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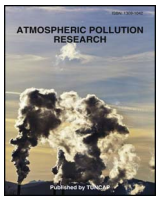

Air microbial quality in certain public buildings, Egypt: A comparative study

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ABSTRACT

This study aims to determine microbiological air quality in public buildings: libraries, faculties, schools, child daycare centers and hospitals and its association with microclimatic conditions, particulate matter (PM) and ventilation type. Airborne bacteria and fungi were collected using Andersen two-stage sampler, it divides particles into coarse (≥7 μm) and fine (< 2.5 μm) size ranges. Bacterial and fungal concentrations ranged between 0 – 10^5 CFU/m^3 and 0–10^3 CFU/m^3, respectively. The 95th percentile values were 3399 CFU/m^3 for environmental bacteria; 2299 CFU/m^3 for mesophilic bacteria and 513 CFU/m^3 for fungi. The Global Index of Microbial Contamination (GIMC/m^3) exceeded 2000 CFU/m^3 in hospitals' admission rooms and educational buildings. Index of Mesophilic Bacterial Contamination (IMC) achieved the greatest value in the faculty of specific education (F.SE), indicating overcrowding and hypoventilation. Fine particle fraction ranged within 2–41% for bacteria and 47–94% for fungi. *Bacillus subtilis* and *Bacillus atrophaeus* were the common bacterial species. *Aspergillus*, *Alternaria*, *Penicillium* and *Cladosporium* were the common fungal types. The secondary and tertiary fungal colonizers were detected in low counts. Agreement ratios showed that, outdoor air was the main contributor of indoor fungal flora, and accumulated dust was important contributor of fungal and bacterial flora in schools and faculties. Indoor/outdoor (I/O) ratios of PM concentrations exceeded 1 in ~37% of the public buildings. Temperature negatively affected bacterial culturability while, relative humidity and PM supported fungal culturability in indoor environment. However, PM positively affected bacterial culturability and temperature negatively affected bacterial and fungal curturability in outdoor environment.

1. Introduction

Indoor air quality is a complex and dynamic system, containing biological and non-biological contaminants (Pereira et al., 2017). Biological particles and their products are common indoor contaminants (Di Carlo et al., 2016), affecting health, wellbeing and productivity of people (Mentese et al., 2015; Śmiełowska et al., 2017). The biological contaminants may cause infection, sick building syndrome, allergies and nosocomial diseases (Skóra et al., 2015) and influence hygienic conditions of building materials and objects (Lech, 2015; Kadaifciler, 2017). Indoor air microorganisms are mainly originated from outdoor air, anthropogenic sources and building materials (Fang et al., 2007). Airborne microorganisms contribute for ~5–34% of the total indoor airborne contaminants (Nevalainen et al., 2015; Gizaw et al., 2016).

Indoor air microbial quality has attracted public attention in recent years. Indoor microbial quality has been evaluated in industrial buildings (Dacarro et al., 2005; Abdel Hameed et al., 2015; Mackiewicz et al., 2015) and in public buildings (Guan et al., 2015; Li et al., 2015; Shiferaw et al., 2016; Osman et al., 2017). The studies have showed that, airborne microbial communities are varied according to type of indoor environment (Kembel et al., 2012). Local climate, microclimatic factors, level of occupancy, type of human activity, season, geographical characters, ventilation type and building maintenance significantly affect indoor microbial concentrations, types and their distribution pattern (Adams et al., 2014; Prussin and Marr, 2015; Ghosh et al., 2015; Tham, 2016).

Intensity of people, activity of occupants and agitation of dust significantly increase microbial concentrations (Meadow et al., 2014). People in densely populated buildings may be more likely suffer from exposure to hazardous biological contaminants (Klepeis et al., 2001). The proliferation of microorganisms in public buildings “schools, universities and hospitals” is indicated as a cause of health problems (Ortiz et al., 2009). Microbial air quality and ventilation in educational settings affected health of students and consequently their learning performance (Daisey et al., 2003). There were associations between high concentrations of airborne fungi and persistent cough and wheeze (Gent

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Table 1
Detail-characteristics of each public building and sampling location under investigation.

Premise	Location/abbreviation	District/Governorate	Description of sampling site	Ventilation type
Library	Old library (OL) (30° 2′11.19″N, 31°12′17.63″E)	Dokki/Giza	It was established in 1956. It consists of 3 storey structure, locates in the 2nd floor inside the main building of the National Research Center (NRC), with an area of ~900 m^2 and level of occupancy ~ ≥150 person. The windows are opened faced a busy- traffic street side. Accumulated dust was obviously found on books and floor. Indoor sampling was taken at the 1st storey in the middle of the library. Outdoor sampling was collected immediately ~50 cm on the front of window faced to the busy street side.	Natural ventilation with some fans
	New library, National Research Center's library (NL) (30° 2′9.57″N, 31°12′19.01″E)	Dokki/Giza	It was built in 2009. It consists of one ground story, locates inside the NRC campus ~75 m away from the main traffic street, and nearby to a big plant garden. The library has an area ~227 m^2 and level of occupancy ~ ≥50 person. No accumulated dust was observed. Indoor sampling was taken at the middle of the library. Outdoor sampling was collected ~5 m from the front door in the street inside the NRC campus.	Mechanical ventilation
Faculty	Kindergarten – Cairo University (F.KG). (30° 2′12.45″N, 31°12′12.80″E)	Dokki/Giza	It is a multi-storey building. The lecture room has an area of ~205 m^2 with the level of occupancy ~175 girl. The lecture's, floor surface is covered by vinyl. The windows are opened on a busy - traffic street side. Accumulated dust was observed on the windows and floors. Indoor sampling was collected from the 4th floor at the middle of the lecture room. Outdoor sampling was collected ~50 cm immediately on the front of windows, faced a busy street side.	Natural ventilation and fans
	Specific Education, Cairo University (F.SE) (30° 2′12.74″N, 31°12′8.21″E)	Dokki/Giza	It is a multi-storey building surrounded by plants and trees. The lecture room has an area ~92 m^2 with the level of occupancy ~140 boy and girl. The floor surface is covered by vinyl and walls by wood. The windows are located faraway of a busy street. Indoor sampling was collected from the 2nd floor at the center of the lecture room. Outdoor sampling was collected in the corridor ~3 m from the front door of the lecture room, inside the building, and away from the streets.	Natural ventilation and fans
Child day care center	National Research Center's child day care center (NRC-CDCC). (30°2′9.87″N, 31°12′27.05″E)	Dokki/Giza	It is located on the ground floor inside the extension of the NRC campus, away from the busy-streets. The number of children averaged ~23 child, with age ranged between 3 and 5 years. The NRC-CDCC is daily cleaned by water and detergents. Indoor sampling was taken at the middle of the nursery. Outdoor sampling was collected ~5 m directly from the front door inside the extension of the NRC campus and next to a car parking.	Natural ventilation and fans
	Al-Zhoor child day care center (ZH-CDCC) (29°53′18.45″N, 31°18′15.89″E)	Wadi Hof/Cairo	It is located on the ground floor, close to a main street in a compact residential area. The number of children averaged ~15 child with age ranged between 1 and 5 years. The ZH-CDCC is surrounded by some ornamental plants. The ZH-CDCC is daily cleaned by water and detergents. Indoor sampling was taken at the middle of the nursery. Outdoor sampling was collected ~5 m directly from the front door in the street.	Natural ventilation and fans
School	Al-Madinaa Algameayah Primary School (MG-SCH) (30° 2′6.65″N, 31°12′25.91″E)	Giza/Dokki	It was established in 1954 and renovated in 2012. The samples were taken from 2 classrooms: Grade 1 (G1) and Grade 6 (G6). G1 is located in the ground floor, with ~30 student average, while G6 is located in the 1st floor, with ~70 student average. The classroom has an area of ~30 m^2. Indoor sampling was taken at the middle of the classroom. Outdoor sampling was collected ~5 m inside the playground of the school. The playground is covered by cement tiles.	Natural ventilation and fans
	El Kholafaa El Rashedeen primary school (KR-SCH) (29°53′24.72″N, 31°18′5.69″E)	Cairo/ Wadi Hof	It was established in 1988.The sampling was taken from 2 classrooms: Grade1 (G1) and Grade 6(G6). G1 is located on the ground floor, with 45 student average, while G6 is located on 5th floor, with 49 student average. The classroom has an area of ~30 m^2. Indoor sampling was taken at the middle of the classroom. Outdoor sampling was collected ~ 5m inside the playground. The playground is covered with sand/dust.	Natural ventilation
Hospital	Bolak Eldakroor (GH) (30° 1′40.27″N, 31°11′56.95″E)	Giza/Bolak Eldakroor	It is a governmental hospital located in a densely populated suburban area. The sampling was taken from 3-locations inside the hospital: Admission department (AD), it is located in ground floor with an area ~50 m^2. Operating theatre (OT): it is located in the first floor with an area ~70 m^2, the floor surface is covered by vinyl and continuously cleaned with detergent and hypo-chloride. Intensive care unit (ICU): it is located in the 1st floor, equipped with 9 beds, with an area of ~120 m^2 average. The outdoor sampling was collected 5 m outside the main front door in the street.	AD is naturally ventilated OT and ICU: are mechanically ventilated
	Al-Farouk (PH) (29°57′26.85″N, 31°15′24.02″E)	Cairo/Al-Maadi	It is a private hospital located in Al-Farouk square, at Al- Maadi district; it is busy square along over the daytime. The sampling was taken from 3 locations inside the hospital:	AD is mechanically and naturally ventilated

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