EDITORIAL BOARD

ESTEEM ACADEMIC JOURNAL
VOLUME 9, NUMBER 1, JUNE 2013
Universiti Teknologi MARA (Pulau Pinang)

ENGINEERING

p-ISSN 1675-7939; e-ISSN 2289-4934

FOREWORD

It is our great pleasure to present the ninth volume and first issue of the ESTEEM Academic Journal UiTM (Pulau Pinang): a peer-refereed academic journal devoted to all engineering disciplines. Since the beginning of the year, a number of articles have been sent to us, some of which are still under review in their first or second phase and the first five of them are being published now. Article submissions came from UiTM campuses across the country, with topics covering most, if not all, of the subfields of electrical, mechanical, civil and chemical engineerings. We celebrate our good fortune in having a strong group of people who created the opportunity for this volume to be born and who made it happen.

First and foremost, we would like to extend our sincere appreciation and utmost gratitude to Associate Professor Mohd Zaki Abdullah, Rector of UiTM (Pulau Pinang), Associate Professor Ir. Bahardin Baharom, Deputy Rector of Academic Affairs and Dr. Mohd Subri Tahir, Deputy Rector of Research, Industry, Community & Alumni Network for their unstinting support towards the successful publication of this volume. Not to be forgotten also are the constructive and invaluable comments given by the eminent panels of external reviewers and language editors who have worked assiduously towards ensuring that all the articles published in this volume are of the highest quality. A special acknowledgement is dedicated to all committees, publication department, and many other relevant parties for making this volume a success. Their affective commitment and close cooperation have facilitated the realization of this volume. Last but not least, our greatest thanks go to all the authors for their interest in publishing their work with us. Their manuscripts are an expression of their commitment towards research and development which, in due course, would benefit the local, national and international communities. Hence, we would like to extend our warm invitation to all researchers who are actively involved in the field of engineering to publish their work with us.

Dr. Chang Siu Hua
Chief Editor
ESTEEM Academic Journal
Vol. 9, No. 1 (2013)
(Engineering)

p-ISSN 1675-7939; e-ISSN 2289-4934

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NEW AND OLD BUILDINGS MICROENVIRONMENT– AN INDOOR AIR QUALITY STUDY

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ABSTRACT

Good indoor air quality promotes healthy indoor environment. Most of the indoor air contaminants originate from biological agents such as bacteria and fungi. Temperature and relative humidity are contributing factors to the growth of bacteria and fungi in indoor environment. The present study aims to (a) determine the concentration of airborne bacteria and fungi in old and new buildings and to compare these with the recommended maximum measurement, (b) correlate the microbial growth with temperature and relative humidity, (c) to identify various airborne bacteria and fungi in indoor environment. Microbial sampling was conducted using Standard Biostage Impactor. The building temperature and relative humidity were measured using Q-Track Plus Indoor Air Quality Meter. A total of 38 bacteria and 83 fungal genera were identified. Statistical analysis showed that the concentrations of total bacteria and fungi were below the maximum concentration as recommended by ICOP IAQ. There was also no correlation of relative humidity and temperature with the total concentrations of bacteria and fungi. The total concentration of bacteria and fungi also exhibited no significant difference between the old and new office buildings. The findings exhibited the presence of low levels of contaminant, thus indicating good air quality in the studied buildings.

Keywords: microbial growth; environmental factors; air quality; building related illness (BRI).

1. INTRODUCTION

Good indoor air quality (IAQ) is a prerequisite for a healthy indoor work environment. Poor indoor air quality can cause many short-term and long-term health problems (DOSH, 2010). Indoor air contaminants mostly originate from living microorganisms which include bacteria, fungi, yeasts, protozoa, dander, mites, pollens and viruses (Hussin, Sann, Shamsudin, & Hashim, 2011). Airborne microbes in the air can be accidentally inhaled by the occupants who at a later stage will cause health problems such as rashes, allergies and infections

p-ISSN 1675-7939; e-ISSN 2289-4934

especially for immuno-compromised individuals (Mandal & Brandl, 2011). In pertinent to that, the term "*sick building syndrome*" (SBS) thus relates to non-specified clinical symptoms e.g. headache, fatigue, eye, nose and throat irritation, and odour annoyance (Juliana, Norhafizalina, Azman, & Kamaruzaman, 2009; Nur Fadilah & Juliana, 2012). Nevertheless newly renovated buildings also develop prevalence of SBS (Cox & Wathes, 1995, Nur Fadilah & Juliana, 2012). On the other hand, the term "*building-related illness*" (BRI) refers specifically to a clinically diagnosed disease in which one or more of the occupants of a building is involved. BRI can be divided into respiratory infections and hypersensitivity disease which building occupants may be exposed to endotoxins or mycotoxins (Alsmo & Holmberg, 2007). According to Sheet Metal and Air Conditioning Contractors' National Association (SMACNA, 1998), not all occupants perceive, observe or react to environmental conditions in the same manner. Therefore, only a small percentage of the occupants are likely to be affected by the microbial contamination. Poor IAQ conditions are able to affect people in markedly different ways. Besides that, different people will have different acceptable temperature tolerance and humidity level (Arundel, Sterling, Biggin, & Sterling, 1986).

In order to manage and ascertain certain level of microbial growth in indoor environments, building management administration must control certain factors which directly contribute to these growths. Among these factors are thermal comfort elements such as humidity and temperature. Understanding these factors will help to strategize building maintenance SOP, thus improving and maintaining the air-conditioning and ventilation systems which directly provide a conducive and productive working environment for the workers.

2. MATERIALS AND METHODS

2.1 Study Design and Location

Cross-sectional studies were carried out at 2 (two) selected office buildings of the National Institute of Occupational Safety and Health (NIOSH), at Bandar Baru Bangi, Selangor. Six microenvironment sampling points were selected for this study which includes the manager's room, utility room, office bench work, access area and discussion room. Samples were collected from the above sampling points at CRD offices of NIOSH headquarters representing samples of the old building. While, samples representing the new building were collected from the training offices at Level 6, NIOSH tower using the same sampling points mentioned above. The indoor bacteria and fungi concentrations measured from both locations were then compared with the recommended maximum concentration measurement for an evaluation of the various relative risks of exposure to the indoor occupants.

2.2 Sampling

The airborne fungi and bacteria were collected using SKC Biostage (single-stage) impactor (SKC Inc., USA) which operated on the principle of initial impaction. Air is drawn through the impactors where the particle is impacted onto the agar collection media on a standard 90mm Petri dish. The sampler pump flow rate was set and calibrated at 28.3 L/min. The sampling was done at 1.0 m above ground level for each 2-minute sampling session at the selected sampling points. Two petri plates were used in each sampling period which contain agar media Tryticase Soy Agar (TSA) supplemented with 500mg cycloheximide and Malt Extract Agar (MEA) supplemented with 100mg chlorampenicol for bacterial and fungal count respectively. The agar plates were placed on the media holder and properly secured under

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impactor head during sampling process. The impactor head was assembled with sampler pump which was already calibrated at 28.3 L/min. The sampling duration was set at 2 minutes as recommended by the manufacturer. The sampling head was autoclaved and then sterilized with 70% alcohol before being used. After each sampling, the media was secured with the lid and sealed with parafilm tape and placed in sealable box with icepack. The box was brought immediately to the laboratory for analysis.

All samples were sent to the Microbiology Laboratory, Hospital Serdang, Selangor for further laboratory investigations. Samples were incubated for 2 days to allow bacterial growth and 5 to 7 days for detection of fungal growth. Colonies were manually counted in each of the plate. The total number of bacteria and fungi counted for every plate was recorded and calculated to obtain the concentration in cfu/m^3.

2.3 Measurement of Relative Humidity and Temperature

Indoor air temperature and relative air humidity were monitored using Q-Track Plus Indoor Air Quality Meter, TSI Model 8554 (TSI Inc., USA). The equipment was calibrated before every usage.

2.4 Identification of Bacteria and Fungi

Identification of bacteria and fungi was performed using a conventional method by examining the pure colonies morphological characteristics (Sharma, 2005; Chan, Leung, Tam, & Jones, 2008). Further investigations were carried out using BD Phoenix™ Automated Microbiology System (BD, USA).

Bacteria colonies which grew on TSA media were counted and sub-cultured onto 5% sheep blood agar (Oxoid, USA) and Mac Conkey agar to obtain pure colonies. Whereas, the fungal colonies from MEA media were then sub-cultured onto a Potato Dextrose Agar (PDA) media (ISOLAB, M). Pure colonies of the bacteria were selected and Gram staining was performed for identifications of gram positive or negative bacteria. The respective gram staining reactions were used either in Phoenix NMIC/ID-24 for gram negative and Phoenix PMIC/ID-14 for gram positive bacteria.

Fungal colonies which grew on PDA media were identified by Lactophenol Cotton Blue (LPCB) stain using cellophane tape preparation. Fungal colony obtained on the cellophane tape was then pasted onto a glass slide filled with a few drops of LPCB stain for 10 to 15 minutes. Morphology of the fungi was examined under a light microscope (Olympus). Fungal colonies were also examined by slide culture technique. A petri dish with the applicator stick and wet gauze was prepared. A small square cut of PDA media was placed in the centre of a clean glass slide. Fungal colonies were then harvested aseptically using a straight wire and streaked at four paths of the square-shaped PDA media. A clean coverslip was placed onto the square media and the glass slide was kept in a covered petri dish. It was then left at room temperature for 3 - 5 days to allow fungal growth and maturation. Then, the slide culture was examined by LPCB stain followed by observation using a light microscope.

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2.5 Statistical Analysis

SPSS software version 18 was used to analyze the data obtained. The normality of the data was assessed using Shapiro-Wilk test due to sample size of less than 100. One sample t-test was used to compare with the recommended value and Spearman's rank order correlation test was used to correlate between environmental factors with bacteria and fungi concentration. Meanwhile, Mann-Whitney U test was used to detect the differences of total bacteria and total fungi concentration at the old and new office buildings.

3. RESULTS

The study revealed that the lowest relative humidity (RH) recorded was at 47.3%, while the highest RH was 66.0%. Therefore, the mean value for RH was 56.1%. The lowest temperature recorded was 20.8˚C, while the highest temperature was 25.5˚C with mean temperature calculated was 23.6˚C. The mean value for total bacterial count (TBC) was 0.78 cfu/m^3, while, the mean value for total fungal counts (TFC) was 0.21 cfu/m^3 (Table 1).

The result gathered in this study indicated that both sampling locations showed ($p<0.05$) for TBC and also TFC (Table 2 and Table 3). Therefore, TBC and TFC for both sampling locations showed there was no significant different between the recommended maximum concentration.

The relationship between indoor bacteria and fungi concentration with temperature and RH were showed in Table 4. The result from the Spearman's rank order correlation test showed that p value for NIOSH tower was $r = 0.031$; $p>0.05$ which indicated that there was no correlation between temperature and TBC. While, at NIOSH HQ, the correlation between temperature and TBC showed $r = 0.107$; $p>0.05$ which indicated there was no correlation between temperature and TBC. The correlation between temperature and TFC at NIOSH tower showed $r = 0.271$; $p>0.05$ which indicated that there was no correlation. Also the NIOSH HQ with $r = 0.453$; $p>0.05$) indicated that there was no correlation between temperature and TFC. The correlation between RH and TBC at NIOSH tower showed $r = -0.219$; $p>0.05$. This indicated that there was no correlation between the RH and TBC. At NIOSH HQ, $r = 0.180$; $p>0.05$, also indicated that there was no correlation between RH and TBC. The relationship between RH and TFC at NIOSH tower showed $r = 0.130$; $p>0.05$. This indicated that there was no correlation between RH and TFC at NIOSH tower. The correlation between RH and TFC at NIOSH HQ showed $r = 0.169$; $p>0.05$ which also indicated no correlation between the two parameters.

Of the 22 samples collected from this study, 4.5% samples were obtained from the discussion room, 13.6% were from the access area, 45.5% from the bench work area, 18.2% were from the utility and manager's room (Table 5). Investigation on TBC (Table 6) in the access areas (lift lobby, waiting area and entrance) showed higher TBC with a mean value of 1.91 cfu/m^3, followed by discussion room with a mean value of 1.47 cfu/m^3. Bench work areas showed TBC with a mean value of 0.58 cfu/m^3. The utility rooms (printing, stationary, AHU and store room) showed a mean value of TBC at 0.57 cfu/m^3. The lowest TBC was detected at the manager's room with a mean value of 0.05 cfu/m^3. Investigation of TFC between the micro-environment (Table 7) showed that the access areas have a higher TFC with mean concentration value of 0.34 cfu/m^3; followed by the manager's room with a mean value of 0.24 cfu/m^3. The utility room showed a mean value of TFC 0.20 cfu/m^3; followed by the second

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lowest TFC at bench work areas with a mean value of 0.18 cfu/m^3. The lowest TFC was detected in the discussion room with a mean concentration of 0.11 cfu/m^3.

Table 1: Descriptive Data of Temperature, Relative Humidity, Bacteria Concentration and Fungi Concentration

Variable	N	Mean	SD	Min.	Max.
Temperature (˚C)	22	23.6	1.4	20.8	25.5
Relative Humidity (%)	22	56.1	4.2	47.3	66.0
Bacteria Concentration (cfu/m^3)	22	0.78	0.57	0.1	2.1
Fungal Concentration (cfu/m^3)	22	0.21	0.11	0.1	0.4

Table 2: Total Bacteria Concentration on Both Sampling Locations Compared with Recommended Maximum Bacteria Concentration at 500 cfu/m^3

Sampling location	Test value = 500 cfu/m^3			
	Mean (SD)	Mean diff (95% CI)	t-stats (df)	P value
NIOSH tower (n=15)	0.819 (0.66)	-499.2 (-499.5, -498.8)	-2938.5 (14)	P < 0.001
NIOSH HQ (n=7)	0.703 (0.36)	-499.3 (-499.6,-499.0)	-3632.3 (6)	P < 0.001

Table 3: Total Fungi Concentration on Both Sampling Locations Compared with Recommended Maximum Fungi Concentration at 1000 cfu/m^3

Sampling location	Test value = 1000 cfu/m^3			
	Mean (SD)	Mean diff (95% CI)	t-stats (df)	P value
NIOSH tower (n=15)	0.196 (0.11)	-0.999.8 (-999.9,-999.7)	-33689.5 (14)	P < 0.001
NIOSH HQ (n=7)	0.251 (0.09)	-999.7 (-999.8,-999.7)	-28877.0 (6)	P < 0.001

Table 4: Correlation Test between Temperature and Relative Humidity Towards Bacteria and Fungi Concentration at Both Locations

Test Variable	Sampling location	r	P value
Temperature vs Bacteria concentration	NIOSH tower	0.310	0.914
	NIOSH HQ	0.107	0.819
Temperature vs Fungi concentration	NIOSH tower	0.271	0.329
	NIOSH HQ	0.453	0.307
Relative Humidity vs Bacteria concentration	NIOSH tower	-0.219	0.433
	NIOSH HQ	0.180	0.699
Relative Humidity vs Fungi concentration	NIOSH tower	0.130	0.644
	NIOSH HQ	0.169	0.717

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Table 5: Percentage Contribution of Each Microenvironment/Area

Sampling site				
	Frequency	Percent	Valid Percent	Cumulative Percent
manager's room	4	18.2	18.2	18.2
utility room	4	18.2	18.2	36.4
bench work	10	45.5	45.5	81.8
access area	3	13.6	13.6	95.5
discussion room	1	4.5	4.5	100.0
Total	22	100.0	100.0	

Table 6: Total bacterial concentration among microenvironment

Descriptive Statistics						
Sampling site		N	Minimum	Maximum	Mean	Std. Deviation
manager's room	TBC (cfu/m^3)	4	.1	1.0	.495	.3708
	Valid N (listwise)	4				
utility room	TBC (cfu/m^3)	4	.5	.8	.566	.1601
	Valid N (listwise)	4				
bench work	TBC (cfu/m^3)	10	.1	1.4	.577	.3528
	Valid N (listwise)	10				
access area	TBC (cfu/m^3)	3	1.6	2.1	1.906	.2356
	Valid N (listwise)	3				
discussion room	TBC (cfu/m^3)	1	1.5	1.5	1.472	0.0
	Valid N (listwise)	1				

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Table 7: Fungi Concentration among Microenvironment

Descriptive Statistics						
Sampling site		N	Minimum	Maximum	Mean	Std. Deviation
manager's room	TFC (cfu/m^3)	4	.2	.3	.241	.0542
	Valid N (listwise)	4				
utility room	TFC (cfu/m^3)	4	.1	.3	.198	.1084
	Valid N (listwise)	4				
bench work	TFC (cfu/m^3)	10	.1	.3	.181	.1126
	Valid N (listwise)	10				
access area	TFC (cfu/m^3)	3	.2	.4	.340	.0980
	Valid N (listwise)	3				
discussion room	TFC (cfu/m^3)	1	.1	.1	.113	0.0
	Valid N (listwise)	1				

The Mann-Whitney U test (Table 8), z = -0.071, p > 0.05, and therefore no significant difference of total bacterial concentration between the old and new office buildings. The total fungi concentration between the old and new office buildings showed z = -1.182, p > 0.05, indicated no significant difference.

Throughout the sampling, 38 bacterial species and 6 fungal genera were isolated in this study (Table 9 and 10). The predominant bacteria isolated at both locations were the *Micrococcus* species followed by *Staphylococcus* species and *Bacillus* species (51.98%, 21.72% and 14.14% respectively). The most common indoor airborne fungal genera isolated were *Cladosporium* (21.69%), *Fusarium* (16.87%) and *Penicillium* (14.46%) as obtained from the TFC.

Table 8: Mann-Whitney U Test of Total Bacteria Concentration (cfu/m^3) between Old and New Office Buildings

Variable	**NIOSH tower (n=15) Median (IQR)**	**NIOSH HQ (n=7) Median (IQR)**	**Z statistic[a]**	**P value[a]**
Total Bacteria count (cfu/m^3)	0.566 (1.0)	0.566(0.5)	-0.071	0.944
Total fungi count (cfu/m^3)	0.170 (0.2)	0.283(0.1)	-1.182	0.237

[a] Mann-Whitney test

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Table 9: Bacteria Genera and Species Isolated at Level 6, NIOSH Tower and CRD Office, NIOSH HQ

Genera	Species	Staining	N = 304	Percentage (%)
Acinetobacter		Gram negative		
A. baumanni				1.32
A. calcoaceticus				0.66
Alcaligenes		Gram negative		
A. faecalis				0.66
Bacillus		Gram positive		
B. cereus				0.99
B. circulans				1.97
B. coagulans				0.99
B. licheniformis				1.97
B. megaterium				1.32
B. pumilus				2.3
B. thurigiensis				0.66
Paenibacillus alvei				0.66
Paenibacillus macerans				1.64
Brevibacterium		Gram positive		
Brevibacterium species				1.64
Corynecbacterium		Gram positive		
C. matruchotti				1.97
Klebsiella		Gram negative		
Klebsiella ozaenae				0.66
Micrococcaceae		Gram positive		
Dermacoccus nishinomiyaensis				5.59
Kocuria varians				0.66
Kytococcus sedentarius				0.66
Micrococcus luteus				22.04
Micrococcus lylae				23.03
Pseudomonas		Gram negative		
P. oryzihabitans				1.97
P. pseudoalcaligenes				0.66
P. putida				0.99
P. stutzeri				0.99
Pseudomonas spp.				0.66
Staphylococcus		Gram positive		
S. aureus				0.99
S. capitis				1.64
S. cohnii susp cohnii				3.62
S. epidemidis				2.63
S. haemolyticus				7.24
S. hominis				1.97
S. intermedius				0.66
S. kloosi				0.66
S. sciuri				0.66

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S.simulans		0.99
S. saprophyticus		0.66
Streptococcus	Gram positive	
S.acidominimus		0.99

Table 10: Fungal Genera and Species Isolated at Level 6, NIOSH Tower and CRD Office, NIOSH HQ

Genera and species	N = 83	Percentage%
Actinomycetes	29	34.94
Aspergillus		
A. niger	2	2.41
A. versicolor	1	1.2
Acremonium	7	8.43
Cladosporium	18	21.69
Fusarium	14	16.87
Penicillium	12	14.46

4. DISCUSSION

The Malaysian Industry Code of Practice of Indoor Air Quality (ICOP IAQ) for healthy indoor work environment has recommended the standard for maximum concentration of bacteria and fungi at 500 cfu/m^3 and 1000 cfu/m^3, respectively (DOSH, 2010). The result obtained in this study showed total bacteria concentration and total fungi concentration at both sampling locations did not exceed the ICOP IAQ standard recommended maximum concentration. Currently Malaysia does not have a legislature standard guideline for indoor air quality that can be strategized for building management. There were other standards for indoor air quality such as World Health Organization (WHO), American Conference of Industrial Hygienists (ACGIH) standard and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standard. Published values for acceptable bacterial and fungal bio-aerosol concentrations vary from country to country (Mandal & Brandl, 2011).

The correlation test indicated that there was no correlation between temperature with bacterial and fungal concentration. There was also no relationship between relative humidity with bacterial and fungal growth. This finding does not support the results by Law, Chau, & Chan, (2001) who observed that background fungi concentration can be strongly correlated with indoor relative humidity. Such similar finding was also concluded by Aydogdu, Asan, Otkun, & Ture, (2005) in pertinent to bacteria and humidity. However their study was unsuccessful to establish the correlation between fungi and relative humidity. Meanwhile, Hussin et al. (2011) mentioned in their findings that there was a correlation between relative humidity and the bacterial concentration. They found that the effect of temperature and relative humidity on indoor airborne microorganisms can be controversial due to the differences between climate conditions.

On the contrary, Nasir & Colbeck (2010) found that there was negative correlation between both fungal and bacterial concentration with temperature in all their sampling locations. On the other hand, humidity showed a positive correlation between both bacteria and fungi concentration. These demonstrated that higher humidity level will increase the bacteria and fungi concentration. According to them, relative humidity has a major role in the survival of

p-ISSN 1675-7939; e-ISSN 2289-4934

airborne microorganism. It has been shown that gram negative bacteria react unfavourably to desiccation, while gram positive bacteria are more tolerant to desiccation stress.

In pertinent to the correlation between relative humidity and temperature with bacterial and fungal concentration, no clear relationship was observed. This might be due to small sample size or study area. If more samples had been collected, with the addition of more study areas, the correlations may be noticeable. This was identified as a limitation of this study.

The present study suggests that bacteria concentration were higher than fungi concentration. The findings from the present study indicate that there was a significant difference between bacteria and fungi concentration between the manager's room, utility room, bench work area, access area and discussion room.

In general, bacterial concentration was higher in the access area (lift lobby, waiting area and entry area), followed by the discussion room with mean concentration at 1.47 cfu/m^3 compared with the utility room and manager's room. The mean concentration of bacteria in the access area was 1.91 cfu/m^3, which was slightly higher compared to the utility room and manager's room. The high concentration of bacteria at the access area may be due to pathway of outdoor source and higher occupancy. Whereas, in the utility room, the bacterial concentration was lower may be due to low usage and low occupancy. High occupant density tends to result in a large amount of moisture released, thus resulting in a high indoor humidity index (Lee, Li, & Ao, 2002; Alsmo & Holmberg, 2007). Another factor mentioned was the culture of having much vegetation in the access area may be for decoration of that place. Since the plant's pot contained soil, the soil can be the reservoir of bacterial contamination.

This research seems to indicate that there is no significant difference between fungi concentration with the said micro - environments. However, access area and manager's room show slightly higher the fungi concentration among others with a mean value of 0.34 cfu/m^3 and 0.24 cfu/m^3. The present findings show that fungi concentration in access area and the manager's room may be due to outdoor source and humidity level. Higher level of humidity promotes fungi proliferation.

In the present study, predominant bacteria found in the indoor air environment in both locations were *Micrococcus* species followed by *Staphylococcus* species and *Bacillus* species. Gram-positive cocci were the dominant bacterial species isolated. This is consistent with the other reports conducted in schools, offices and residential buildings in Europe, Poland, Korea and Turkey as most of gram-positive cocci are widespread in nature (Lee et al., 2002; Kim, Park, Jang, Kim, & Lee, 2007; Hussin et al. 2011). However, detection of these micro-organisms at high level would indicate high density occupancy and inadequate ventilation. In a study by Kim et al. (2007), they also reported 50% of total bacteria concentration from Seoul Subway station was dominated by *Staphylococcus* and *Micrococcus*.

Micrococcus species were the predominant bacteria species encountered in this study. Members of the bacillus are mostly aerobic saprophytes and endospore formers and also commonly distributed in nature, but some species are pathogenic to humans, including animals and other mammals. However, the gram-negative bacteria was the less common bacteria found in the present study. Gram-negative bacteria are believed to have more harmful effects due to endotoxin production. Endotoxin, produced in the cell walls of Gram-negative bacteria can cause acute pulmonary function changes and inflammation of its mucous

p-ISSN 1675-7939; e-ISSN 2289-4934

membranes resulting in irritation of the eyes, nose and throat, hoarseness and dry cough (Godish, 1995).

The third most predominant bacteria isolated from this study was bacili species. This gram positive bacili was predominantly found due to common in soil and water habitants and many are part of the normal skin and mucous membrane flora of humans and various animals.

Predominant fungal genera isolated from this study were of *Cladosporium, Fusarium* and *Penicillium* that were consistent with Kim, Kim, & Kim (2010). Other fungal genera commonly isolated were *Alternaria, Aspergillus* and *Acremonium* (Chen, Cui, & Dong, 2010).

Aydogdu et al. (2005) stated that *Aspergillus, Penicillium, Alternaria, Fusarium* may be found abundantly in the air due to many factors. These include geographical region, seasonal variation, wind, humidity, temperature, rainfall, altitude, vegetation, some specific reservoir of contamination, sampling time, sampling procedure, media used for cultivation of microorganism, human and agricultural activities. Fungal hyphae or spores have the ability to produce mycotoxins, leading to mycotoxicoses as a result of exposure to mycotoxins (Godish, 1995). The most common fungi involved in mycotoxicoses are *Fusarium, Aspergillus* and *Penicillium*, which were predominantly found in the present study.

Fungi can cause three distinct primary adverse effects; (1) damage building; (2) unpleasant smell in the building; and (3) aeroallergens in sensitive humans (Aydogdu, et al. 2005). In a research work by Kim et al. (2010), they found the predominant fungal genera isolated were *Aspergillus* species. They noted the facts that *Aspergillus* species have xerophilic properties which might enable them to survive in the air for a relatively long time. These fungal spores of *Aspergillus* species were pathogenic microorganisms to immuno-compromised persons leading to respiratory disease such as pneumonia, asthma and bronchitis (Larone, 2002). These facts were also supported by Hussin et al. 2011, where they suggested the need to identify genus *Aspergillus* further to species level. This is due to some species of *Aspergillus* such as *A. flavus, A. fumigatus* and *A. versicolor* have allergenic, toxigenic and infectious effects (Nasir & Colbeck, 2011).

5. CONCLUSION

This is a preliminary study in an office building at NIOSH to provide comprehensive baseline data on microbe concentration. There was no significant correlation between relative humidity and temperature with bacteria and fungi concentration. The bacteria and fungi concentration also do not exceed the recommended maximum concentration provided by ICOP IAQ. The concentration of bacteria and fungi at the new and old office buildings also showed no significant difference. However, there was a significant difference on bacterial concentration among micro-environment but not fungi.

ACKNOWLEDGEMENT

The authors would like to thank NIOSH and Hospital Serdang for the approval and permission to utilize their said facilities. The authors also thank the Faculty of Health Sciences, Universiti Teknologi MARA, Puncak Alam for full financial support.

p-ISSN 1675-7939; e-ISSN 2289-4934

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