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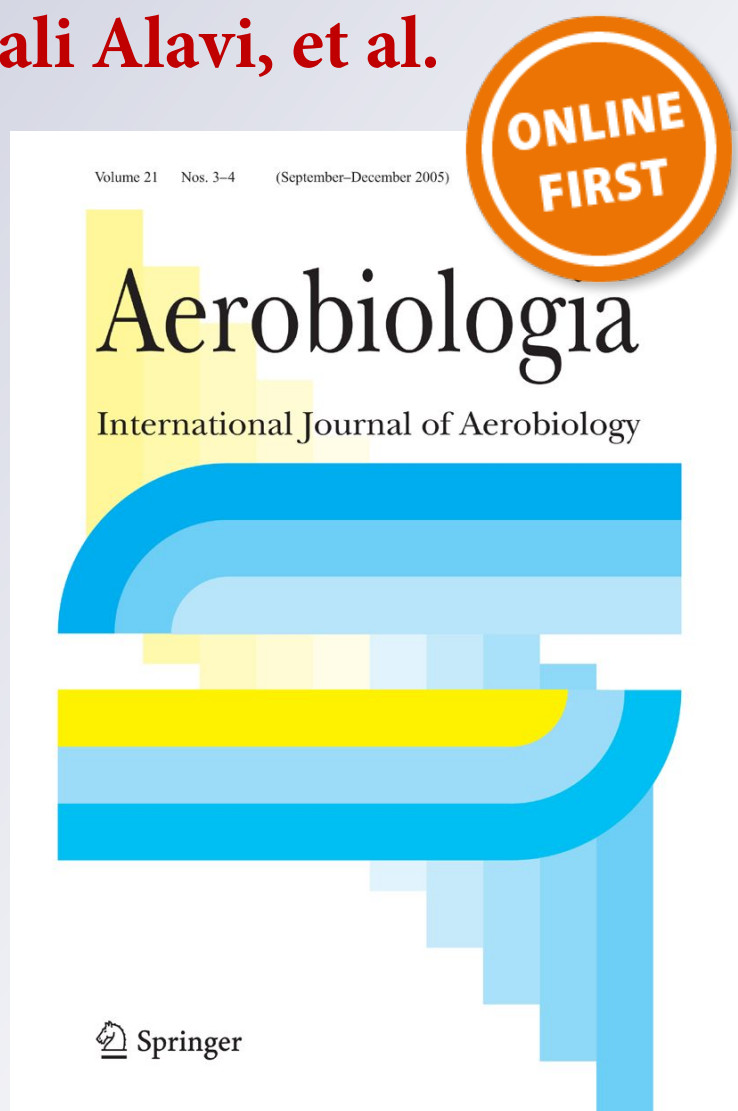
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Abstract The first purpose of our study was to determine culturable indoor airborne fungi in different places in Ahvaz during normal and dust event days. Ahvaz is the biggest city in southwest of Iran which has suffered from dust storms in recent decade. To minimize personal exposure to polluted air, governmental and private sectors excluding critical places such as hospitals, fire department and security organization are closed during dust event days. Therefore, the second objective of this survey was to see whether this plan (forced shutdown) is in place. Samples were collected from July 2010 to March 2011 by using quick take 30 equipped with a single-stage sampler. Fungal popula-

tion was measured in school, university and hospital during normal and dust event days. Five dominant fungi genera in three sampling stations were *Cladosporium*, *Alternaria*, *Aspergillus*, *Penicillium* and *Rhizopus* the concentrations (CFU/m³) of which were higher during dust events than normal days. Airborne fungi such as *Aspergillus*, *Mucor* and *Rhizopus* are opportunistic fungi which can cause *aspergilliosis* and *mucormycosis* infections in immunodeficiency individuals, vulnerable groups as well as healthy people. The results of this study confirmed the measure of forced shutdown in Ahvaz city due to increased concentration of fungi during dust event days.

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1 Introduction

Ahvaz with latitude 31°32', longitude 48°68' and with a population of one million persons is the capital city of Khuzestan province. Ahvaz has experienced many environmental problems such as old infrastructure, deficiencies in wastewater collection systems, increasing salinity in water distribution network as well as air pollution. Recently, dust storms over southwestern of Iran have added an anthropogenic source of air pollution to this city. Dust storm frequencies were 29, 33, 55, 45 and 17 in 2005, 2006, 2007, 2008 and 2009, respectively. In some cases, it has lasted for 48–72 h.

An average man inhales almost 10 m³ of air each day (Adhikari et al. 2004). Although indoor air quality is absolutely associated with ventilation, temperature, organic matter in building material and load of bioaerosols that entered from outdoor, the outdoor air quality is related to natural or anthropogenic air pollution, climatic factors, wind speed and direction, precipitation and atmospheric stability (Sautour et al. 2009; Abdelhameed et al. 2009; Cordeiro et al. 2010; Sautour et al. 2007). Bioaerosols, formaldehyde, carbon monoxide, asbestos and radon are the most important pollutants in the indoor environments. Bioaerosol is at the paramount of importance due to its complexity in mineralogical, biological, chemical and physical nature (Salvato Joseph et al. 2003). The massive volume of dust originated from arid land and deserts can elevate to high altitudes, and it can carry biological agents to far distances (Kellogg and Griffin 2006).

Environmental concerning, flight cancellation, economic loss and apparent anxieties in community were the most obvious drawbacks for this phenomenon. Immigration, brain drain and increasing in cardiopulmonary hospital admission cases can be considered as other detriments (Griffin 2007). In general, People spend more than 90 % of a day in residential, commercial and official environments during normal weather, and this is why indoor air quality plays an important role in community health (Chan et al. 2009; Tippayawong et al. 2009).

Many studies have revealed that exposure to airborne fungi may possibly be related to acute toxic effects,

allergy and dermatitis (O'Gorman and Fuller 2008). Other studies also have shown that many health endpoints such as cardiopulmonary diseases, asthma attacks, COPD, infarctions, hospital admissions for cardiovascular and respiratory disease are attributed to fungi (Pastuszka et al. 2000). Fungal spores and pollens can be transported to thousands of kilometers in the presence or absence of dust (Kellogg and Griffin 2006). Physical, chemical and biological composition of incoming dust can be completely changeable depending on dust sources whether it is originated from deserts or dried wetlands. For example, in field of biological quality of dust, previous studies have shown that most of *Aspergillus* can originate from desert of Saudi Arabia (Griffin 2007). There were a few investigations for fungi in indoor environments during dust event days but many studies have shown characteristics of microorganisms in ambient air during dust storms around the globe (Griffin et al. 2006; Prospero et al. 2005; Yeo and Kim 2002; Schlesinger et al. 2006). Comparisons of fungal population during normal and dusty weather in indoor environments have not been investigated in Ahvaz. Therefore, the main purpose of our study was to determine culturable indoor airborne fungi in three stations (indoor environment of educational and therapeutic centers), three seasons and during normal as well as dust event days.

2 Materials and methods

We selected children school due to vulnerable group (age ranges 7–15), university in standpoint of being crowded (age ranges 19–50) and hospital, that is, very sensitive place in view of patients (covering all ages, 6 months–120 years). Wind rose and sampling stations are depicted in Fig. 1.

Samples were collected from school, university and hospital, from July 2010 to March 2011, to determine culturable indoor airborne fungi and also to realize their significant differences between normal and dust event days. There were no air conditioning systems, and ventilation of three sampling stations was natural. Bioaerosols were collected by using portable Quick Take 30 Sample Pump, made by SKC Corporation, which was equipped with single biostage.

This single biostage was included a plate with a 400 holes of uniform diameter through which air was



Fig. 1 Wind rose and three sampling points (from left to right school, university and hospital) in Ahvaz

drawn at 28.3 L/min to impact on Petri dish (Wu et al. 2000; Fang et al. 2005). At each point of sampling, biostage was disinfected with 70 % isopropanol. As it mentioned, the average flow rate was 28.3 L/min that was the basis for all calculations.

CFU/m³ was calculated as follows:

$$\frac{(\text{Number of colonies} \times 1,000)}{(\text{sampling time} \times \text{velocity of air flow})}$$

Samples were collected in 5 and 2 min at each station during normal and dust event days, respectively (Kim et al. 2009). Samples were taken at all stations during normal and dust event days two times per day, regular morning (10–12) and afternoon (16–17), simultaneously. During normal days, sampling was repeated once every 6 days (EPA 2006), but during dust event days, sampling was repeated in the same day. Sampling was performed in three seasons, 264 times during normal days and 66 times during dust event days. The average of temperature and relative humidity was measured by using humidity and thermometer devices (Barometer Model: PHB-318) at each point of sampling.

Sampling devices were installed on levels for taking sample in the height of 1.5–2 m above the ground. The common media on 9-cm Petri dish for fungal culturing was potato dextrose agar (PDA) with chloramphenicol (100 µg/L) to inhibit bacterial growth. Exposed culture dishes were incubated for 72–96 h at 20 °C (Kim et al. 2009; Fang et al. 2005; Jo and Seo 2005). The species or genera of cultured dishes were identified based upon their micro- and macro morphological characteristics which were mentioned in standard taxonomic keys (Rippon 1988).

2.1 Statistical analysis

Analysis of variance (ANOVA) with Tukey's post hoc test for pairwise comparisons was used to compare means in different places and seasons. The one Sample Kolmogorov–Smirnov test was employed to evaluate the normality of the data. If the normality assumption of the data for the nonparametric equivalence of one way analysis of variance was rejected, Kruskal–Wallis test was used. The Mann–Whitney *U* test was employed for assessing significant difference of fungal

concentration during normal and dust event days. $p < 0.05$ was considered as significant. Spearman's rank correlation coefficient was used to realize statistical dependence between airborne fungal concentration and some of meteorological parameters such as temperature and humidity. Statistical analyses were conducted using SPSS version 17 (SPSS, Inc. Chicago, IL) during this study.

3 Results

3.1 Fungi concentration in different stations

The average, minimum, maximum and median of dominant and total airborne fungi as colony-forming unit per cubic meter of air and also mean percentage in three stations during normal and dust event days are presented in Table 1. Five dominant fungi genera in three sampling stations were *Cladosporium*, *Alternaria*, *Aspergillus*, *Penicillium* and *Rhizopus*. During normal weather, concentration of total fungi and *Aspergillus* was higher in school station than in university and hospital stations. There were significant differences between university with hospital and school ($p < 0.05$), however, no significant differences were found between hospital and school ($p > 0.05$).

Alternaria, *Cladosporium* and *Penicillium* concentration levels at hospital station were higher than university and school stations. The concentration levels of *Cladosporium* at university station have shown significant differences with those observed levels at hospital and school ($p < 0.0001$); Moreover, the overall concentration of *penicillium* was significantly different at three stations of this study ($p < 0.05$).

During dust event days, the total concentration of *Alternaria* and *Cladosporium* were significantly higher in hospital station than in university and school stations, but concentration of *Alternaria* was different at university station compared to hospital and school stations ($p < 0.0001$ and $p = 0.001$, respectively). It should be noted that there was no significant difference for total concentration of *Alternaria* in school station compared to hospital station and also for concentration of total fungi and *Cladosporium* in three stations of this study ($p > 0.05$). The total concentration of *Penicillium* was higher in hospital station than university and school stations; In addition, the overall concentration of *Penicillium* was significantly

different in hospital station compared to university and school stations ($p = 0.004$ and $p = 0.019$, respectively). It was found that *Rhizopus* concentration in school was higher than those levels recorded in hospital and university stations during normal and dust event days; furthermore, concentration of *Rhizopus* in school differed significantly compared to concentration of this genera in hospital and university stations during normal days ($p < 0.05$).

3.2 Fungi survey in seasons

In Table 2 minimum, mean, median and maximum values of airborne fungi in seasons are presented. During normal days the total samples in summer, autumn and winter were 86, 88 and 90, whereas total samples for dust event days were 24, 24 and 18, respectively. Number of samples during dust event days were a function of incoming dust storm times. The average concentration of total fungi (621.2 CFU m^{-3}) in winter was higher than those measured levels in autumn (551.2 CFU m^{-3}) and summer (300 CFU m^{-3}) during normal days. However, significant difference for total fungi between summer with two next seasons was found ($p < 0.05$).

The average concentration level of total fungi in autumn ($1504.3 \text{ CFU m}^{-3}$) were higher than those measured levels in summer and winter; in fact, the concentration of total fungi was significantly different between three seasons of this study during dust event days ($p < 0.05$).

3.3 Daily fluctuations of total and isolated fungi

Frequency and concentration percentage of total and isolated fungi in the morning and in the afternoon during normal and dust event days are presented in Table 3. Range of five dominant fungi genera concentration percentages were 2.35–48.4 %, whereas the frequency of total fungi and five dominant fungi were 96.2 and 40.2–78.8 % in the morning of normal days. Range of frequency and concentration percentages for other fungi in the morning of normal days were 9.1–45.4 and 0.14–3.6 %, respectively.

The above ranges in the afternoon of normal days changed to 100, 44.7–63.6 % and 2.65–51.3 for total fungi frequency, five dominant fungi frequency and five dominant fungi concentration percentages, respectively. 15.2–47.7 and 0.2–4.24 % were ranges of

Table 1 Concentration of airborne fungi (CFU m⁻³), temperature (°C) and relative humidity (RH %) measured during normal and dust event days in three stations

Fungi/Tem/RH	Time sample	University ^a					Hospital ^b					School ^c				
		Min	Max	Mean	Mean %	Median	Min	Max	Mean	Mean %	Median	Min	Max	Mean	Mean %	Median
<i>Aspergillus</i> sp.	Normal	0	296	54.7	14.3	50.7	0	359	53.8	10.3	32.7	0	819	72.2	12.4	31.2
	Dust	0	16456	489.6	42.7	128.0	0	288	85.3	10.6	60.5	120	480	252.4	24.8	240.0
<i>Alternaria</i> sp.	Normal	0	39	7.9	2.0	0	0	78	17.9	3.4	0	0	117	12.6	3.2	4.0
	Dust	0	144	30.9	2.7	24.0	0	248	105.4	13.1	96.0	40	216	99.6	9.7	80.0
<i>Cladosporium</i> sp.	Normal	0	1700	136.5	35.8	19.5	0	780	355.5	68.2	225.0	0	1482	251.5	43.1	183.3
	Dust	0	1736	404.0	35.3	360.0	176	1480	428.0	53.2	384.0	0	1482	218.5	21.5	179.5
<i>Penicillium</i> sp.	Normal	0	7800	48.1	12.6	0	0	281	52.8	10.1	19.5	0	94	10.2	1.7	8.0
	Dust	0	192	38.2	3.3	24.0	0	264	96.1	11.9	84.0	0	64	9.2	0.9	6.0
<i>Rhizopus</i> sp.	Normal	0	780	17.2	4.5	0	0	390	12.9	2.5	0	0	780	192.0	33.0	0
	Dust	0	800	64.2	5.6	8.0	0	100	42.6	5.3	40.0	80	776	392.9	38.6	368.0
Total fungi	Normal	0	7500	381.3	100	117.0	0	1560	521.4	100	483.6	0	1560	583.1	100	569.5
	Dust	288	16456	1146	100	400.0	512	1396	804.2	100	824.0	300	1832	1018.6	100	1135
Temperature	Normal	18	36	25.9	–	24.3	20	27	24.8	–	24.0	22	32	25.0	–	24.6
	Dust	16	33	22.2	–	20.3	20	23	21.3	–	21.0	19	24	21.7	–	22.5
Humidity	Normal	24	72	37.6	–	34.0	29	65	42.7	–	42.0	18	65	40.9	–	40.8
	Dust	25	58	32.2	–	28.4	26	38	33.0	–	33.2	34	55	42.3	–	42.3

Number of total samples collected for normal days: ^a*n* = 90 ^b*n* = 86 ^c*n* = 88

Number of samples collected for dust event days: ^a*n* = 22 ^b*n* = 22 ^c*n* = 22

Table 2 Concentration of total fungi (CFU m⁻³), temperature (°C) and relative humidity (RH %) measured during normal and dust event days in three seasons

Fungi/Tem RH	Time sample	Summer ^a				Autumn ^b				Winter ^c			
		Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median
Total fungi	Normal	42	480	300.0	296.0	0	7500	551.2	347.0	0	1560	621.2	561.6
	Dust	288	800	446.9	408.0	400	16456	1504.3	1016.0	502	1832	1026.8	823.0
Temperature	Normal	27	36	29.2	31.0	18	33	24.4	24.2	20	27	23.1	23.7
	Dust	25	33	28.2	32.4	17	26	18.5	21.0	16	24	17.5	19.4
Humidity	Normal	24	39	33.5	33.0	25	72	42.5	40.4	18	65	44.9	42.5
	Dust	32	43	36.2	36.5	25	58	39.6	38.0	26	48	30.4	29.0

Number of collected samples during normal days: ^a $n = 86$ ^b $n = 88$ ^c $n = 90$

Number of collected samples during dust event days: ^a $n = 24$ ^b $n = 24$ ^c $n = 18$

frequency and concentration percentage for other fungi in the afternoon.

The overall frequency of total fungi, frequency range of five dominant fungi and range of their concentration percentages in the morning of dust events were 100, 57.6–97 % and 5.6–35.9 %, respectively. Instead of statistical figures mentioned above, 100, 51.5–90.9 and 4.2–35.1 % were obtained in the afternoon.

Ranges of frequency and concentration percentage for other fungi in the morning of dust events were 15.1–54.5 and 0.13–3.31 %, respectively, whereas 18.2–48.5 and 0.3–1.31 % were ranges of frequency and concentration percentage for other fungi in the afternoon of dust event days.

3.4 The comparison of fungi concentration levels in seasons and stations during normal and dust event days

Figures 2 and 3 are presented to illustrate dominant isolated fungal percentages in three seasons and three sampling stations during normal and dust event days. In the first month of present study (summer), the highest concentration percentage of fungi was associated with *Aspergillus* by 35.7 and 46.5 % during normal and dust event days, respectively (Fig. 2). Clearly, dominant fungi genera concentration levels during dust event days were higher than normal days in which differences for total fungi, *Rhizopus* and *Aspergillus* were statistically significant ($p < 0.0001$, $p = 0.003$ and $p = 0.029$, respectively). Differences became significant for total fungi during normal and dust event days in autumn ($p = 0.009$). Significant

differences also were observed for *Rhizopus*, *Cladosporium*, *Alternaria* and *Aspergillus* ($p < 0.05$) during normal and dust event days. *Penicillium* did not show significant difference during normal and dust event days in this season ($p > 0.05$).

In winter there were no significant differences for *Penicillium*, *Cladosporium* and *Rhizopus* concentration levels ($p > 0.05$) during normal and dust event days. However, significant differences between normal and dust event days for *Alternaria*, *Aspergillus* and total fungi were found ($p < 0.05$).

It was evident from Fig. 3 and Table 1 that the maximum concentration values among dominant isolated fungi in university station were *Cladosporium* and *Aspergillus* by 35.8 and 42.7 % during normal and dust event days, respectively.

Statistically, significant differences between normal and dust event days for total fungi, *Penicillium* and *Aspergillus* concentration values were observed in university station ($p < 0.05$). In addition, differences became more significant between normal and dust event days for *Alternaria*, *Rhizopus* and *Cladosporium* concentration levels ($p < 0.0001$, $p < 0.0001$ and $p < 0.05$, respectively).

Figure 3 and Table 1 indicated that *Cladosporium* was the most predominant fungi by 68.2 and 53.2 % in hospital station during normal and dust event days, respectively. Statistically, significant differences between normal and dust event days for total fungi and *Alternaria* concentration levels were found in this station ($p < 0.05$); however, there were no significant differences for *Cladosporium* and *Penicillium* in hospital station ($p > 0.05$). *Cladosporium* by 43.1 % indicated the highest concentration in school station

Table 3 Overall frequency (%) and concentration percentage of airborne fungi, in the morning and afternoon during normal and dust event days

Bioaerosol	Time sample	Normal days ^a (N = 264)		Dust days ^b (N = 66)	
		Frequency (%)	Concentration percentage (%)	Frequency (%)	Concentration percentage (%)
<i>A. flavus</i>	Morning	33.3	2.44	75.8	3.50
	Afternoon	21.2	2.67	48.5	2.50
<i>A. terreus</i>	Morning	24.2	1.50	36.6	2.50
	Afternoon	26.5	1.09	39.9	1.40
<i>A. fumigatus</i>	Morning	37.9	3.30	63.6	6.25
	Afternoon	35.6	3.40	66.7	5.52
<i>A. niger</i>	Morning	65.9	3.90	75.8	11.21
	Afternoon	38.6	3.80	84.8	22.61
Total <i>Aspergillus</i> sp.	Morning	78.8	11.14	97.0	23.46
	Afternoon	63.6	10.96	90.9	32.03
<i>Alternaria</i> sp.	Morning	40.2	2.35	66.6	8.84
	Afternoon	44.7	2.65	66.6	7.16
<i>Cladosporium</i> sp.	Morning	51.5	48.40	84.8	35.90
	Afternoon	63.6	51.30	90.9	35.10
<i>Penicillium</i> sp.	Morning	47.7	9.78	57.6	5.60
	Afternoon	51.5	5.21	51.5	4.20
<i>Rhizopus</i> sp.	Morning	51.5	17.46	75.8	17.50
	Afternoon	44.7	12.61	57.6	16.23
Others sp.	Morning	15.2	0.32	15.1	0.13
	Afternoon	47.7	4.24	18.2	0.10
<i>Acremonium</i> sp.	Morning	9.1	0.14	21.2	0.40
	Afternoon	22.0	0.50	18.2	0.30
<i>Fusarium</i> sp.	Morning	22.7	0.50	48.5	3.31
	Afternoon	15.2	0.20	30.3	1.62
<i>Yeasts</i>	Morning	15.2	1.11	42.4	1.10
	Afternoon	45.4	1.30	39.4	0.70
<i>Mucor</i> sp.	Morning	15.2	1.46	42.4	0.91
	Afternoon	38.6	2.31	48.5	1.25
<i>Curvularia</i> sp.	Morning	10.6	1.89	0	0
	Afternoon	15.2	1.52	0	0
<i>Drechslera</i> sp.	Morning	10.6	1.85	0	0
	Afternoon	38.6	4.70	0	0
Non-sporulating	Morning	45.4	3.60	54.5	2.85
	Afternoon	46.2	2.50	48.5	1.31
Total fungi	Morning	96.2	100	100	100
	Afternoon	100	100	100	100

^a Number of samples collected for normal days: 264; morning = 132, afternoon = 132

^b Number of samples collected for dust event days: 66; morning = 33, afternoon = 33

during normal days, and *Rhizopus* was the predominant fungus by 38.6 % during dust event days. Statistically, significant differences between normal and dust event days were observed for total fungi, *Aspergillus* and *Alternaria* concentration ($p < 0.05$) in this station.

Concentration levels of isolated fungi during dust event days to those measured during normal days (D/N) at a range of 1.3–13.4 in the present study are depicted in Fig. 4. The highest ratios were related to *Fusarium* and *A. niger* (13.4 and 8.8, respectively). This ratio was 2 for total fungi which implied

Fig. 2 Percentage of fungi isolated in three seasons sampling during normal and dust event days

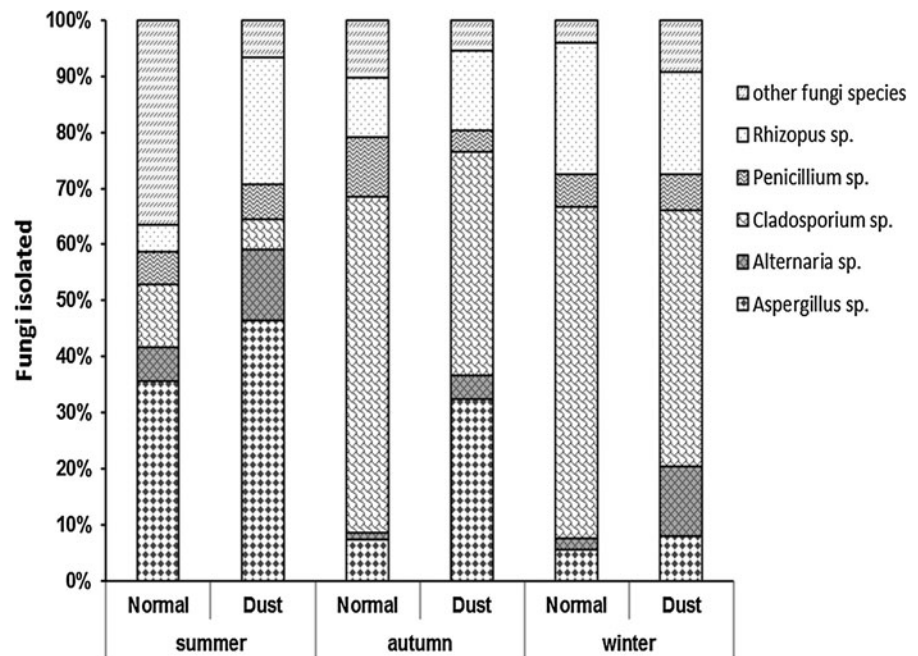
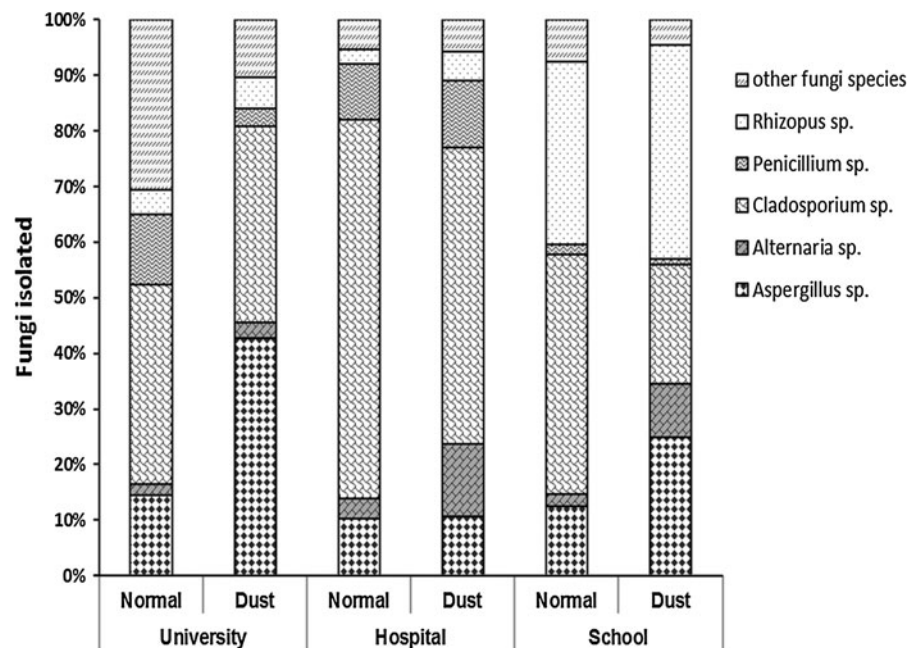


Fig. 3 Percentage of fungi isolated in three sampling sites during normal and dust event days



deterioration impact of dust storm on indoor air quality. As it had mentioned, there were significant differences between normal and dust event days for the total fungi concentration in the present study ($p = 0.033$). As shown in Fig. 5, concentrations of

total fungi in 50 % of samples during dust event days were higher than standard value of Korean guideline. This result in addition to the obtained findings from Fig. 4 confirmed adverse effect of dust storm on indoor air quality.

Fig. 4 The ratios of indoor airborne fungi in dust days to normal days

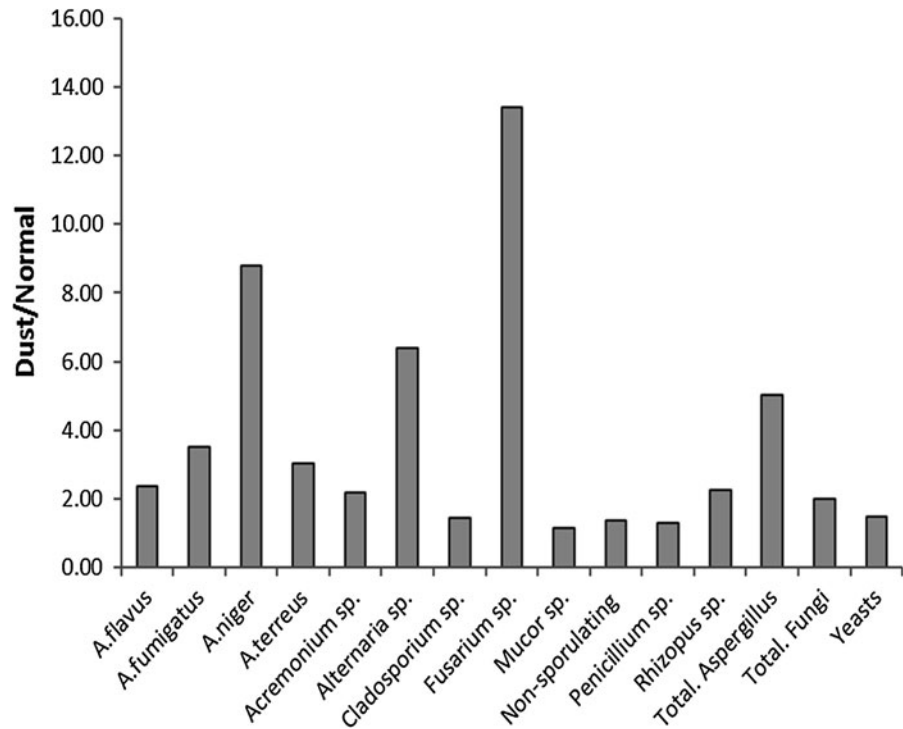
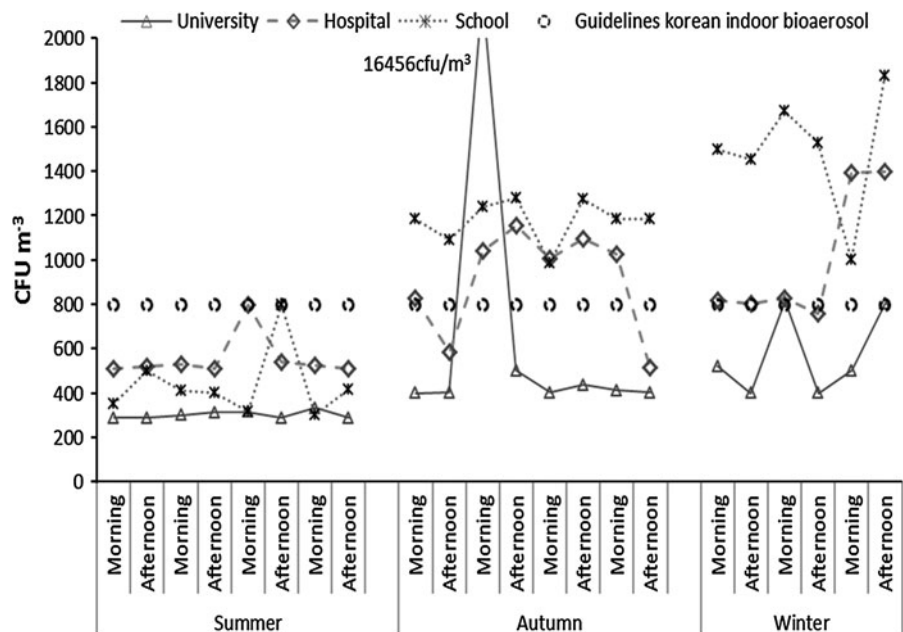


Fig. 5 Airborne fungi concentration in three stations during dust event days compared to Korean guideline



3.5 3.5. fungi concentration and environmental factors

Table 2 showed that in normal days, the highest and the lowest temperatures were in summer and winter,

respectively. Significantly higher temperature were found in summer than in autumn and winter ($p < 0.0001$), while no significant variation of temperature was observed between autumn and winter ($p > 0.05$). After happening dust storms, the ambient

temperature was also decreased apparently in all seasons due to interference at incoming sunlight.

A lower mean of relative humidity percentage was observed in summer than in winter and autumn during normal days. Statistically, there were significant differences for relative humidity percentage between summer with autumn and winter ($p < 0.05$).

Table 2 exhibited that in dust event days, averages of relative humidity in summer, autumn and winter were 36.2, 39.6 and 30.4, respectively. Significant difference existed for mean of RH % between three seasons of this study ($p < 0.05$) during dust event days.

Statistically, significant association was also found between total fungi concentration with dust event days ($p < 0.0001$) as well as humidity ($p = 0.036$).

4 Discussion and conclusion

In general, fungi concentration and population increase during dust events in indoor and outdoor environments. According to Kellogg and Griffin (2006), some types of fungi (*Basidiospores*, *Aspergillus*, *Nigrospora*, *Arthrinium* and *Curvularia*; *rusts*, *Stemphylium*, *Cercospora*, *Pithomyces* and unidentified fungi) were 2–12 times more frequent in dust event days. They reported genera diversity during dust events. This study also indicated that different genera of fungi occurred during dust event days. Fungi concentration during dust event days at three stations was higher compared to those levels in normal days. Schlesinger et al. (2006) also found that fungi concentration during dust events was higher compared to normal days. During normal days in Ahvaz city, the average fungi concentration in hospital (521.4 CFU m^{-3}) and school (583.1 CFU m^{-3}) were higher than other studies conducted in these places (Sautour et al. 2009; Jo and Seo 2005; Azizyfar et al. 2009). For example, Jo and Seo (2005) reported a fungal concentration ranging from 281 to 871 CFU m^{-3} at schools in winter. Sautour et al. (2009) estimated low airborne fungi concentration ranging from 2 to 26 CFU m^{-3} in French hospital. Azizyfar et al. (2009) recorded a mean concentration of $200 \pm 79.9 \text{ CFU m}^{-3}$ for fungi in Kamkar Hospital (Qom city). In this study, dominant fungi genera at hospital were *Cladosporium*, *Penicillium*, *Alternaria* and *Aspergillus*, and this finding was similar to other studies conducted in hospitals (Sautour et al. 2009; Medrela-Kuder 2003; Rosas et al. 1997).

According to the present study in Ahvaz, there were significant differences between normal and dust event days for *Cladosporium*, *Alternaria*, *Aspergillus*, *Penicillium*, *Rhizopus* and total fungi concentration ($p < 0.05$). The same result was reported between background and dusty weather in Hualian city for total fungi, *Cladosporium* and *Alternaria* concentration (Ho et al. 2005).

We observed *Cladosporium*, *Alternaria*, *Aspergillus*, *Penicillium* and *Rhizopus* as predominant fungi genera in Ahvaz city. In another study, *Cladosporium*, *Fusarium* and *Mucor* were isolated from Saudi Arabia desert soils as predominant fungi (Griffin 2007). Singh et al. (1990) showed that *Cladosporium*, *Alternaria* and *Penicillium* species were predominant during winter, summer and autumn, respectively. Based on our study, predominant genus was *Aspergillus* in summer and autumn whereas it was *Cladosporium* in winter. Higher concentration levels of fungi were found in the morning in Ahvaz city. The same result was also reported by other researchers (Sen and Asan 2009; Ho et al. 2005). There were higher levels of total fungi in winter in this study during normal days while there were maximum levels in autumn and summer in previous studies (Sen and Asan 2009; Jo and Seo 2005; Ren et al. 1999; Pastuszka et al. 2000; O’Gorman and Fuller 2008). There were not obvious reasons for those great differences but they could be attributed to different types of sampler, different type of culture media (fungal growth substrates), different experimental and sampling approaches, presence or absence of air conditioning system, individual activities in indoor environments, as well as geographic location (Adhikari et al. 2004; Hargreaves et al. 2003; Jo and Seo 2005; Rosas et al. 1997). In view of geographic and weather conditions, Khuzestan province particularly Ahvaz city has a long period of hot seasons from April to October, but it has a short period of coldness from December to January. It should be noted that the first two months of autumn are very similar to summer time, and in turn, the last month of autumn and two next months are very similar to winter time.

The governor of province announced to stop working at the time of dust storm occurrence, and it was only practical measure to protect citizens against dust storm, but did note that every forced shutdown imposed an irreparable loss on economy of country. As a result, schools and universities were closed during dust plume occurrence and because of not

cleaning dust by crews, fungi concentration levels were high at these stations compared to a sensitive place like hospital. Based on present study, more than fifty percent of fungal samples during dust event days were exceeded from Korean guideline (800 CFU m^{-3}). Consequently, the measure of forced shutdown in Ahvaz city was confirmed with regard to these results.

Some opportunistic and invasive fungi such as *Aspergillus*, *Mucor* and *Rhizopus* can pose a threat to vulnerable individuals particularly at hospital and school stations (Bhansali et al. 2004). These fungi were found in more than fifty percent of collected samples especially from sensitive places such as hospital and school during dust event days in Ahvaz city.

Jo and Seo (2005) indicated that these fungi intensified allergic symptoms and asthmatic attacks in children.

If the *Aspergillus* spores concentration in indoor environment exceeded from 50 CFU m^{-3} , it might happen sick-building syndrome (SBS) (Augustowska and Dutkiewicz, 2006). *Aspergillus* concentration in 75 % of all samples was higher than 50 CFU m^{-3} during dust event days in Ahvaz city. *Aspergillosis*, the most common invasive mold infection worldwide, is attributed to the ubiquitous fungus *Aspergillus* spp. Another study revealed that risk of invasive *Aspergillosis* increased when mean concentration of this fungus was close to 0.9 CFU m^{-3} (Perdelli et al. 2006). In Ahvaz city, the mean concentration of *A. Fumigatus* in more than 50 % of collected samples was 65 times greater than 0.9 CFU m^{-3} during dust event days. Once again, the measure of forced shutdown in Ahvaz city was confirmed.

Regarding natural ventilation of three stations, present study showed that indoor air quality impressed with ambient atmosphere. Because of increasing bioaerosol concentration during dust events, it is recommended to install air conditioning which is equipped with HEPA or ULPA filter in such places to mitigate effects of ambient atmosphere on indoor air quality.

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