Arab J. Nucl. Sci. Appl., Vol. 53, 2, 46-55 (2020)

Arab Journal of Nuclear Sciences and Applications

ISSN 1110-0451 ***Web site: ajnsa.journals.ekb.eg*** **(ESNSA)**

Characteristics of Biological and non-biologicalAerosol Particlesin Indoor Environment and their Inhalable Fractions in the Human Lung

Mona Moustafa [1], [*]
[1]*Physics department, Faculty of Science, MiniaUniversity, El-Minia, Egypt*

ABSTRACT

Received 11th July 2019
Accepted 22th Dec. 2019

Air quality of public buildings is an important issue to assess human health. School and university buildings represent an important category of indoor environments. This study aimed evaluating the concentration and size distribution of fungal and non-biological aerosol particles in classrooms of Minia University, Egypt. In addition, the inhalable fractions were determined and indoor exposure dose (IED) of fungi and aerosols were estimated for the students. A six-stage Andersen impactor was used for collecting the fungal particles and Berner cascade impactor was used for sampling the non-biological aerosol particles. Indoor average concentration of fungiwas307±102 CFU/m3. The most frequently isolated genera were Aspergillusniger with concentration 175±85 CFU/m3 representing about 57% of the of the total collected fungi. Aspergillus flavus represents about 31% of the total fungi with concentration 96±32 CFU/m3. A low concentration 36 ±12 CFU/m3 of Penecilliumwas investigated representing only 12% of the total collected fungi. The Mean mean concentration of non-biological aerosols was 442±99 µg/m3. The concentration of airborne fungal aerosol particles were lower than the World Health Organization guideline while the corresponding concentration of non-biological aerosols exceeded WHO limit. Most of the collected fungal particles were found in the inhalable size range (< 5µm) where inhalable fraction of fungi represents 84% of the total collected particles while inhalable fraction of non- biological aerosols represents 92% of the total collected particles. Size distributions of biological and non-biological aerosols were bimodal in nature. IED of fungi was 25.6 CFU/kg while the IED of non-biological aerosols was 37 CFU/kg.
.

Keywords: Indoor exposure dose/ Inhalable fraction/ Fungi/Aerosols/ impactor

Introduction

Indoor air is a very dynamic system that contains a mixture of biological and non-biological aerosol particles [1, 2].Biological aerosols or microorganisms contain bacteria, fungi and viruses, attached to aerosol particles forming bioaerosols [3, 4] or organic compounds derived from these microorganisms such as endotoxins, toxins, metabolites and other microbial fragments in indoor environment[5, 6].Bioaerosols vary in size (from 20 nm up to 100 µm) and composition depending on the source, mechanisms of formation and the conditions of environment[7].Bioaerosols are released from indoor and outdoor air including natural and artificial sources[8, 9]. Indoor air is a predominant source of different bioaerosols [10].
Non-biological particles or aerosols are liquid or solid particles suspended in gaseous medium with

Corresponding author: mona_moustafa9@yahoo.com
DOI: 10.21608/ajnsa.2019.14716.1233

a size range rangingfrom 1 nm up to 100 µm [11].Aerosols are generated by multiplicity of sources[12]. In indoor air, non-biological aerosol particlesinclude tobacco smoke, motor vehicle emission particles, cooking-generated particles and organic and inorganic gases [13].

Biological particles contributeabout 5-34% of the indoor air pollution [14-16]. Indoor air has more pollution than the outdoor air [17, 18]. Most people spend about 90% of their time in indoor environments, therefore the indoor air quality could significantly affect general health of human beings[19].In many indoor environments, bacterial, fungal microbes and their fragments fall in the inhalable size range (<5 µm) which can enter a thelower parts of the respiratory system [9] and can cause different infectious diseases, allergic reactions, asthma and sick building syndrome (SBS)[20-24].

Fungal particles are one of the most important components of biological aerosol particles where fungi can cause a public health hazard[25]. The majority of indoor fungi is released from outdoor sources [26].The deposition of fungal spores in the lung and their health effects depends on their composition, concentration and size [27].
High levels of particle pollutants are associated with decreased lung function, increased respiratory symptoms such as cough, shortness of breath, wheezing and asthma, as well as chronic obstructive pulmonary disease, cardiovascular diseases and lung cancer[28].In recent years, indoor air quality has attracted public attention [29, 30].The adverse health effects depend on the absorbed dose of air pollutants [31].
Therefore, the objectives of the present study are to: i) investigate the concentration and the size distribution of indoor fungi and aerosol particles ii) investigate the composition of the collected fungi; iii) estimate the inhalable fractions of fungi and aerosol particles; iv) estimate the indoor exposure dose (IED) of fungi and aerosol particles.

MATERIALS AND METHODS

1. Sampling strategy

Samples were collected from indoor air of lecturing rooms at Minia University (El-Minia/ Egypt) during a summer season (low occupancy period). The rooms have an area of about 50 m^2. Minia University is located in the middle of El-Minia city, upper Egypt (Coordinates: 28°07′10″N 30°44′40″E)located about 300 Km south to Cairo. El-Minia map is shown in Figure(1). The university lies on a vegetation area from the west and on the highway of Cairo-Aswan from the east. While it is near to a residential area of North and South. Sampling was conducted during normal ventilation where windows and door were kept open. At least one run was taken a week for both biological and non-biological aerosols during the working days. The samplers were located about 1.3 m above the floorto simulate the breathing zone of the sitting students. Temperature and relative humidity were recorded during the sampling.

Fig. (1): Map of El-Minia city/Egypt

2. Biological aerosols sampling

Airborne fungi were collected using Six-stage Andersen impactor (ACI).The impactor is connected to a vacuum pump and a flow meter for operating at a constant flow rate of 28.3 L/min. Andersen impactor fractionates the collected microorganisms according to their aerodynamic diameters. The impactor sorts the viable particles into six fractions: > 7.0 µm, 7.0-4.7 µm, 4.7-3.3 µm, 3.3-2.1 µm, 2.1-1.1 µm, 1.1-0.65 µm. The size of the impactor stages simulates the human respiratory tract regions. The collection efficiency of Andersen impactor was previously validated [32, 33]. The impactor is calibrated so that all particles collected (regardless their physical size, shape or density) are sized aerodynamically and can be directly related to human lung deposition.

Sabouraud dextrose agar (SDA) supplemented with chloramphenicol was used as a culture media for collecting fungi. A volume of not less than 27 ml of culture medium was placed in each plate then they were inserted into each impactor stages. The sampling time of each run ranged from 10-15 min. This small time is chosen

to avoid overestimated number of colonies. After microorganism sampling, the plates were incubated at 28°C for 3-5 days and the total number of fungal colonies were counted. Based on the micro and macro morphological features, fungal isolates were identified by direct observation. The airborne bioburden was calculated in terms of colony-forming units per cubic meter air by Equation (1):

$$C = \frac{n}{V.t} \ldots\ldots\ldots\ldots cfu/m^3 \qquad (1)$$

Where n is number of collected colonies on each stage of the impactor
V is the impactor flow rate in m^3/h.
t is the sampling time in h.

2.3. Non-biological aerosol sampling

Aerosol particles were collected using low pressure Berner cascade impactor (BCI). The impactor is connected to vacuum pump operating at a flow rate of 1.7 m^3/h. Berner impactor has eight stages with cut-off diameters:0.082, 0.157, 0.270, 0.650, 1.100, 2.350, 4.250 and 5.960µm. The impactor was calibrated in the isotope laboratory of Gottingen University, Germany [34]. Aluminum foils were used as a substrate for collecting the aerosols and a glass fiber filter as a backup filter. The sampling time of each run was 6 h. Filters and foils were weighted before and after sampling using a sensitive balance model Mettler analytical AE240 Dual Range Balance. Mass concentration (C) was calculated using Equation (2):

$$C = \frac{m}{V.t} \ldots\ldots\ldots\ldots \mu g/m^3 \qquad (2)$$

Where m is the particle mass collected on each stage in µg,

RESULTS AND DISCUSSION

1. Concentration of fungal and non-biological particles

the mean concentration of airborne fungi and the most frequently isolated genera measured in indoor are summarized in Table (1). The mean concentration of airborne fungi was 307±102 CFU/m^3. On one hand, the airborne fungal aerosol particles were lower than the World Health Organization guideline value of 500 CFU/m^3[35] and on the other hand, the present fungal concentration lie in a high level (301-1000 CFU/m^3) according to the categorization of [36].
The most frequently isolated genera were Aspergillusniger with concentration of 175±85 CFU/m3 representing about 57% of the of the total collected fungi. Aspergillus flavus represents about 31% of the total fungi with concentration of 96±32 CFU/m3. Low A low concentrationof 36 ±12 CFU/m3 of Penecilliumwas investigated representing only 12% of the total collected fungi. The dominance of Aspergillus and Penecillium in the atmosphere may be attributed to their ability to grow in various substrata and meteorological conditions [37, 38].Outdoor sources are considered as the main source of indoor fungi[26].

Air quality standards for particulate matters are expressed in terms of mass concentration. Mean The mean concentration of non-biological aerosols was 442±99 µg/m3. The present value exceeds the limit recommended (120 µg/m3) by World Health Organization, [39] and the limit value of 230 µg/m3 suggested by the Egyptian Environmental law of [Environment [40].

It was confirmed that human activity is an important factor for the emission of coarse particles while ambient aerosol concentration, which originates in traffic-related combustion process, affects the emission of fine particles [41].

Non-biological particles may serve as a carrier and source of nutrients for biological particles (bioaerosols) and at the same time affect their behavior and viability depending on particle composition and microorganism type and its tenacity to aerosol particles [42].

2. Inhalable fraction of fungal and non-biological particles

Transport and deposition of aerosols in the atmosphere and human lung depend mainly on the particle size [43]. Fine particles can penetrate deep in the respiratory tract [44].Inhalable fraction (< 5 µm) of fungi is defined as the sum of the concentrations collected on the stage 3 (3.3-4.7 µm), stage 4 (2.1-3.3 µm), stage 5 (1.1-2.1 µm) and stage 6 (0.65-1.1 µm) of viable Andersen impactor with respect to the total concentration of fungi on all the six-stages of the impactor [45].

Concentration fractions % of fungi are summarized in Table (1) and are illustrated in Figure (2) from (a to d). Inhalable fraction of fungi represents 84% of the total collected particles; Aspergillusniger represents 91%, Aspergillus flavus represents 74% and Penecillium represents 93%. It is clear that most of the collected fungal particles were found in the inhalable size range. The present results are in agreement with others those obtained in other studies[41, 46, 47].

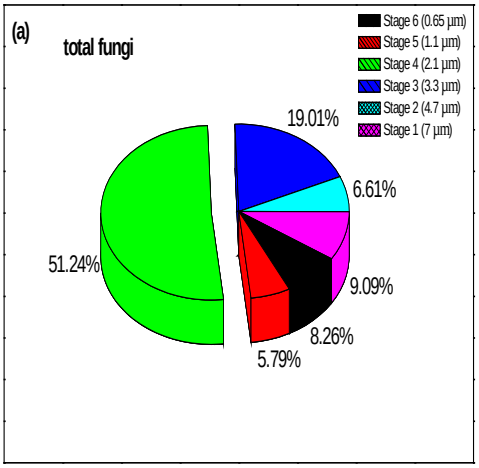
Inhalable fraction of non-biological aerosols is defined as the sum of the concentrations collected on the stage 3 (2.35-4.25 µm), stage 4 (1.1-2.35 µm), stage 5 (0.65-1.1 µm) and stage 6 (0.27-0.65 µm), stage 7 (0.157-0.27 µm) and stage 8 (0.082-0.157 µm) of Berner impactor with respect to the total concentration of aerosols collected on all the eight stages of the impactor.

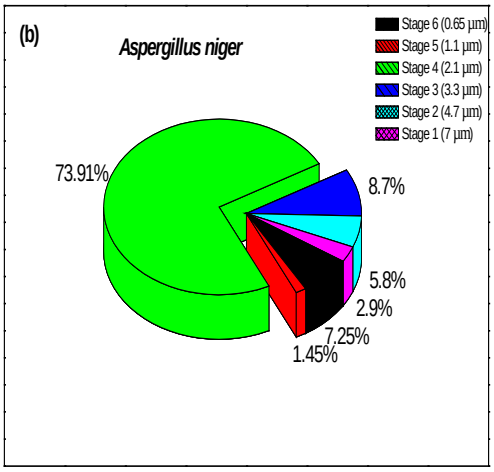
Concentration fractions % of aerosols is summarized in Table 1 and is illustrated in Figure (3). Inhalable fraction of aerosols represents 92% of the total collected particles. The presence of aerosol particles suspended in the air depends on their size that determines the mechanisms of the deposition and their residence time. This may explain the high percentage of fine particles in the collected sampled.

3. Size distribution of fungal and non- biological particles

Size distributions of indoor total fungi and isolated genera; *Aspergillusniger*, *Aspirgillusflavus and penicillium* are presented in Figure (4) from(a to d). The distributions are bimodal in nature according to the accumulation and the coarse modes. The highest concentrations were investigated at the size range 2.1-3.3 µm for total fungi *Aspergillusniger* and *Aspirgillusflavus* with concentrations percentage 51%, 74 % and 39%, respectively. However, the highest concentration of *penicillium* was investigated at the size range 1.1-2.1 µm with concentration % of 29.

Aspirgillusflavus has the highest Median Aerodynamic Diameter (MAD) of 2.9 µm while *penicillium* has the lowest MAD of 2 µ m and it was the more dispersed genus where the geometric standard deviation (GSD) was 2.2. *Aspergillusniger* has the lowest GSD of 1.6. Similar size distributions of bacteria and fungi were reported by other studies [31, 48-50].





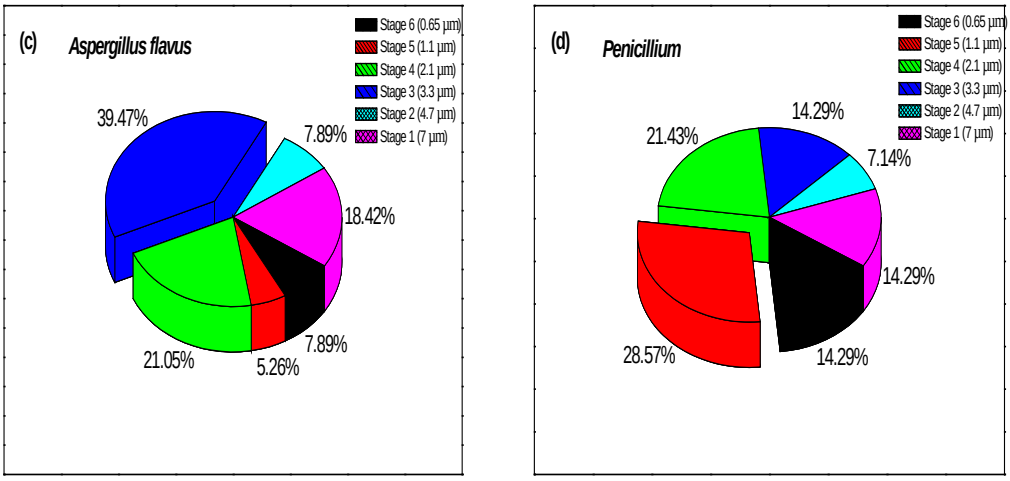


Fig. (2): Concentration fraction % of isolated and total fungi

Table (1) Concentration and inhalable fraction % of fungi and non-biological aerosols

Particles	Concentration ± SD	Inhalable fraction%
Total fungi	307±102 CFU/m^3	84
Aspergillusniger	175±85 CFU/m^3	91
Aspergillus flavus	96±32 CFU/m^3	74
Penicillium	36±12 CFU/m^3	93
Total aerosols (nonviable)	442±99 µg/m^3	92

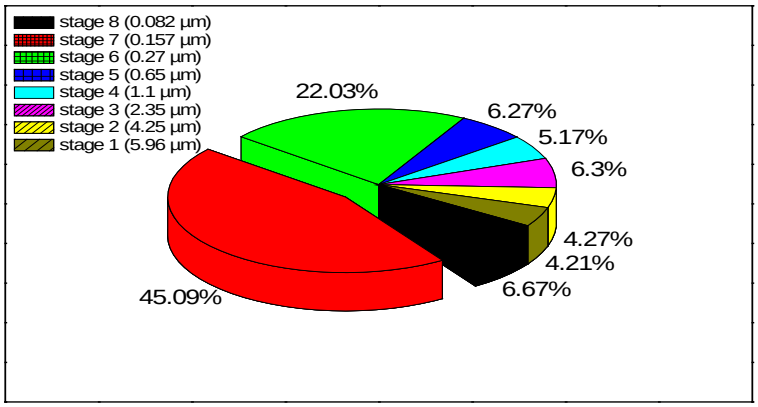


Fig. (3): Concentration fraction % of non-biological aerosols

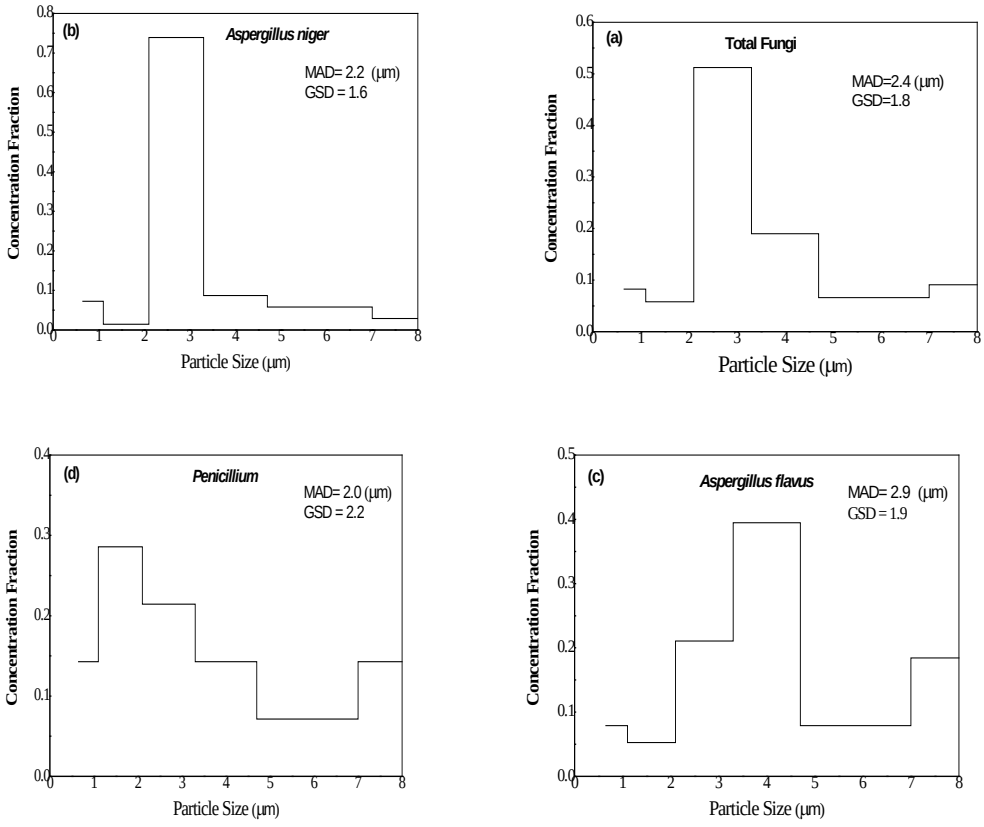


Fig. (4): Size distribution of isolated and total fungi

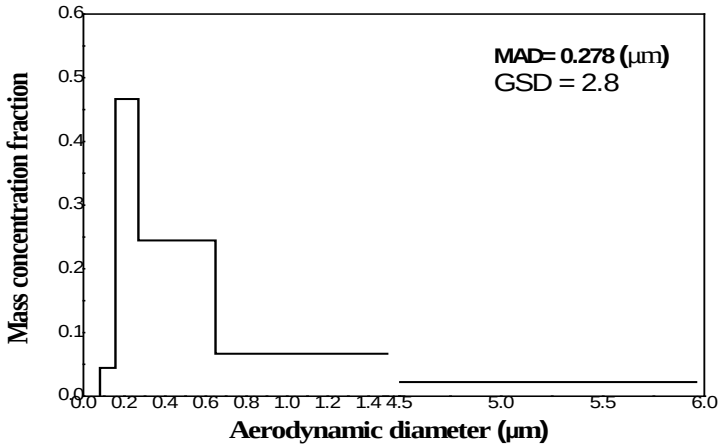


Fig. (5): Size distribution of non-biological particles

a

Conclusions

Epidemiological studies reported statistical and positive relation between aerosol particles and increased human mortality and morbidity. People in developed countries spend muchof their time in various indoor environments. Lecture rooms and other spaces of schools and universities sometimes represent hazardous and unhealthy environments. Although the concentration of fungi does not exceed the WHO limit, it is in the high category level. Non-biological aerosols exceeds the WHO limit. The high concentration of both aerosols were investigated in the inhalable size range. These particles can be inhaled deeply in the human respiratory tract. It is recommended that more environmental and more public health programs should be conducted in public buildings and particularly in the universities for achieving a healthy indoor environment with a high air quality.

ACKNOWLEDGMENTS

This work was supported by faculty of science, MiniaUniversity, El-Minia,Egypt

References

(1) Jyostshna, M., Helmut, B. (2011) Bioaersols in indoor environment – A review with special reference to residential and occupational locations, *The Open Eviron&Biolo Monitor J.*, (4), 83-96.

(2) Pereira, M.L., Knibbs, L.D., He, C., Grzybowski, P., Johnson, G.R., Huffman, J.A., Bell, S.C., Wainwright, C.E.,Matte, D.L., Dominski, F.H., Andrade, A., Morawska, L. (2017) Sources and dynamics of fluorescent particles in hospitals, *Indoor Air* (27), 988-1000.

(3) Fabian, M.P., Miller, S.L., Reponen, T., Hernandez, M.T. (2005) Ambient bioaerosol indices for indoor air quality assessments of flood reclamation , *J. Aerosol Sci.*, (36),763-783

(4) Nasir, Z.A., Colbeck, I. (2010) Assessment of bacterial and fungal aerosol in different residential settings, *Water Air Soil Pollut.* (211), 367-77.

(5) Heikkienen, M.S.A., Hjelmroos-Koski, M.K., Haggblom, M.M., Macher, J.M. (2005) Bioaerosols. In: Ruzer LS, Harley NH, Eds. Aerosols Handbook. Boca Raton: CRC Press 291-342.

(6) Manisha, J., Srivastava, R.K. (2013) Identification of indoor airborne microorganisms in residential rural houses of Uttarakhand, India, *Int. J. Curr. Microbiol. App. Sci.*, (2), 146-152.

(7) Pillai, S.D., Ricke, S.C. (2002) Bioaerosols from municipal and animal wastes: background and contemporary issues. *Can. J. Microbiol.*, (48), 681-696.

(8) Wu, Y.H., Chan, C.C., Chew, G.L., Shih, P.W., Lee, C.T., Chao, H.J. (2012) Meteorological factors and ambient bacterial levels in a subtropical urban environment, *Int. J. Biometeorol*. (56), 1001-1009.

(9) Ghosh, B., Lai, H., Kushwaha, R., Hazarika, N., Srivastava, A., Jain, V.K.. (2013) Estimation of bioaerosol in indoor environment in the university library of Delhi, *Sustain Environ. Res.*, (23), 199-207.

(10) Undochukwu, U., Inetianbor, J., Omorotionmwan, F.O., Okpuruka, N.S. (2016) Effect of high customer patronage on the indoor air quality of restaurants in Lokoja Metropolis and its public health impact, *Am. J. Moicrobio. Res.*, (2), 51-55.
(11) Georgakopoulos, D.G., Despres, V., Froehlich-Nowoisky, J., Psenner, R., Ariya, P.A., Posfai, M., Ahern, H.E., Moffett, B.F., Hill, T.C.J. (2009) Microbiology and atmospheric processes: biological, physical and chemical characterization of aerosol particles, *Biogeosciences*, (6), 721-737.
(12) Willeke, K., Baron, P.A. editors (1993) Aerosol measurement: Principles, techniques and applications. New York: Van Nostrand Reinhold.
(13) Morawska, L. (1998) Indoor air risk assessment and management Encyclopedia of environmental analyses and remediation.JohnWiley& Sons, Inc, 2292-2316.
(14) Fekadu, H.S., Amanuel, E., Aklilu, D.F. (2015) Quantitative assessment of bio-aerosols contamination in indoor air of university dormitory rooms, *Int. J. Health Sci.*, (3), 249-256.
(15) Zemichael, G., Mulat, G., Chalachew, Y. (2016) High bacterial load of indoor air in hospital wards: the case of University of Gondar teaching hospital, Northwest Ethiopia, *MultidiscipRespir. Med.*, (11), 24 doi: 10.1186/s40248-016-0061-4.
(16) Samson, E., Ihongbe, J.C., Okeleke- Ochei, Hi Effedua, Phillips Adeyemi O. (2017) Microbiological assessment of indoor air quality of some selected private primary schools in Ilishan-Remo, Ogun state, *Nigeria* (3), 2454–9142.
(17) Kotzias, D. (2005) Indoor air and human exposure assessment-Needs and approaches. *Exp. Toxicol. Pathol.*, (57), 5-7.
(18) Yassin, M.F., Almouqatea, S. (2010) Assessment of airborne bacteria and fungi in an indoor and outdoor environment, *Int. J. Environ. Sci. Technol.*, (7), 535- 544.
(19) Fekadu, H.S., Melaku, M.A. (2014) Microbiological quality of indoor air in universitylibraries, *Asian Pac. J. Trop. Biomed.*, (4), S312–317.
(20) Ege, M., Mayer, M., Normand, A., et al. (2011) Exposure to environmental microorganisms and its inverse relation to childhood asthma, *Allergy Eur. J. Allergy Clin. Immunol.*, (6), 57.
(21) Després, V.R., Alex Huffman, J., Burrows, S.M., Hoose,C., Safatov, A., Buryak, G., Frohlich-Nowoisky, J., Elbert, W., Andreae, M., Poschl, U.,Jaenicke, R. (2012) Primary biological aerosol particles in the atmosphere: A review. *Tellus B Chem. Phys. Meteorol.*, 64.
(22) Kallawicha, K., Lung, S.C.C., Chuang, Y.C., et al., (2015) Spatiotemporal distributions and land-use regression models of ambient bacteria and endotoxins in the greater Taipei area, *Aerosol Air Qual. Res.*, (15), 1448–1459.
(23) Skóra, J., Beata, G., Katarzyna, P., Stępień, Ł., Pietrzak, K., Piotrowska, M., Pietrowski, P. (2015) Assessment of microbiological contamination in the work environments of museums, archives and libraries, *Aerobiologia*, (31), 389–401.
(24) Uk Lee, B., Lee, G., JoonHeo, K.. (2016) Concentration of culturable bioaerosols during winter, *J. Aerosol Sci.*, (94), 1–8.
(25) Abdel Hameed, A.A., Khoder, M.I., Ibrahim, Y.H., Yousra, S., Magdah, O., Samah, G. (2012) Study on some factors affecting survivability of airborne fungi, *Sci. total environ.*, (414), 696-700.
(26) Hargreaves, M., Parappukkaran, S., Morawska, L., Hitchins, J., He, C., Gilbert, D. (2003) A pilot investigation into associations between indoor airborne fungal and non-biological particle concentrations in residential housesin Brisbane, Australia. *Sci. Total Environ.*, (1), 89-101.
(27) Reponen, T., Grishpun, S., Reponen, A., Ulevicius, V. (1996) Characteristics of exposure to fungal spores in indoor air, *Am. Indus. Hyg. Asso.* http://www.aiha.org/abstract/6evalbio.html,
(28) World health organization (2002) Guidelines for concentration and exposure-response measurements of fine and ultrafine particulate matter for use in epidemiological studies. World health organization, Geneva.
(29) Abdel Hameed, A.A., Habeebuallah, T., Mashat, et al. (2015) Airborne fungal pollution at waste application facilities, *Aerobiologia*, (31), 283–293.

(30) Osman, M.E., Abdel Hameed, A.A., Ibrahim, H.Y., Yousef, F., Abo Elnasr, A.A., Saeed, Y. (2017) Air microbial contamination and factors affecting its occurrence in certain book libraries in Egypt, *Egy. J. Bot.* (57), 93–118.

(31) Bragoszewska, E., Mainka, A., Pastuszka, J. (2016b) Bacterial and fungal aerosols in rural Nursery schools in southern Poland, *Atmos.*, (7), 142.

(32) Jones, W., Morring, K., Morey, P. (1985) Evaluation of the Andersen viable impactor for single sampling, *Am. Ind. Hyg. Ass. J.*, (46), 294-298.

(33) Buttner, M.P., Stetsenbach, L.D. (1993) Monitoring of airborne fungal spores in an experimental indoor environment to evaluate sampling methods and the effects of human activity on air sampling, *Appl. Environ. Microbiol.*, (59), 219-226.

(34) Reineking, A., Scheibel, H.G., Hussin, A., Becker, K.H., Porestendorfer, J. (1984) Measurements of stage efficiency functions including interstage losses for Sierra and Berner impactors and evaluation of data by modified simplex method, *J. Aerosol Sci.*, (15), 376.

(35) World Health organization,WHO (1990) Indoor air quality: biological contaminants.World Health Organization, Copenhagen.WHO- Regional Publications. European series11031.

(36) Platt, S.D., Martin, C.J., Hunt, S.M., Lewis, C.W. (1989) Damp housing,mould, growth and symptomatic health state, *Br. Med. J.*, (298), 1673–1678.

(37) Abdel Hameed, A.A. (2005) Vegetation: A source of air fungal bio-contaminant, *Aerobiologia*, (21), 53–61.

(38) Abdel Hameed, A.A., Khoder, M.I., Yuosra, S., Osman, A.M., Ganem, S. (2009) Diurnal distribution of airborne bacteria and fungi in the atmosphere of Helwan area, Egyp, *Sci. Total Environ.*, (407), 6217–6222.

(39) World Health organization, WHO (2000) Guidelines For air Quality.Geneva

(40) Egyptian Environmental Affair Agency, EEAA . (1994) Environmental protection law

(41) Abdel Hameed, A., Yuosra, S., Yasser, H., Yousef, F., Mohamed, O. (2018) Air microbial quality in certain public buildings, Egypt: A comparative study, *Atmo. Pollu. Res.* (9), 617–626.

(42) Alghamdi, M.A., Shamy, M., Redal, M.A., et al. (2014) Microorganisms associated particulate matter: A preliminary study. *Sci. of the Total Environ*, 479-480, 109-116.

(43) Sadyś, M., Kennedy, R., West, J.S. (2016) Potential impact of climate change on fungal distributions: analysis of 2 years of contrasting weather in the UK., *Aerobiologia*, (32), 127–37.

(44) Darquenne, C. (2012) Aerosol deposition in health and disease, *J. of Aerosol Med. Pulm. Drug Deliv*. (25), 140–147.

(45) Kim, K.Y., Kim, C. N. (2007) Airborne microbiological characteristics in public buildings of Korea,*Build Environ*., (42), 2188-2196.

(46) Li, C.S., Kuo, Y.M. (2014) Characteristics of indoor viable fungi in Taiwan. In: Proceedings of the 6th International Conference on “Indoor Air Quality and Climate”, Helsinki, Finland, pp. 183–187. libraries. *Asian Pac. J. Trop. Biomed*., (4), S312–317.

(47) Dekoster, J.A., Thorne, P.S. (1995) Bioaerosol concentrations in noncompliant, compliant, and intervention homes in the Midwest, *Am. Ind. Hyg. Assoc. J.*, (56), 573–580.

(48) Pastuszka, J.S., KyawTha Paw, U., Lis, D.O., et al. (2000) Bacterial and fungal aerosol in indoor environment in Upper Silesia, Poland, *Atmos. Environ.*, (34), 3833–3842.

(49) Bragoszewska, E.,Kowal, A.M., Pastuszka, J.S. (2013) Bacterial aerosol occurring in atmospheric air in Gliwice, Upper Silesia, Poland, *Archit. Civ. Eng. Environ.*, (4), 61-66.

(50) Hospodsky, D., Yamamoto, N., Nazaroff, W., Miller, D., Gorthala, S., Peccia, J. (2015) Characterizing airborne fungal and bacterial concentrations and emission rates in six occupied children's classrooms, *Indoor air*, (25), 641-652.

(51) Toscano, G., Moret, I., Gambaro, A., Barbante, C., Capodaglio, G. (2011) Distribution and seasonal variability of trace elements in atmospheric partilcuate in the Venice Lagon, *Chimosph.* (85), 1518-1524.

(52) Mbengue, S., Allenman, L.Y., Flament, P. (2014) Size-distribution metallic elements in submicronic and ultrafine atmospheric

particles from urban and industrial areas in northern France, *Atmos. Res.* (135), 35-47.

(53) Bragoszewska, E., Mainka, A., Pastuszka, J. (2016a) Bacterial aerosols in an urban nursery school in Gliwice, Poland: A case study, *Aerobiol.,(* 32), 469-480.

(54) US Environmental Protection AgencyChild-specific Exposure factors Handbook (2002) Environmental Protection Agency. Washington, DC, USA.

(55) Johnson-Restrepo, B., Kannan, K.. (2009) An assessment of sources and pathways of human exposure to polybrominated diphenyl ethers in United states. *Chemos.,* (76), 542-8.

(56) Bragoszewska, E. (2014) Bacterial aerosol occurring in atmospheric air in Gliwice and it is share of the total human exposure to the bacteria absorbed by inhalation. Ph. D. Thesis. Silesian university of technology, Gliwice, Poland.