97	1.07
Men internal ward	Sunny	1.06	1.92	0.77	0.82	0.99	0.95
	Cloudy - Rain	1.79	1.68	0.87	1.66	1.21	0.68
	Dust	1.23	1.72	0.84	0.96	1.02	1.07
Women internal ward	Sunny	1.71	2.20	0.96	1.24	1.01	1.08
	Cloudy - Rain	2.67	2.79	0.93	1.62	1.22	0.76
	Dust	1.33	1.51	1.22	1.03	0.97	1.07
CCU	Sunny	1.61	2.27	0.77	3.56	0.99	1.08
	Cloudy - Rain	2.70	2.52	0.92	1.74	0.76	0.77
	Dust	2.72	2.53	0.93	1.77	0.77	0.79
Emergency ward	Sunny	2.07	2.28	0.72	1.35	1.04	1.08
	Cloudy - Rain	1.43	2.48	1.28	1.71	1.31	0.67
	Dust	1.13	0.84	1.17	0.78	1.01	0.87

midity were associated with ASHRAE standard ($P<0.001$). Density of particulate matters in various parts of the hospital was affected by several factors such as the type of disease, number of beds in each room, room occupant quantity, ventilating rate, number of personnel, weather conditions, temperature, relative humidity and carbon dioxide. Ventilation was done naturally through opening the windows for the wards (and rooms) that were suffering from the lacked ventilation and air conditioning systems. In women internal ward, there was a positive significant relationship between temperature, carbon dioxide and PM_{10}. Also, the same relationship was observed between temperature, carbon dioxide, weather conditions and $PM_{2.5}$. The results of the study in CCU ward represented a positive significant relationship between the weather condition, PM_{10} and $PM_{2.5}$.

The highest concentration of PM_{10} particulate matters in the men cardiac ward was due to several factors such as length of stay, short distance between the ward and street, excessive traffic of patients' companions, inappropriate ventilation of rooms, small space of the ward, and the large number of beds. The concentrations of PM_{10} in ambient air had a positive and significant relationship with the weather conditions so that its concentration was increased with the entry of a mass of dust or with the reduction of relative humidity. The reported concentrations of particulate matters were under the influence of different weather conditions so that the concentration of particulate matters on sunny days was less than the other two weather conditions. Also, it was even less than the amounts reported in cloudy and rainy days. This behavior might be explained by the fact that doors and windows are open on sunny days and the air mobility and ventilation are easily performed. In another words, the windows are closed on cloudy and rainy days due to the cold weather. As this study was performed in a cold season, air mobility was limited in cold days which in turn led to the accumulation of particles at the indoor environment of hospital.

Mean 8 h concentration of carbon dioxide in all indoor and outdoor parts of the hospital was less than the recommended values. The occasional increase of temperature and carbon dioxide concentration was due to use of the heating equipment, weather conditions and density of the visitors during the visit hours, especially. According to results obtained at the infectious disease ward, indicators of relative humidity and temperature had the highest effect on PM_{10} and $PM_{2.5}$. In addition, the results obtained in the men and women cardiac wards showed that weather condition had the highest effect on PM_{10}. At men internal ward, there observed positive significance relationships between carbon dioxide ($P<0.004$), weather condition ($P<0.003$) and PM_{10} in a way that the concentrations of PM_{10} were increased by changing weather conditions from sunny to dusty mode. Also, the concentrations of carbon dioxide and PM_{10} were increased with entering people into the wards followed by increasing of the breath. Weather condition represented a positive significance relationship to $M_{2.5}$. Also, a significance positive relationship was observed between the air relative humidity ($P<0.009$), weather conditions ($P<0.029$) and $PM_{0.3}$ in men internal ward.

The highest level of $PM_{2.5}$ concentrations was observed in women internal ward which had a positive significance relationship with temperature ($P<0.023$), carbon dioxide ($P<0.003$), and the weather conditions ($P<0.001$). The high level of $PM_{2.5}$ particulate matters concentration was observed in women internal ward. The main reason for this observation was that the women internal ward was in the vicinity of the street. In addition, the lack of proper ventilation system, interior space of patients' rooms, length of stay, dry cleaning with unsuitable equipment and high traffic of patients and staff were among the factors affecting this phenomenon. This is while, in the study conducted by many researchers with the aim of evaluating air quality in hospital, the undesired air quality was referred to the parameters including carbon monoxide, ozone, PM_{10} and $PM_{2.5}$particulate matters, formaldehyde, Total Volatile Organic Compounds (TVOC), air quality in the hospital wards and the number of patients admitted to hospital [22]. Comparing the results of present study with the research reported in others research [23] that was conducted to evaluate the concentration of particulate matter ($PM_{10}$and $PM_{2.5}$) in indoor and outdoor air of a hospital in Tehran, it was concluded that the concentration of $PM_{10}$and $PM_{2.5}$particles was 80% and 64% (respectively) in the hospital rooms, which exceeded the WHO standards.

Similar to [23], in present study, the comparison between results obtained for indoor and outdoor air quality indicated that the indoor air quality is affected by the outdoor air quality. In most of the wards, the ratio of hospital indoor to outdoor (I/O) mean concentration of particulate matters ($PM_{2.5}$, $PM_{0.3,}$ and PM_{10}), temperature, relative humidity, and carbon dioxide in air were above one. The highest I/O ratios for particulate matters were as follows: PM_{10}=3.75 in men cardiac ward, $PM_{2.5}$=2.16 in women internal ward and $PM_{0.3}$=1.31 in women cardiac ward. $PM_{0.3}$ can penetrate deep into the lung [24]. It has no allowed limit however, it requires further studies. For example, 250 particulate matters sized 2.5 µm are equal to 52000 particulate matters sized 0.3 µm [25]. They have the same weight however; they can make more effects because they are more abundant in quantity, applying more negative effects on health, larger surfaces and smaller diameters [26].

In the present study, it was revealed that the I/O ratio was above one by investigating the concentrations of indoor and outdoor particulate matters [27]. Study of relationship between the concentration of particulate matters was investigated at indoor and outdoor environment of a hospital in Shiraz. It was concluded that the quality of indoor air is influenced by outdoor air. In addition, the I/O ratio was observed to be more than one in some wards of the hospital. It was due to the poor ventilation and air exchange, number of beds, type of patients, number of personnel, and the ventilation rate [27].

In a study conducted in Guangzhou, China [28], the concentration of PM_{10} and $PM_{2.5}$ particulate matters at indoor and outdoor environments were associated to each other and the mean I/O was measured as 1.01 for $PM_{2.5}$ which was similar to the results of the present study. But, the mean I/O for PM_{10} was obtained as 0.89 (below one) which was not in accordance with the results of the present study [24].

In general, the results obtained from Air quality Index Calculator [29] showed that the outdoor air quality index for PM_{10} and $PM_{2.5}$ particulate matters was good. In this study the air quality index was calculated by software. Results of the concentration of particulate matters in the outdoor environment (enclosure) of hospital by this software and considering the EPA standards were evaluated in good (optimal level) and satisfaction ranges. Concerning the indoor environments, the index was moderate in 57.14% of cases for PM_{10} and it was evaluated as good as the other cases, too. The index was also fine for $PM_{2.5}$ particulate matters in all indoor environments of the hospital.

CONCLUSIONS

In this study the high quality of indoor to outdoor air (I/O) indicates the low rate of air exchange and ventilation with in the mentioned sections of hospital. The results of this study emphasize production and distribution of airborne particles in all sectors which is responsible for hospital infections. This problem can be improved by installing ventilation systems, entrance of clean air and if it is not be considered caused the transmission of infectious agents to other sections of hospital and outside environment and finally create a potentially dangerous situation for society. So improving of indoor ventilation and filtration systems ,distribution of air uniformly, the number of air exchange play an important role in improving of air quality and reducing particulate matters.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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ETHICAL CONSIDERATIONS

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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