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INDOOR MICROBIAL CONTAMINATION AND ITS RELATION TO PHYSICAL INDOOR AIR QUALITY CHARACTERISTICS AT SELECTED LIBRARIES IN PAHANG

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Abstract

Library contains huge collection of books that can undergo biodeterioration process after period of time. Due to this biological reaction, the existence of airborne particulate matters and microbes in the air of the library can be disturbed and elevated, thus can cause health implications to occupants. Therefore, it is an urge to assess and understand the correlation between physical indoor air quality (IAQ) characteristics, airborne pollutants and microbial contaminants in different library settings and locations. This study was carried out at three different libraries, which are Library A (Gambang as suburban area), Library B (Kuantan as urban area) and Library C (Pekan as rural area). The physical IAQ characteristics and particulate matter (PM) monitoring were assessed by using IAQ Meter and DustMate respectively. Surface Air System IAQ (SAS IAQ) was used to collect the airborne microbes. The microbial contamination was further assessed and identified in the laboratory by using API 20E and API 20 Strep while SPSS was used to analyze the relationship of physical IAQ characteristics, airborne pollutants and airborne microbes contaminants. The scientific method protocol and standard reference limits were compared based on Industrial Code of Practise on Indoor Air Quality, 2010 (ICOP, 2010) regulated by the Department of Occupational Safety and Health (DOSH). Respirable PM in Library A and CFU counts in Library A and C exceeded the standard limit with the value of 0.30 mg/m^3, 2744 CFU/m^3 and 1833 CFU/m^3 respectively. Significant differences ($p < 0.05$) between the selected libraries were observed among relative humidity ($p=0.001$), inhalable PM ($p=0.001$), thoracic PM ($p=0.001$), respirable PM ($p=0.01$), CO_2 reading ($p=0.001$) and CFU counts ($p=0.01$). This study demonstrated Library C has poor air quality as the reading for CO_2 and CFU counts are very high compared with the other two libraries. The bacterial identification findings indicated that Gram positive bacteria were abundant compared to Gram negative bacteria. *Aerococcus viridans* is the most dominant type of bacteria isolated in all the libraries.

Keywords: Indoor air quality (IAQ), library, airborne pollutants, particulate matter (PM), CFU microbes, *Aerococcus viridans*

1.0 INTRODUCTION

Indoor Air Quality (IAQ) is represented by the temperature, humidity, ventilation and chemical or biological contaminants of the air inside buildings. All of pollutants can affect the health, comfort, and performance of the building occupants [1]. In average, most of the people spend 80% of the time of the day in enclosed environment [2]. Besides, pollutants exposure in indoor air environment is predicted to cause 2 million deaths worldwide per year and is now becoming a major global public health risk [3].

Library is an enclosed building, where people spent their time to gain extra information and references. It occupied huge collection of books, manuscripts and other academic materials as well as furniture and electronic devices. In a certain time,

the books may undergo bio-deterioration processes, while furniture and electronic devices such as computers photocopy machines, and printers may release chemicals substances, such as unreacted monomers, solvents and additives into the indoor environment [4, 5].

This biological reaction can disturb and heighten the existence of airborne particulate matters and microbes in the library. Poor air ventilations in some rooms that are rarely been used may also promote the growth of microbes. Frequent library users may expose to indoor air pollutants which pose detrimental effects on their health. Therefore, it is necessary to investigate the physical IAQ characteristics and airborne pollutants as well as microbial contaminant in the libraries. It is also essential to identify airborne microbes isolated from libraries to initiate the establishment of reference data for IAQ in libraries for the sake of occupants' safety and health.

2.0 MATERIALS AND METHODS

2.1 Study Area

Three university libraries at different location in Pahang were selected as investigation sites. Library A Global Positioning System, (GPS) (3.721998, 103.120985), Library B GPS (3.844382, 103.302535) and Library C GPS (3.542838, 103.431614) were chosen based on its homogeneity in terms of the nature of the buildings and its library collection. Library A and Library B were located in suburban and urban area while Library C was located in a rural area.

In each library, two sampling points were selected which were the office and the book area. The points were chosen due to centralized Mechanical Ventilation Air Conditioning (MVAC) system applied within the area. The sampling approach for this assessment was grab sampling from the direct reading equipment. IAQ assessment at the site were conducted three times a day during working hours, which were morning session (10.00am-12.00pm), afternoon session (12.00pm-2.00pm) and evening session (4.00pm-5.00pm) for each library.

2.2 Instrumentation and Sampling Protocol

The physical parameters of the air at the sampling locations were recorded by using portable IAQ meter (TSI®, Minnesota, USA). It is an instrument to measure the velocity of the airflow with a real time monitoring which will give a direct reading. The probe of IAQ meter was held directly to the MVAC system and the readings were taken for about 2 minutes. The reading was displayed on the screen. The data were then recorded on a data sheet and compared to the standard set by ICOP, 2010 for further assessment. Besides, particulate matter was analyzed using Dustmate (Turnkey Instruments, UK). This instrument measured the concentration of thoracic, inhalable and respirable particles down to 0.1 μg/m^3. Dustmate used light scattering technique to determine the concentration of airborne particles and dust in the size range from about 0.4 microns to about 20 microns in diameter. During the assessment of the airborne pollutants, Dustmate was placed near to the sampling points. All the data were recorded and transferred to the computer for further analysis.

Surface Air System Indoor Air Quality (SAS IAQ), (PBI International, Italy) was the device used for microbes' sampling. Airborne microbes were collected from each station by placing SAS IAQ 2m above ground level and near the MVAC system. Each air sample was taken at a flow rate of 15 L/min. The sampling of airborne microbes was carried out for 1minute at each sampling point. The head of SAS IAQ was unscrewed and a petri dish was placed into the housing. The environmental air is aspirated over the agar surface of the plate and airborne particles were captured on the agar by impaction. At the end of the sampling cycle, the plates were removed, sealed, labelled and incubated at 37°C for 24 hours before colony forming unit was counted. The number of CFU (colony forming unit) will provide the information related to microbial contamination.

2.3 Laboratory Analysis

The microbes' identification was performed using Analytical Profile Index (API) test which were API 20E and API 20 Strep. This identification system of bacteria is extensive and had standardizes databases to characterize biochemical reactions of microorganisms. API 20E system is a special identification system designed for *Enterobacteriaceae* and other gram-negative bacteria. There are 21 miniaturized biochemical tests on the strips. Some complementary tests needed to be conducted upon identifying the bacteria such as oxidase test, oxidation fermentation test, motility test and also MacConkey test. API 20 Strep was chosen for the identification of the Gram-positive bacteria. The independent complementary test for the API 20 Strep is the blood agar test. All tests were run according to the manufacturer's instruction.

2.4 Data Analysis

Statistical analysis was performed with Statistical Package for the Social Sciences Program (SPSS 20) Software and Microsoft Excel 2007. The data were analyzed using Kruskall-Wallis test with p-value ($p< 0.05$) to determine the statistical difference via two or more groups of independent variables. A p-value less than 0.05 were considered statistically significant.

3.0 RESULTS AND DISCUSSION

Based on the Table 1, the average measurement for all the physical IAQ parameters, airborne pollutants

and CFU counts were compared with ICOP 2010 set by DOSH.

Table 1 Interrelationship of parameters among the libraries and comparison with standard reference ICOP, 2010

	Parameters	Library			P value	Standard ICOP 2010
		A	B	C		
Physical IAQ	Temperature (°C)	23.59 ±1.27	23.37 ± 0.92	23.28 ± 1.09	0.911	23-26
	RH (%)	53.78 ± 3.13	68.57 ± 4.07	68.41 ± 8.38	0.001*	40-70
	Velocity (m/s)	0.23 ± 0.17	0.21 ± 0.13	0.16 ± 0.05	0.417	0.15-0.50
	Flow (m^3/h)	26.7 ± 19.46	24.40 ± 14.86	12.56 ± 6.09	0.359	NA
Airborne Pollutants	Inhalable (mg/ m^3)	1.96 ± 0.31	NA	0.56 ± 0.27	0.001*	NA
	Thoracic (mg/ m^3)	1.00 ± 0.19	NA	0.34 ± 0.13	0.001*	NA
	Respirable (mg/ m^3)	**0.30** ± 0.05	NA	0.15 ± 0.06	0.01*	0.15
	UF (mg/ m^3)	0.10 ± 0.01	NA	0.12 ± 0.05	0.895	NA
	CO_2	984.00 ± 189.27	471.83 ± 47.80	415.33 ± 48.26	0.001*	1000
	CFU/ m^3	**2744.00** ± 781.25	233.33 ± 150.64	**1833.00** ±1822.96	0.01*	500

* Indicates that there is a significant differences between the three libraries as the *p* value is less than 0.05
Bold readings are the values that exceed the acceptable limit set by DOSH.

3.1 Assessment of IAQ Parameters

The physical IAQ parameters measured which were temperature, RH, and velocity met the acceptable range limit set by DOSH. None of the physical IAQ parameters exceeded the limit value indicate that MVAC was in good condition and well maintained in all the libraries.

Proper ventilation in all libraries has influenced the physical IAQ characteristics. An effective ventilation system in the library area is able to channel out the air contaminants in the indoor library and replaces them with a fresh air. Furthermore, statistical analysis also showed a significant different (p=0.001) on relative humidity between the three libraries. It may suggest that, the outdoor ambient environment could be the reason for humidity fluctuation in the indoor environment through opening of entrance door. Based on previous study, RH which exceeded 60% is considered very humid. However, DOSH has set the standard range for RH to be in 40-70% as Malaysia is a tropical country where the outdoor air is usually very hot and humid throughout the year [6].

CO_2 concentration represents library ventilation performance. None of these libraries have shown that CO_2 level exceeds limit set by the DOSH. Thus indicated ventilation systems in the libraries were good as low levels of CO_2 reflected proper ventilation [7]. Despite that the CO_2 reading in these libraries were below the standard set by ICOP 2010, the CO_2 level in Library A was considered high compared with the other two libraries. This can be related to the high number of occupants in the library. Furthermore, the increase level of CO_2 inside the library may come from the outdoor sources as the library is located in front of the busy highway.

3.2 Airborne Pollutants

Inhalable PM, thoracic PM, and respirable PM, showed significant differences between the three libraries. The readings for the respirable PM, which were 0.30 mg/m^3 in Library A, were higher than the standard limit. This is due to vast amount of books inside Library A as it is an old library. The presence of the large amount of old books in the libraries also lead to high concentration of dust accumulated. Dust gives a particular challenge for libraries as books were made from organic materials. The materials can be degraded and fragmented and eventually creating dust [8]. The previous study also suggested that, books, documents or the storage boxes were the predominant cause to the production of PM. Other factors that could increase PM concentration were the shedding of walls and old ceiling inside the library. Library A had shedding wall and old ceiling compared with other two libraries. Basically, concrete wall could emit particulates, while the shedding of the wall may increase the indoor emission of the particulates [9]. The presence of

carpets could cause a re-suspension of dust particles. Besides, PM distribution is also affected by season, time of day and location. It was due to imbalance in the ventilation system which allowed the accumulation of possible contaminants within the indoor environment [11].

3.3 CFU Counting and Bacteria Identification

Table 2 Bacterial Identification from API Web

API database code	Total Groups of Colonies	Strains	Percentage (%)	Remark	Gram (+/-)	Libraries
1160000	12	Gemella haemolysans	94.7	Excellent identification	+	A, B, C
2060000	7	Aerococcus urinae	93.4	Good identification	+	A, C
1006010	7	Leuconostoc spp	99.6	Very good identification	+	A, B, C
1006751	8	Aerococcus viridans 1	95.5	Good discrimination	+	A, B, C
5103414	7	Enterococcus durans	99.1	Very good identification	+	A, B, C
6142410	13	Aerococcus viridans 1	76.2	Good identification	+	A, B
0160000	8	Granulicatella adiacens	80.4	Low Discrimination	+	B, C
3102014	20	Aerococcus viridans 2	99.6	Very Good identification	+	A, B, C
201402017	2	Photobacterium damselae	87.5	Doubtful profile	-	A
101412057	1	Pantoea agglomerans	99.6	Very good identification	-	C
001410007	1	Yersinia pseudotuberculosis	71.7	Doubtful profile	-	C

CFU counts in Library A and Library C were exceeded the acceptable limit with the value of 2744 CFU/m^3 and1833 CFU/ m^3 respectively. These values were considered very high compared with 500 CFU/m^3. High number of total bacteria can be related to low temperature and high humidity. These parameters provided a suitable and favourable condition to increase the growth rate of bacteria. As reported by previous study, variations and fluctuations in indoor humidity and temperature were found to have significant effects on bacterial counts [12]. Another study also mentioned that higher numbers of bacteria were obtained due to the maximum number of occupants in the library [13]. This finding was tally with the present study, as the bacterial concentration was found to increase with increasing occupancy level in Library A.

As shown in Table 1, there is a significant difference (p=0.01) of CFU counts in the three selected libraries. Staff and student's respiratory fluid which may be emitted via talking, sneezing and coughing may contribute as the origin of airborne microbes in the library [14]. Besides that, large numbers of books in the reading hall of the library would stimulate the number of bacteria [13] as books and documents are rich of many nutritional substances needed by the microbes. In addition, nutrients that microbes require to grow are typically found in dust particulates or humid environment which includes human skin flakes and other dead or decaying biological materials [15]. High CFU count indicated poor IAQ in library. It can lead to health problems among the occupants such as nasal symptoms. Besides, microbial exposure significantly developed asthma and allergy in building occupants ecspecially children [16].

Among the selected bacteria, eight important Gram-positive bacteria were identified by using API 20 Strep and only three Gram-negative bacteria was determined by using API 20 E. According to the Table 2, *Enterococcus durans, Aerococcus viridans,*

Leuconostoc spp and Gemella haemolysans were the most found Gram-positive bacteria in all three selected libraries. *Pantoea agglomerans*, Gram-negative bacteria that was found only in UMP Pekan Library.

Aerococcus viridans was the most dominant type of bacteria isolated in all the libraries. *Aerococcus viridans* was a Gram-positive, catalse-negative coccus and they were predominantly aerobic which often found in the environment. This microorganism was usually susceptible to penincillin [17]. *A.viridans* is generally a saprophytic bacterium. The bacterium has been reported as a rare pathogen that can be found in a very small number as indigenous inhabitants in the upper respiratory tract and on the skin of normal persons [18]. Based on previous study, even though *A.viridans* was rarely associated with human infections, it could be a causative agent of urinary tract infection [19]. *A.viridans* was also described as an airborne organism prevalent in occupied rooms [20].

Another species found in this study was *Leuconostoc* species which catalase-negative, Gram-positive microorganisms with coccoid morphology. *Leuconostoc*, a facultative anaerobe, was usually nonpathogenic acid-tolerant organisms. It was reported that the first case of *Leuconostoc* infection in human was in 1985 [21]. Since then, *Leuconostoc spp.* has been implicated in a variety of infections. However, these species had never been considered as agents that threaten the lives of large numbers of persons [22]. *G. haemolysans* is a Gram-positive coccus which causes betahaemolysis on blood agar. The species can grow at a wide range of temperatures with optimum growth occurring between 35 °C – 37 °C. They were facultative anaerobic and gave negative reactions to both oxidase and catalase tests.

G. haemolysans has been found to be involved in pulmonary exacerbations of cystic fibrosis patients and is a known human pathogen [23]. *G. haemolysans* is part of the normal human flora in the oral cavity and upper respiratory tract [24]. *Enterococcus durans*, a species of *Enterococcus*, was originally known as *Streptococcus durans*. It was a Gram-positive, catalase-negative and oxidase-negative, coccus bacterium. Infections in humans associated with *E. durans* were apparently very rare. *E. durans* was not regarded as particularly pathogenic to humans [25].

Pantoea agglomerans is a Gram-negative bacterium that belongs to the family Enterobacteriaceae. This bacterium is known to be an opportunistic pathogen in the immunocompromised, causing wound, blood, and urinary-tract infections [26]. *Pantoea agglomerans*, most commonly isolated from humans, is widely distributed in nature and has been isolated from numerous ecological niches, including plants, water, soil, humans, and animals [27]. This explained why this particular bacterium was found only in UMP Pekan Library, as this library is situated in a rural area surrounded with forest and lake.

4.0 CONCLUSION

In general, the IAQ assessment conducted at these libraries has achieved its objectives where the baseline data and related issues were highlighted based on the Indoor Air Quality Guide: Industrial Malaysia Code of Practice (ICOP, 2010). Based on the results obtained, the findings of the assessment reflect issue on high concentration of respirable PM and, high bacteria count when compared to ICOP, 2010. However, all other IAQ parameters inside these three libraries met the favoured range of the standard set by DOSH. Besides that, there was a significant difference for RH, inhalable PM, thoracic PM, respirable PM, CO_2 and CFU counts between different types of library settings. It can be highlighted that the IAQ parameters and PM concentration play an important role of microbial contaminants in library as well as at its different types of library settings and locations. In addition, level of occupancy and activities of the occupants in the library are also associated with IAQ parameters. Thus, scheduled monitoring of IAQ parameters and maintenance of ventilation system must be done to ensure excellent and safe IAQ in the library to the occupants.

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