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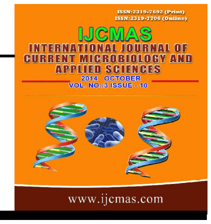

Original Research Article

Seasonal and spatial variation of microbial contents in falling dust in Riyadh city, Saudi Arabia

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A B S T R A C T

Cities which are located in arid zones and surrounded by vast desert areas like the city of Riyadh, Saudi Arabia suffer from dust storms and mineral aerosols mixed with pollutants of dust-borne microorganisms. This study carried out to evaluate of seasonal and spatial variation ofmicrobial contents (bacteria and fungi) in the collected samples of dust deposition from 15 different locations almost covering Riyadh city area. Generally, it is clear from this study that Saudi Arabia is affect by global change, as shown by the increase of the temperature, evaporation and decreasing of rainfall, relative humidity and there is a remarkable increase in the number regional dust storm. The results indicated that the counts of different tested microorganisms in all dust samples during months of 2012G were higher in spring season as well as early months of summer season compared to winter orautumn seasons under various sites in Riyadh city. It is worthy to state that the higher microbial content in falling dust samples were always associated with the high pollution effects from tested locations in Riyadh city. The higher microbial contents were recordedin Al-azeezya (cement factory), industrial district and industrial-2 compared to other sites under different months during 2012G. *Bacillus* sp. was more common bacterial isolates, followed by *Staphylococcus* sp., while the least value was reported by *Ps. aeruginosa*. Regarding the fungal isolates,*Aspergillus* sp. was the most common compared other fungus. The highest values of bacterial and fungal pathogens counts were among spring season and early summer season due to increased dust storms incidence.

Introduction

Riyadh city; the capital of Saudi Arabia is surrounded by desert areas and having an altitude of 600m is exposed to dust storms several times in the year.Saudi Arabia constitutes the vast majority of the Arabian Peninsula and much of the Saudi lands surface is made up of deserts and semi-arid lands. Due to its topography, drought, light–

textured topsoil and scanty vegetative cover, Saudi Arabia is susceptible to the dust and dust storms.The impact of dust events on local air quality and public health are now becoming of greater concern in the Kingdom of Saudi Arabia after the occurrence of frequent and severe dust storms in recent years. Although the study of dust storm material has attracted many researchers in the world, little work has been carried out in Saudi Arabia. Al-Tayeb and Jarrar (1993), estimated the average quantity of dust falling on Riyadh to be around 220 tons/km^2/year. Earlier Basahy (1987) estimated the dust deposition rate to be 196-220 tons/km^2/year.Dust storm activity in the deserts of Asia is seasonal, with the majority of atmospheric transport occurring during the spring, from February to May (Xiao *et al.*, 2002). Dust storms cause serious environmental consequences and have negative effects for human society (Chun *et al.*, 2002; Shao and Dong, 2006). Therefore, dust storms are an important environmental problem and receive increasing attention by the government and by the public.

These transoceanic and transcontinental dust events inject a large pulse of microorganisms and pollen into the atmosphere and could therefore have a role in transporting pathogens or expanding the biogeographical range of some organisms by facilitating long-distance dispersal events. In Saudi Arabia, Kwaasi *et al.*, (1998) reported that many genera of bacteria and fungi found in dust storm samples were identified by using microscope method as *Bacillus*, *Pseudomonas*, *Staphylococcus* (bacterial genera), and *Alternaria, Aspergillus, Botrytis, Cladosporium, Mortierella, Mucor, Penicillium, Pythium Ulocladium, Verticillium* (fungal genera). The distribution of microorganisms, and especially pathogens, over airborne particles of different sizes has been ignored to a large extent, but it could have significant implications regarding the dispersion of these microorganisms across the planet, thus affecting human health (Polymenakou *et al.*, 2008). The aim of this study is to evaluate of seasonal and spatial variation formicrobial contents (bacteria and fungi)in the collected samples of dust deposition from different locations in Riyadh city.

Materials and Methods

Dust fallout samples were collected from 15 different locations almost covering Riyadh city area (15 Civil defense buildings were selected for the installation of the dust collectors). Details about the sites and coordinates is presented in Fig. 1. Meteorological conditions of temperature, humidity, rainfalland wind speed were obtained from the Presidency of Meteorology and Environmental Protection (Table 1). Samples werecollected once a month during twelve months of 2012G. Dust samples were collected using Marble Dust Collector (Ganor, 1975). The collector consists of a rectangular plastic tray 52.5 cm long, 31.5 cm wide and 10.0 cm high with a marble filter at the top. The filter is made of two layers of marbles 1.5 cm in diameter, which are stored in a sieve container on top of the plastic tray (mesh diameter of the sieve openings: 0.5 cm).

Falling dust microbial content was monitored by using standard plate count method (Mahmoud, 1988). Serial dilution of dust samples was performed. From certain dilutions, different selective agar culture plateswere inoculated. Total microbial count was determined by using Nutrient Agar Medium, total fungi count was determined by using Martin's Medium, *Staphylococcus* sp. count was determined by Staphylococcus' medium NR 110 agar base and *Pseudomonas aeruginosa* count was determined by using cetrimide agar medium.Spore forming bacteria count was determined by placing some tubes into a test tube rack in a hot water bath (at 80°C for 20 minutes). This treatment will kill the non-spore forming vegetative cells. Then, the plats of nutrient agar medium was used and incubated at 28°C for five days.

At the end of incubation periods, colony forming units (CFU) for different tested microorganisms were recorded. Average of each three months for different microorganisms counts were represented according to year seasons (winter, spring, summer, autumn).Bacterial isolates were initially characterized by morphology and microscopic appearance. Identification of fungi was based mainly on growth colonial appearance, microscopic examination of the spore and hyphal caracteristics of the stained preparations (Larone, 1995; Samson *et al.*, 2007).

Statistical analyses of the data were undertaken using STATISTIX 10 computer program (analytical software). The data were analyzed by one-way analysis of variance (AVONA) and the significance of the differences between means was calculating using the Duncan test. All values given in this research are means of three months values in the same season. The results are presented as mean ± standard error (SE).

Results and Discussion

Data represented in Tables (2–5) revealed microbial content of bacteria and fungi in falling dust samples from fifteen sites in Riyadh city during year seasons (winter, spring, summer, autumn) in 2012G. Counts of total bacteria, total fungi, spore forming bacteria, *Pseudomonas aeruginosa*, and *Saphylococcus* sp. were determined monthly in dust samples under various sites in Riyadh city.

From data presented in Tables (2–5) it could be stated that the counts of different tested microorganisms in all dust samples during four seasons were generally higher in spring season (March, April , May), followed by summer season (June, July, August) and autumn season (September, October, November). The lowest microbial concentrations are observed during winter season (December, January, February). Xiao *et al.* (2002) reported that dust storm activity in the deserts of Asia is seasonal with the majority of atmospheric transport occurring during the spring. Worth mentioning, many recent researches address the correlations between dust concentrations and microbial load in air during dust storms (Griffin *et al.*, 2006; Schlesinger *et al.*, 2006).The seasonal variations of microbial aerosol concentrations has been observed by many authors (Tong and Lighthart, 2000; Borodulin *et al.*, 2005a; Harrison *et al.*, 2005). Total microbial concentrations are positively correlated with the air temperature (Harrison *et al.*, 2005).

The higher microbial concentrations during summer may be due to seasonal differences in temperature and its effects on source strength and atmospheric convection (Tong and Lighthart, 2000). In addition, the most significant environment factors influencing the viability of microorganisms are temperature, wind velocity and relative humidity. Dust-borne dispersion of microorganisms play a significant role in the biogeographical distribution of both pathogenic and nonpathogenic species, as long-range atmospheric transport routes and concentrations shift through time due to climatic and geologic change (Martiny *et al.*, 2006; Moreno *et al.*, 2001). Data represented in Tables (2–5) showed that total bacterial counts were calculated always higher numbers in Al-azeezya (Cement Factory), industrial 2 and industrial district as compared to others sites.This is largely because it is now appropriately recognized that exposures to biological agents in several industrial activities sites are associated with a wide range of adverse health effects with major public health impact, including contagious infectious diseases, acute toxic effects, and allergies (Douwes *et al.*, 2003). It is common knowledge that many bacterial diseases are transmitted through the air over short distances. In the case of some diseases, there is evidence of airborne transmission up to 6 km from contaminated industrial locations (Nguyen *et al.,* 2006).

Data of total fungal counts in Tables (2–5) indicated that fungi were found in all sites during different seasons 2012G. Mostly, the total counts of fungi in dust samples during spring season exceeded that of in most tested sites. Moreover, it was also noted that the highest fungi counts were recorded 108 $\times 10^3$and 88$\times 10^3$ CFU/g dust in Al-azeezya and industrial 2 sites respectively compared to other sites, as a result of highly polluted in these locations. One of the genetic advantages that fungi have over many other microorganisms is that they are capable of producing spores. Spores enhance survival during transport and periods of prolonged environmental stress.On the other hand, Lacey (1981) reported that the airborne concentrations of fungal spores typically occur in temperate and tropical regions and the lowest in desert environments.

It is of interest to note that Aspergilli and Penicillia were the most predominant groups in dust samples from different sites. The most ubiquitous species of Aspergilli were *Aspergillusniger*. These results are in agreement with Ismail *et al.,* (2002) who found that the airborne fungi in the eastern and western deserts of Egypt, 44 genera and 102 species (*Aspergillus* sp. was the dominant genus) with the areas of highest fungal concentrations and diversity corresponding to increases in vegetative cover and anthropogenic activity. Similar results are reported also by Durand *et al.*, (2002). Fungi are of health concern because many of them are aero allergens as *Aspergillus* and other as allergenic agent.

The total counts of spore forming bacteria in falling dust samples from different sites in Riyadh city during months 2012G is presented in Tables (2–5). Spore forming bacteria are highly resistant to hostile physical and chemical conditions. These are a dormant form of the bacterium that allows it to survive sub-optimal environmental conditions and are a frequent cause of contamination. It is clearly noted that abrupt increases in total spore forming bacteria counts in dust samples took place in all tested sites during different months. Total counts of spore forming bacteria were recorded generally higher in spring season as well as summer season. Concerning the effect of various locations in Riyadh city on spore forming bacteria counts in dust samples, recorded higher counts in airport, Al-azeezya (cement factory), industrial district, industrial 2, and Al-Waha. As expected, the aerobic spore forming bacterium, *Bacillus* species were the most predominant group in all tested locations. It is clear from the current study that the *Bacillus* sp. were highest during spring season, may be due to many dust storms events in in Kingdom of Saudi Arabia and the environment was suitable for bacterial growth or it might be due to transportation from the countries near to KSA which have the same climate such as temperature, high evaporation and low relative humidity. On other hand, the aerobic spore forming bacteria concentrations were positively correlated with the air temperature. These results are in agreement with those of Al-Dabbas *et al.,* (2011) who found that the prominent bacterial isolate from dust storms samples of Iraq was the gram-positive bacilli, *Bacillus* species (40.6%). As well as Griffin *et al.* (2006) found that African desert dust concentrations consisted of 13 genera, with those dominant being *Bacillus* sp. (32%).

It is worthy to mention that *Pseudomonas aeruginosa* detection in falling dust samples from different sites in Riyadh city during season months of 2012G were very low, may be due to *Ps. aeruginosa*, as a species, occurring naturally in moist environmental, but is generally considered a ubiquitous bacterium. *Ps. aeruginosa* is essentially an opportunistic pathogen. As such, to initiate infection, *Ps. aeruginosa* usually requires a substantial break in first-line defenses. *Ps. aeruginosa* is associated with numerous chronic and progressive respiratory diseases. Counts of *Ps. aeruginosa* were generally higher in spring season as well as autumn season compared to other seasons of year under various sites in Riyadh city.

Total counts of *Staphylococcus* sp. in falling dust samples from different sites in Riyadh city during 2012G is presented in Tables (2–5). Generally, counts of *Staphylococcus*species in dust samples gavehigher counts in spring months season compared to other months season under various sites in Riyadh city. Al-azeezya, Industrial district, industrial 2, airport and Al-Sulay sites recorded higher *Staphylococcus* sp. counts in dust samples in Riyadh city during different months. Most of *Staphylococcus*species can cause a wide variety of diseases in humans and other animals through either toxin production or tissuespenetration.A similar study conducted in Kuwait by Lyles *et al.* (2005) demonstrated that dust can serve as a carrier for pathogens, including *Staphylococcus aureus* (as wide range of infections).

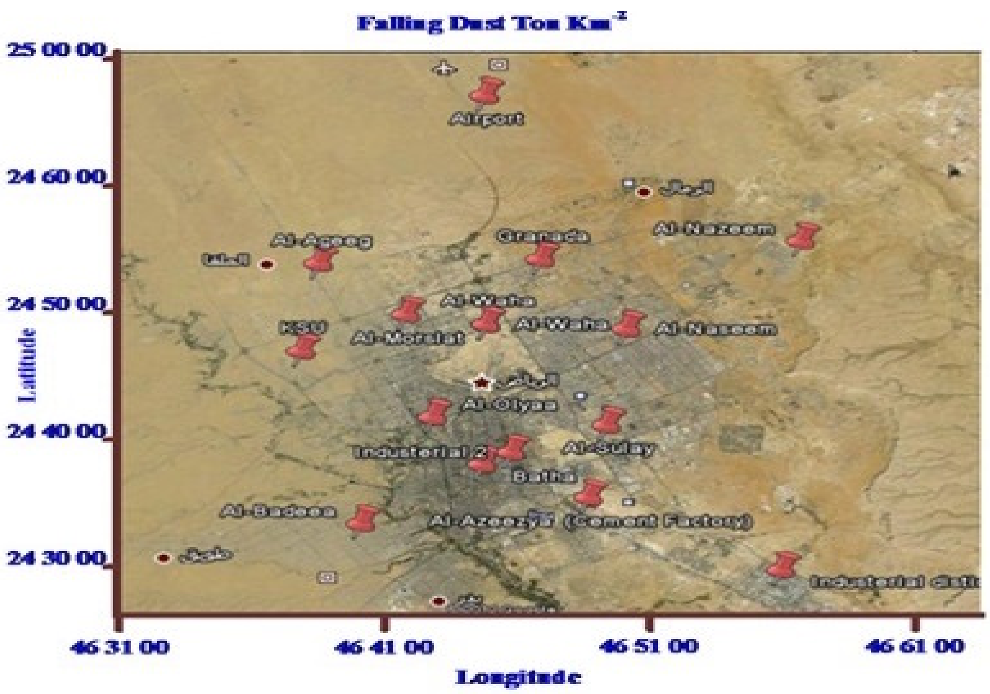

Fig.1 Locations of the study are in Riyadh city and the Co-ordinates of the measurement stations

Table.1 Seasonal mean for some characteristics of Riyadh city climate

Climate	January	April	July	October
Temperature (^oC)				
-Minimum Temperature	7	17	24	15
-Maximum Temperature	22	33	43	35
-Mean Temperature	14	25	34	25
Relative humidity (%)	53	37	19	33
Rainfall (MM)	9	16	0	3
Wind Speed (Km/h)	5	5	6	4

Table.2 Microbial content in falling dust samples from different sites in Riyadh city during Winter Months, 2012G

Site of sample	**Total counts** (CFU×10^4/g)	**Total fungi** (CFU×10^2/g)	**Spore forming bacteria** (CFU×10^2/g)	***Pseudomonas aeruginosa*** (CFU/g)	***Staphylococcus* sp.** (CFU×10/g)
Al-Naseem	89.667^{d}	90.00^{abcd}	165.67^{a}	0.00^{a}	82.33^{cdef}
Al-Nazeem	172.00^{abcd}	110.00^{abc}	158.67^{a}	0.00^{a}	56.00^{def}
Al-Sulay	177.33^{abcd}	51.00^{de}	123.67^{a}	0.00^{a}	101.67^{bcde}
Industerial 2	234.00^{abc}	76.67^{bcde}	140.00^{a}	1.00^{a}	118.33^{bcd}
Al-Azeezya	270.00^{ab}	132.00^{ab}	291.00^{a}	1.67^{a}	191.00^{a}
Industrial district	283.33^{a}	135.00^{a}	259.67^{a}	1.00^{a}	161.67^{ab}
Batha	153.67^{bcd}	40.00^{de}	126.00^{a}	0.00^{a}	41.00^{ef}
Al-Morslat	91.333^{d}	26.00^{e}	48.00^{a}	0.00^{a}	35.33^{ef}
Airport	196.67^{abcd}	93.33^{abcd}	192.33^{a}	0.67^{a}	125.00^{abc}
Al-Ageeg	114.00^{cd}	65.00^{cde}	126.00^{a}	0.67^{a}	51.67^{def}
KSU	180.00^{d}	57.67^{cde}	169.00^{a}	0.00^{a}	74.00^{cdef}
Al-Badeea	79.000^{d}	53.67^{cde}	54.67^{a}	0.00^{a}	22.67^{f}
Al-Olyaa	84.333^{d}	28.00^{e}	91.33^{a}	0.00^{a}	37.67^{ef}
Al-Waha	188.67^{abcd}	42.00^{de}	201.50^{a}	0.00^{a}	22.00^{f}
Granada	77.333^{d}	38.00^{de}	178.50^{a}	0.00^{a}	41.00^{ef}

Means in the same column followed by the same letter are not significantly different according to Duncan's multiple range test.

Table.3 Microbial content in falling dust samples from different sites in Riyadh city during Spring Months, 2012G.

Site of sample	Total counts (CFU×10^4/g)	Total fungi (CFU×10^2/g)	Spore forming bacteria (CFU×10^2/g)	*Pseudomonas aeruginosa* (CFU/g)	*Staphylococcus* sp. (CFU×10/g)
Al-Naseem	65.00^{de}	37.33^{de}	57.33^{bc}	0.00^{e}	16.33^{c}
Al-Nazeem	92.00^{cde}	58.00^{bcde}	62.00^{bc}	0.00^{e}	17.00^{c}
Al-Sulay	233.33^{abc}	32.00^{de}	53.33^{bc}	2.00^{cd}	54.33^{abc}
Industerial 2	337.67^{ab}	88.00^{ab}	73.67^{abc}	4.33^{b}	66.33^{bc}
Al-Azeezya	355.67^{a}	108.33^{a}	92.33^{ab}	6.00^{a}	99.67^{a}
Industrial district	223.00^{abcd}	86.00^{abc}	78.00^{abc}	3.00^{bc}	96.00^{a}
Batha	183.67^{bcde}	45.33^{cde}	40.67^{bc}	1.33^{de}	34.67^{bc}
Al-Morslat	58.00^{e}	17.00^{e}	25.00^{c}	0.00^{e}	21.33^{bc}
Airport	170.67^{cde}	62.00^{bcd}	133.00^{a}	1.33^{de}	58.00^{abc}
Al-Ageeg	65.00^{de}	36.67^{de}	46.67^{bc}	0.00^{e}	27.33^{bc}
KSU	155.33^{cde}	33.00^{de}	73.00^{abc}	0.00^{e}	20.67^{bc}
Al-Badeea	61.67^{de}	18.00^{e}	30.33^{bc}	0.00^{e}	17.33^{c}
Al-Olyaa	57.67^{e}	20.67^{de}	21.00^{c}	0.00^{e}	22.67^{bc}
Al-Waha	206.00^{abcde}	23.67^{de}	89.67^{ab}	0.00^{e}	16.00^{c}
Granada	65.67^{de}	16.67^{e}	44.33^{bc}	0.07^{e}	23.00^{bc}

Means in the same column followed by the same letter are not significantly different according to Duncan's multiple range test.

Table.4 Microbial content in falling dust samples from different sites in Riyadh city during Summer months, 2012G

Site of sample	Total counts (CFU×10^4/g)	Total fungi (CFU×10^2/g)	Spore forming bacteria (CFU×10^2/g)	*Pseudomonas aeruginosa* (CFU/g)	*Staphylococcus* sp. (CFU×10/g)
Al-Naseem	79.67^{fgh}	21.67^{fgh}	49.33^{gh}	0.00^{c}	14.00^{de}
Al-Nazeem	72.00^{gh}	24.00^{efg}	60.67^{h}	0.00^{c}	14.00^{de}
Al-Sulay	117.00^{e}	26.00^{ef}	84.67^{de}	1.00^{b}	16.00^{cd}
Industerial 2	260.67^{b}	35.33^{cd}	126.67^{b}	1.67^{a}	18.33^{bc}
Al-Azeezya	298.33^{a}	56.00^{a}	153.33^{a}	2.00^{a}	22.33^{ab}
Industrial district	263.33^{b}	47.33^{b}	138.00^{b}	1.00^{b}	22.33^{a}
Batha	222.00^{c}	37.67^{c}	93.67^{d}	0.00^{c}	19.00^{bc}
Al-Morslat	61.333^{h}	18.33^{gh}	63.66^{fg}	0.00^{c}	13.00^{de}
Airport	213.00^{c}	30.00^{de}	108.33^{c}	0.00^{c}	16.00^{cd}
Al-Ageeg	105.67^{ef}	24.33^{efg}	87.67^{de}	0.00^{c}	12.33^{de}
KSU	184.67^{d}	30.33^{de}	96.67^{cd}	0.00^{c}	14.33^{e}
Al-Badeea	84.67^{fgh}	18.00^{gh}	63.67^{fg}	0.00^{c}	12.00^{e}
Al-Olyaa	92.00^{efg}	18.67^{gh}	61.33^{gh}	0.00^{c}	13.667^{de}
Al-Waha	104.00^{ef}	16.33^{h}	76.33^{ef}	0.00^{c}	13.00^{de}
Granada	ND	ND	ND	ND	ND

Table.5 Microbial content in falling dust samples from different sites in Riyadh city during Autumn months, 2012G

Site of sample	Total counts ($CFU\times10^4/g$)	Total fungi ($CFU\times10^2/g$)	Spore forming bacteria ($CFU\times10^2/g$)	*Pseudomonas aeruginosa* (CFU/g)	*Staphylococcus* sp. (CFU×10/g)
Al-Naseem	23.00[cd]	9.67[e]	8.00[bc]	0.00[d]	32.67 [bcd]
Al-Nazeem	45.33 [abcd]	8.33[e]	8.33[bc]	0.00[d]	32.67 [bcd]
Al-Sulay	59.00 [abcd]	9.00[e]	17.00 [a]	2.67 [a]	31.67 [bcd]
Industerial 2	86.67 [abd]	14.33[cde]	9.33[bc]	2.00[b]	44.33[abcd]
Al-Azeezya	105.00 [a]	31.00 [a]	11.33[b]	2.33 [ab]	57.00 [a]
Industrial district	90.00 [ab]	24.33 [abc]	11.00[bc]	1.33 [c]	57.00 [abc]
Batha	86. 67 [abc]	22.67 [abcd]	11.00[bc]	0.00[d]	44.33
Al-Morslat	20.00[d]	12.67[de]	7.67[c]	0.00[d]	29.67[cd]
Airport	98.00 [a]	22.67 [abcd]	8.33[bc]	0.00[d]	36.67[bcd]
Al-Ageeg	100.67 [a]	25.00 [ab]	11.00[bc]	0.00[d]	47.33 [abc]
KSU	84.33 [abcd]	21.33 [abcd]	8.00[bc]	0.00[d]	38.00 [abcd]
Al-Badeea	46.67 [abcd]	15.00 [abcde]	9.00[bc]	0.00[d]	23.67[d]
Al-Olyaa	24.00 [bcd]	14.00[cde]	8.33[bc]	0.00[d]	32.33 [bcd]
Al-Waha	28.33[bcd]	22.00 [abcd]	11.00[bc]	0.00[d]	28.00[cd]
Granada	ND	ND	ND	ND	ND

Means in the same column followed by the same letter are not significantly different according to Duncan's multiple range test.
ND: No Detection

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