EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 11(2) (2018) 67-79
DOI 10.14456/ea.2018.23
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Indoor Air Quality in a Northeast Coast Malaysian Medical School

Noor Asyikin Aziz [a], Nik Rosmawati Nik Husain [b*], Mohamed Rusli Abdullah [b], Nabilah Ismail [b], and Zaliha Ismail [c]

[a] *Allied Health Science College Sungai Buloh, Ministry Of Health, Selangor, Malaysia*
[b] *School of Medical Sciences, Health Campus, Universiti Sains Malaysia, Kelantan, Malaysia*
[c] *Population Health & Preventive Medicine Department, Faculty of Medicine, Universiti Teknologi MARA, Selangor, Malaysia*

*Corresponding author: rosmawati@usm.my

Received: November 29, 2017; Accepted: March 1, 2018

Abstract

Hospital settings potentially contain many indoor air pollutants, which will affect the healthcare of workers and patients. A cross sectional study was conducted to determine the indoor air quality in a medical school situated in the Northeast Coast of Malaysia. The hospital consists of eight floors and 33 wards. Eleven wards were randomly selected. A walk through survey was conducted prior to indoor air sampling. Results showed the mean temperature in seven wards above 26.0 °C; only one ward with acceptable mean relative humidity (67.5%), and the illumination was below 300 lux in all wards. The mean carbon dioxide level in two wards was 920.4±48.32 and 911.5±48.83 ppm respectively, approaching the standard ceiling limit. All wards showed acceptable level for carbon monoxide, particulate matter less than or equal to 10 micrometers, and total fungal counts. Two wards showed borderline total bacteria counts, 500 cfu/m^3. The unacceptable level of a few indoor parameters in the hospital needs further attention. Regular indoor air monitoring in the hospital and medical surveillance among healthcare workers are required in order to improve the indoor air quality and prevent related health effects.

Keywords: Indoor air quality; Medical school air pollutants; Bacteria counts; Fungal counts

1. Introduction

People spend 80% to 90% of their time indoor and at least eight hours in an office environment (Dennekamp *et al.,* 2001; Wood *et al.,* 2006). Thus, indoor air in the workplace is a great concern to employers, workers, and health professionals. Indoor air quality (IAQ) is a subset for indoor environmental quality (IEQ). IEQ refers to the mixtures of factors such as temperature, relative humidity, noise, illumination, space design, layout, and structural systems (Dorgan and Dorgan, 2006). Many pollutants such as chemicals, hazardous microbial contaminants, allergens, particulate matters, and any mass further compromise IEQ.

Many studies have documented a strong association between health outcomes and the influence of the physical environment (Gesler *et al.,* 2004; Rollins, 2004; Ulrich *et al.,* 2008; Whitehouse *et al.,* 2001). Zaini Ujang (2000) raised a concern that indoor air pollution is even more dangerous than outdoor air pollution. The most important parameters for air quality identified in commercial buildings and public areas include gaseous pollutants such as carbon dioxide, carbon monoxide, ozone; volatile organic compounds; respirable particulates; and hazardous microorganisms such as bacteria and fungi (Leung and Chan, 2006). These will affect one's health to varying degrees from Sick Building Syndrome (SBS) to Building Related Illness (BRI) (Leung and Chan, 2006). In addition, they may reduce productivity (Ooi *et al.,* 1998). Hospitals deal with a diversity of occupants, patients and visitors. There is a broad spectrum of patients such as outpatients and inpatients, who require facilities that may become sources of indoor air pollutants. The foremost occupants are health care workers working in intensive care units, and operating theatres. Health care workers have different susceptibilities and exposures to hazardous indoor air pollution depending on their roles and working locations. Unacceptable or poor hospital IAQ may contribute to more serious health effects including SBS, BRI, occupational related diseases, and nosocomial (hospital-acquired) infection (Leung and Chan, 2006). Besides the above-mentioned airborne pollutants, Leung and Chan (2006) added that the more serious hospital air contaminants include glutaraldehyde ($C_5H_8O_2$), nitrous oxide, and pathogenic microbes. Microbes with diameters of 1 to 5 μm are easily inhaled and transmit diseases such as *Mycobacterium tuberculosis* (*TB*) bacteria, *Legionella* bacteria, methicillin-resistant *Staphylococcus aureus*, and *Aspergillus spores*.

Currently, there is a lack of IAQ monitoring in the Malaysian healthcare setting since it is not a mandatory procedure stated in the law or act. Thus, this study aims to assess the status of IAQ in one of the medical schools situated in the Northeast Coast of Malaysia. The information gathered would be helpful to hospital management for better managing and planning of space design, including the layout of structural systems, and ensure a healthy environment for their staff, patients, and the public.

2. Materials and Methods

This study was a cross-sectional design conducted in October until December, 2011. There are 33 wards in the hospital involved in this study. Eleven out of the 33 wards were selected. The wards were randomly selected by its location; north, south, and east and level of the floors (eight floors).

The floor size of each ward studied did not exceed 1000 m^2. According to the Malaysian Industry Code of Practice 2010, for such floor size, only one sampling point is adequate for measurement of IEQ (DOSH, 2010). However, in this case, two sampling points were taken from each ward to look for differences that might exist in the parameters, especially physical parameters due to the layout and design of the ward. Only one sample for biological parameters was taken at each ward. The sample was taken at the nurse station because it represents the primary workstation layout.

2.1 Measurement of carbon monoxide (CO), carbon dioxide (CO_2), temperature and relative humidity

The measurement was done by surrogate measurement at four time-slots in a day; at 0800 am, 1000 am, 1200 pm, and 1600 pm. We used Q-TraxPlus Model 8554 IAQ Monitor to measure CO, CO_2, temperature and relative humidity. The monitor was put at the level between 75-120 cm from the floor.

2.2 Measurement of particulate matter (PM_{10}) and illumination

A Dustmate Turnkey Instrument was put at 75 to 120 cm from the floor level to measure PM_{10}. The instrument will continuously measure the concentration of thoracic, inhalable and respirable particles down to 0.1 micrograms per cubic metre. The Dustmate sampled air at a flow rate of 0.6 L/min. An air sample was continuously drawn through the nephelometer. The readings were taken at an interval of 5 min over a total sampling period of 30 min. To measure the illumination, a Center 337 Lightmeter (Center Technology Corp.) was used. The measurements were made at each location of sampling points.

2.3 Microbial air sampler for microbio logical sampling

We used the Microbial Air Sampler (MAS 100 NT) to collect air sample at 100 liter/minute air flow. We applied the NIOSH Manual of Analytical Method 0800 for microorganism identification from air sampling. After completed the air sampling, the sampling media was covered and securely packed for transportation to the laboratory within 24 hours. Microbiological analysis was carried out using Tryptone Soy agar plates that was incubated for 24 - 48 hours at 35°C and Sabaroud's Dextrose agar plates incubated for 5 day at 25 °C to enhance the growth of bacteria and fungi respectively. Escherichia coli ATCC strain and Candida albicans ATCC strain were used as control plate for Tryptone Soy agar and Sabaroud's Dextrose agar respectively.

3. Results

3.1 Building characteristics and environmental exposures

This hospital is situated nearby to the state capital with approximately 500,000 inhabitants. It is near to a moderate traffic with few heavy vehicles. The area does not have any neighbouring polluting industries. All of the hospital buildings were built of concrete with tiles. The age of the buildings ranges from 15 to 33 years. The wards are either open wards with natural and mechanical ventilation or closed wards with the air-conditioning system. The hospital building is a non-smoking area with some signage in place. Out of the 11 selected wards, four wards

Table 1. Overall indoor environmental quality parameters of 11 wards in medical school

Parameters	Standard[a]	Mean (± SD)		p-value[b]
		Nurse station	Centre	
Temperature (°C)	23.0-26.0	**26.53 ± 1.808**	**26.40 ± 1.688**	0.611
Relative humidity (%)	40.0-70.0	**79.43 ± 7.334**	**79.57 ± 7.058**	0.896
Illumination (lux)	300[d]	**126.84 ± 61.962**	**146.81 ± 66.001**	0.040
Carbon dioxide (ppm)	1000[c]	637.15 ± 253.321	656.66 ± 245.15	0.604
Carbon monoxide (ppm)	10	0.99 ± 0.519	1.01 ± 0.565	0.814
PM_{10} (mg/m^3)	0.15	0.04 ± 0.021	0.04 ± 0.019	0.394

[a]Standard stated in ICOP-IAQ by DOSH 2010, [b]independent t-test, [c]ceiling limit, [d]Ministry of Works standard

are high dependency or intensive care units. For the ventilation system, four wards used natural ventilation and fans as their mechanical ventilation system, whereas the remaining seven wards used air-handling unit.

3.2 *Indoor environmental quality*

Table 1 shows the mean of the assessed indoor environmental quality parameters in wards at two locations: nurse stations, and the centre. The overall results demonstrated the temperature, and relative humidity at both locations were above the standard limit stated in the Industry Code of Practice on Indoor Air Quality (ICOP-IAQ) by the Department of Safety and Health (DOSH) Malaysia 2010, that is, more than 26°C and 70.0% respectively. The illumination level in the wards overall was below the standards, namely less than 300 lux. The other IAQ parameters (CO_2, CO, and PM_{10}) were within the normal range. Comparing the two measured locations, the nurse station showed a significantly low light level compared to the centre even though both were below the standard. The other parameters were not significantly different.

The mean temperature for all wards ranged between 23.3°C and 28.5°C. Two wards with the highest temperature were Ward 1 and Ward 2 (28.5°C), which used fans as mechanical ventilation. The recorded lowest temperature was Ward 11 (23.3°C), which used air conditioning. The standard recommended reading for relative humidity is 40% - 70%. However, almost all of the wards exceeded the standard limit stated by DOSH (2010). The most violated parameter was illumination. All of the wards had illumination less than 300 lux. The highest level for illumination was 212.3 ± 67.78 lux, and the lowest was 93.3 ± 44.23 lux in Ward 10 and Ward 6 respectively. Carbon dioxide level was within the standard requirement. However, CO_2 level in Ward 3 and Ward 6 were approaching the ceiling limit, 920.4 ± 48.32 and 911.5 ± 48.83 ppm respectively. The mean CO and PM10 level in all wards were far below the ceiling limit set by the standard, as illustrated in Table 2.

Table 2. Details indoor environmental quality parameters and type of ventilation for each ward in medical school

Wards	Mean (± SD)						Buidling ventilation
	Temp (OC)	RH (%)	Illumination (lux)	CO_2 (ppm)	CO (ppm)	PM_{10} (mg/ m^3)	
Ward 1	**28.5 ± 0.39**	**82.9 ± 1.97**	**103.1 ± 21.56**	463.5 ± 17.49	0.8 ± 0.26	0.06 ± 0.015	MV
Ward 2	**28.5 ± 1.06**	**75.6 ± 3.34**	**188.6 ± 61.47**	768.8 ± 57.26	0.6 ± 0.28	0.04 ± 0.015	MV
Ward 3	**27.5 ± 0.96**	**84.3 ± 9.07**	**107.5 ± 69.46**	**920.4 ± 48.32**	1.6 ± 0.56	0.05 ± 0.009	ACS & MV
Ward 4	**27.3 ± 0.71**	**87.2 ± 3.14**	**155.7 ± 60.63**	892.4 ± 43.29	0.9 ± 0.45	0.06 ± 0.137	MV
Ward 5	**26.9 ± 1.23**	**76.1 ± 2.49**	**125.4 ± 61.54**	319.7 ± 45.36	1.7 ± 0.47	0.01 ± 0.066	ACS
Ward 6	**26.6 ± 0.33**	**89.6 ± 2.40**	**93.3 ± 44.23**	**911.5 ± 48.83**	1.4 ± 0.40	0.05 ± 0.014	MV
Ward 7	**26.3 ± 0.53**	**79.9 ± 5.70**	**130.6 ± 57.36**	867.5 ± 75.60	0.8 ± 0.23	0.04 ± 0.208	MV
Ward 8	25.9 ± 1.19	67.5 ± 2.07	**103.0 ± 9.94**	649.9 ± 253.70	0.5 ± 0.21	0.04 ± 0.010	ACS & MV
Ward 9	25.4 ± 1.43	**75.2 ± 3.02**	**178.8 ± 32.32**	351.8 ± 74.53	1.2 ± 0.41	0.01 ± 0.083	ACS
Ward 10	24.9 ± 0.98	**77.5 ± 2.31**	**212.3 ± 67.78**	532.9 ± 133.07	0.5 ± 0.19	0.04 ± 0.008	ACS
Ward 11	23.3 ± 0.85	**78.9 ± 4.13**	**106.7 ± 51.78**	437.5 ± 113.85	0.9 ± 0.30	0.02 ± 0.007	ACS

Temp = Temperature; RH = relative humidity; ACS = air-conditioning systems;
MV= mechanical ventilation

Table 3 shows the total bacteria counts (TBC) and total fungal counts (TFC) for each ward. Based on the standard stated by DOSH (2010), the TBC and TFC should not exceed 500 cfu/m3 and 1000 cfu/m3 respectively. Two (Ward 3 and Ward 5) out of the 11 Wards (18.2%) were found to have borderline TBC, 500 cfu/m3. The other wards were below the TBC standard. The TFC in all wards were far below the standard limit.

Table 3. Bacteria counts and fungal counts of 11 wards in medical school

Wards	Total Bacteria Counts (cfu/m^3)	Total Fungal Counts (cfu/m^3)
Ward 1	352	26
Ward 2	219	53
Ward 3	500	23
Ward 4	300	33
Ward 5	500	23
Ward 6	426	34
Ward 7	272	31
Ward 8	286	17
Ward 9	214	16
Ward 10	489	15
Ward 11	160	36

[a]Standard stated in ICOP-IAQ by DOSH 2010 for total bacteria counts is 500 cfu/m^3 and total fungal counts is 1000 cfu/m^3

4. Discussion

The setting and design of modern hospital wards are driven by several functions including to reduce the risk of cross-transmission of infections, to maintain the thermal comfort of occupants, to warrant patient privacy and dignity, to facilitate nursing staff to easily monitor patients and to ensure energy efficiency (Gilkeson et al., 2013). The setting should consider the safety aspect to reduce the risk of infection transmission. Although many nosocomial infections are associated with the person-to-person contact, there is increasing evidence that some nosocomial infections are transmitted via the airborne route particularly Mycobacterium tuberculosis and aspergillosis, nosocomial outbreaks of MRSA, *Acinetobacter* spp. and *Pseudomonas* spp. (Beggs, 2003).

4.1 Physical measurements

Temperature and relative humidity are important factors in aerosol survival particularly in a hospital setting. The survival of bio-aerosol pathogens varies in different temperatures and relative humidifies. For example, viral survival is better at a lower temperature; influenza virus survives better in low relative humidity; polio viruses show the greatest survival at high relative humidity (Cole and Cook, 1998). Indoor air temperature and humidity also have a significant direct impact on the perception of IAQ among their occupants (Fang *et al.*, 2000) because both elements are closely related to thermal comfort. According to Fang *et al.* (2000), the inhaled air should be below the mucosal temperature, which is normally at a level of 30°C to 32°C for human comfort. He reported that the indoor environment with a temperature above 32°C and relative humidity above 60% is considered as a hot and humid environment. The body physiology of those who work in hot and humid environments will obviously change such as heart rate, body temperature, blood pressure and sweat production (Lu and Zhu, 2007).

The acceptable limit for relative humidity is 40% - 70% (DOSH, 2010). Cole and Cook (1998) documented that the relative humidity of 80% was the favourable environment for the survival of the aerosolised virus. The health consequences of exposure to a low humidity environment include dryness of the eyes, nose and throat, and increase in the number of the static electricity shocks. Meanwhile, a relative humidity of more than 80% is associated with fatigue and stuffy bad air (DOSH, 2006; Nordström *et al.,* 1994). According to ASHRAE, when 20% or more of its occupants voluntarily complain of discomfort symptoms for periods exceeding two weeks and the symptoms are a rapid relief when away from the building, then the building is classified as sick. The complaint symptoms are known as SBS (Passarelli, 2009). The SBS, particularly a sensation of dryness, headache, fatigue symptoms, is associated with the air humidity and temperature because it affects the moisture loss from the skin and mucous membranes (Fang *et al.,* 2000).

This study found the overall mean indoor environmental temperature was 26.5 and 26.4 at the nurse station and centre of the ward respectively. For each ward, seven out of 11 wards had recorded temperature higher than the standard, more than 26.0°C. The mean relative humidity was above the standards in both measured sites where 10 out of 11 wards showed the relative humidity, not in the acceptable range. Most wards with unacceptable higher indoor temperature used mechanical ventilations. The indoor temperature that used mechanical ventilation was affected by outdoor temperature, as supported by Ismail *et al.* (2010) especially in Malaysia, which is located in the tropical region with a hot and humid climate. However, two wards that used air-conditioning system showed higher temperature. The possible reason would the operating air-conditioning system are poor, not a thight space, or due to space crowding.

In a study carried out by Wong and Huang (2004), in buildings that used natural ventilation, the reported indoor temperatures ranged from 29 ºC to 30 ºC and for air-conditioning areas, the temperatures ranged from 23 ºC to 27 ºC. Even though the indoor temperature was better in the air-conditioning areas, the reported health related symptoms was higher. According to Seppänen and Fisk (2002), the prevalence of SBS increased between 30% and 200% in buildings with air-conditioning systems compared to buildings with natural ventilation systems. A study to measure the risk of airborne infections in wards with natural ventilation found an open ward layout had well air mixing and dilution and thus reduced the airborne contaminants (Gilkeson *et al.,* 2013). The same study and another past study (Hobday and Dancer, 2013) supported that natural ventilation offers protection from transmission of airborne pathogens.

Government offices including treatment rooms should maintain the luminance level at 300 lux (DOSH, 2010). Good illumination is important to ease tasks and help work performed accurately and comfortably. Illumination for a human is necessary for visual function in order to increase the sharpness of vision, visual comfort and neuroendocrine regulation, and enhance a feeling of well-being. Based on the literature review of the effects of natural light on building occupants, they concluded that there is an important association between good illumination in the building with higher productivity, lower absenteeism, fewer errors or defects in products, positive attitudes, reduced fatigue, and reduced eyestrain among occupants (Edwards and Torcellini, 2002).

The current study found the illumination level was too low at all measured locations with the mean level of 126.84 lux and 146.81 lux for nurse station and centre respectively. The low light in the hospital buildings could have an effect on the health care staff and could influence patients' healing process (Edwards and Torcellini, 2002). In line with that, Alimoglu and Donmez (2005) reported a lack of daylight was related to poor job performance and medication errors by nurses. The possible ways to improve illumination are by adding more light sources, using higher performance illumination lamps such as light emitting diodes (LED) based lamp (Aman et al., 2013).

Natural light should be used whenever possible because it does not cause overheating of the space or too much glare. Natural light especially sunlight during daytime was thought to be able to discourage the survival and spread of infectious agents, has better consequential health benefits for occupants, and reduce energy consumption (Passarelli, 2009). In line with that, effective window design is recommended and should be well distributed throughout the workspace (Public Works Department, 2013). Edwards and Torcellini (2002) stressed the importance of regulations on windows in hospitals that specify the window area to be included in patient rooms with a bed and rooms where patients stay for more than 23 hours.

4.2 Chemical parameters

A key parameter in assessing indoor air quality and efficiency of the ventilation system is CO_2 level (Godish, 2000). The level of indoor CO_2 also indicates the acceptability of space and occupancy pattern (Persily, 1997). According to Erdmann and Apte (2004), CO_2 is an approximate surrogate for occupant-generated indoor air pollutant. Evidence from past studies reported the commonest respiratory symptoms associated with indoor CO_2 pollution were dry eyes, sore throat, nose/sinus, sneeze, and wheeze symptoms, and these symptoms are dose-dependence (Erdmann and Apte, 2004). In fact, exposure to low-to-moderate CO_2 concentrations was reported to have direct effects on decision-making performance. Satish *et al.* (2012) conducted a study to determine the effect of CO_2 at 600, 1,000, and 2,500 ppm in an office-like chamber. They found moderate and statistically significant decrements in decision-making performance in those exposed to 1,000 ppm CO_2, and large and statistically significant reductions occurred at 2,500 ppm CO_2 exposure relative to 600 ppm.

The current study shows all the selected wards were within the acceptable standard limit for CO_2. However, five wards were found to have the CO_2 concentration of more than 600 ppm, and two of them were more than 900 ppm. The ceiling limit for CO_2 is 1000 ppm (DOSH, 2010). Some studies (Ooi *et al.,* 1998; Syazwan Aizat *et al.,* 2009) have underlined the concentration level of CO_2 above 650 ppm has a potential to influence the risk of SBS. As highlighted before, there is a close association between indoor CO_2 level and ventilation (Godish and Spengler, 1996; Persily, 1997). Therefore, the responsible management should carry out close monitoring on the ventilation system used in this setting particularly its maintenance, cleaning procedures and inspection duration. The beneficial effects of natural ventilation may need to be considered.

For the CO and PM_{10}, this study found all wards were within the acceptable limit. The highest CO concentration was 1.7 ppm and for PM_{10} was 0.06 mg/m^3. These results were almost similar to findings observed by Ooi *et al.* (1998) in which the level of CO in indoor air of 56 randomly selected public and private sector buildings ranged from 0.1 to 5 mg/m^3. Even though there is consistent evidence that indoor CO pollution increases the risk of chronic obstructive pulmonary diseases, acute respiratory infections particularly in childhood, unconsciousness and death after acute or chronic exposure to higher concentrations (Raub et al., 2000), thus far there have been very few studies that show CO pollution in offices or hospital buildings. High level of CO commonly occurs in homes which mainly use fuel combustion and biomass as their sources (United States Environmental Protection Agency, 2017). One study on indoor air pollution in developing countries found homes that used biomass fuels had a higher concentration of CO, ranging between 2–50 ppm and during cooking the values reached as high as 10–500 ppm (Bruce et al., 2000). Another past study reported CO exposure occurred during the weekend, not on weekdays because people may be likely to engage in more leisure time such as using motorized equipment for home improvement or engine repair (Sircar et al., 2015).

PM_{10}, due to its smaller size, is a respirable particulate matter and can be inhaled deeply into lungs. The main source of particulate is from automobile dust, agricultural activities, fires or fuel combustion (United States Environmental Protection Agency, 2017). Low level of PM_{10} and CO found in the current study indicates good indoor air and is also a reflection of good outdoor air quality since the location of this hospital is far from pollution sources.

4.3 Biological parameters

The present study found the TBC in all wards were within the acceptable range. However, two wards showed borderline level, 500 CFU/m^3. The Malaysian Industrial Code of Practice states that an excess of bacterial counts which is more than the standard limit does not necessarily imply health risk but, it serves as an indicator for further investigation (DOSH, 2010). Morey (as cited in Daisey *et al.,* 2003) warranted for further investigation when the indoor microbial contamination, TBC, above 1000 CFU/m^3.

Based on the sources of microbial indoor contamination, Tang *et al.* (2006) claimed the common hospital source is from a patient with flu-like symptoms such as coughing and sneezing. Sneezing can produce as many as 40,000 droplets, and it can be expelled at a velocity of 100 m/s to be able to reach distances of several meters. Furthermore, the released droplet size can change with time, depending on the environmental condition. In a high humidity environment like in this hospital setting, the droplets tend to evaporate slowly, take a longer time to reduce its size, and faster time to fall on the ground. The ventilation system and temperature may further alter the dispersion of the droplet nuclei. The indoor environment with high temperature as found in this study will speed up the evaporation of the droplets (Tang *et al.,* 2006). According to Mendell *et al.* (2003), two principal risk factors favour the growth of microorganisms in a setting provided with air conditioning were debris in ventilation air intake and poor drainage in air-conditioning drip pans.

There is scarcity in the literature regarding the bacteria identification from hospital indoor air sampling. Based on a study that was conducted in University Hospital of Turkey, the predominant isolated bacteria from indoor air of the hospital were coagulase-negative *Staphylococcus* (72.2%), *Micrococcus* (10.7%), and *Corynebacterium* sp. (8.8%) %) (Sarıca *et al.,* 2002). Future study is suggested to include the ventilation rate, occupancy density, and identification of bacteria in order to identify the favouring factors and help to determine the source.

All the selected wards were found to have a low concentration of indoor fungal contamination in which the highest TFC reading was 36 CFU/m^3. Contrary to our results, Sautour, Sixt Sautour *et al.* (2009) reported much lower level of TFC detected from indoor adult and pediatric haematology units, between 4.1 and 3.9 CFU/m^3. They found the most frequent isolated indoor hospital fungal were *Penicillium* sp. (23 to 25%), and *Aspergillus* sp. (15 to 23%). It is believed that fungi will actively grow in the ventilation system and may contaminate indoor environments, and release volatile substances with unpleasant smell leading to psychological responses in the occupants such as fatigue and nausea (Portnoy *et al.,* 2004). In fact, the more life-threatening effect of aerosolisation of fungal spores leads to invasive infection in immune compromised patients, particularly bone or organ transplant patients, patients with leukaemia, lymphoma, and other malignancies. The potential reservoir or sources of fungal in a hospital setting are from water distribution systems (Anaissie *et al.,* 2003), construction work (Sautour *et al.,* 2007), dust from duct cleaning and renovation, and sites of water damage and moisture condensation (Curtis *et al.*, 2005). Curtis *et al.* (2005) recommended hospital management to control the indoor moisture, use high-efficiency particulate air (HEPA) filters, seal positive-pressure rooms, and conduct regular indoor air monitoring in controlling the fungal contamination.

This study is subjected to a few limitations. During the sampling of bio-aerosol samples, some portion of microorganism may be damaged or fatal. Few factors may contribute to the microorganism injury including impaction onto culture media, sampler wall losses, turbulence in impingement fluid, or desiccation on filter media (Cole and Cook, 1998), as well as the uncertainty regarding the viability of bio-aerosol pathogens on the culture media. Beggs (2003) raised a concern that many microorganisms remain viable in the aerosolised state even though they are non-culturable, resulting in an underestimate of the actual count. Future research should consider to assess the ventilation rate at study settings as being reported to have significant association with air quality outcomes (Seppänen and Mendell, 1999).

5. Conclusion

The current result demonstrates that this hospital setting had good air quality and excellent control and maintenance of environmental health. However, specific physical parameters particularly temperature, humidity and light may need to be controlled and managed by the employer with adequate management plans. Special attention on the hospital indoor environment is crucial as it is a place for treating diseased people, and to maintain the health of their workers and visitors. This study highlights the need for regular environmental surveillance for IAQ and airborne contamination to help prevent outbreaks of nosocomial infection.

Acknowledgements

This research was ethically approved from the Research and Ethics Committee, School of Medical Sciences, Universiti Sains Malaysia (USMKK/PPP/JEPeM [238.4.(1.6)]) and was supported by the Universiti Sains Malaysia Short term Grant.

References

Alimoglu MK, Donmez L. Daylight exposure and the other predictors of burnout among nurses in a University Hospital. International journal of nursing studies 2005; 42(5): 549-55.

Aman M, Jasmon G, Mokhlis H, Bakar A. Analysis of the performance of domestic lighting lamps. Energy Policy 2003; 52: 482-500.

Anaissie EJ, Stratton SL, Dignani MC, Lee C-k, Summerbell RC, Rex JH, Monson TP, Walsh TJ. Pathogenic molds (including Aspergillus species) in hospital water distribution systems: a 3-year prospective study and clinical implications for patients with hematologic malignancies. Blood 2003; 101(7): 2542-46.

Beggs C. The airborne transmission of infection in hospital buildings: fact or fiction? Indoor and Built Environment 2003; 12(1-2): 9-18.

Cole EC, Cook CE. Characterization of infectious aerosols in health care facilities: An aid to effective engineering controls and preventive strategies. American Journal of Infection Contro 1998; 26(4): 453-64. doi: http://dx.doi.org/10.1016/S0196-6553(98)70046-X

Curtis L, Cali S, Conroy L, Baker K, Ou C-H, Hershow R, Norlock-Cruz F, Scheff P. Aspergillus surveillance project at a large tertiary-care hospital. Journal of Hospital Infection 2005; 59(3) ; 188-96.

Daisey JM, Angell WJ, Apte MG. Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information. Indoor air 2003; 13(1): 53-64.

Dennekamp M, Howarth S, Dick C, Cherrie J, Donaldson K, Seaton A. Ultrafine particles and nitrogen oxides generated by gas and electric cooking. Occupational and Environmental Medicine 2001; 58(8): 511-16.

Dorgan E. coli, Dorgan BC. "Assessment of link between productivity and indoor air quality", in Clements-Croome, D. (Ed.), Creating the Productive Workplace, 2nd ed. E and FN Spon., London, 2006; 113-35.

DOSH (Department of Occupational Safety and Health). Ministry of Human Resources Malaysia Code of Practice on Indoor Air Quality 2006.

DOSH (Department of Occupational Safety and Health). Ministry of Human Resources Malaysia Code of Practice on Indoor Air Quality 2010.

Edwards L, Torcellini P. Literature Review of the Effects of Natural Light on Building Occupants, National Renewable Energy Lab., Golden, CO.(US) 2002.

Erdmann CA, Apte MG. Mucous membrane and lower respiratory building related symptoms in relation to indoor carbon dioxide concentrations in the 100-building BASE dataset. Indoor Air 2004;14(s8): 127-34.

Fang L, Clausen G, Fanger PO. Temperature and humidity: Important factors for perception of air quality and for ventilation requirements/ Discussion. ASHRAE transactions, 2000; 106: 503.

Gesler W, Bell M, Curtis S, Hubbard P, Francis S. Therapy by design: evaluating the UK hospital building program. Health & place 2004; 10(2): 117-28.

Gilkeson C, Camargo-Valero M, Pickin L, Noakes C. Measurement of ventilation and airborne infection risk in large naturally ventilated hospital wards. Building and environment 2013; 65: 35-48.

Godish T, Spengler JD. Relationships between ventilation and indoor air quality: a review. Indoor Air 1996; 6(2): 135-45.

Hobday R, Dancer S. Roles of sunlight and natural ventilation for controlling infection: historical and current perspectives. Journal of Hospital Infection 2013; 84(4): 271-82.

Ismail M, Sofian NZM, Abdullah A. Indoor air quality in selected samples of primary schools in Kuala Terengganu, Malaysia. Environment Asia 2010; 3(103): e108.

Leung M, Chan AH. Control and management of hospital indoor air quality. Medical science monitor 2006; 12(3): SR17-23.

Lu S, Zhu N. Experimental research on physiological index at the heat tolerance limits in China. Building and Environment 2007; 42(12): 4016-21.

Mendell MJ, Naco GM, Wilcox TG, Sieber WK. Environmental risk factors and work-related lower respiratory symptoms in 80 office buildings: An exploratory analysis of NIOSH data. American Journal of Industrial Medicine 2003; 43(6): 630-41.

Nordström K, Norbäck D, Akselsson R. Effect of air humidification on the sick building syndrome and perceived indoor air quality in hospitals: a four month longitudinal study. Occupational and environmental medicine 1994; 51(10): 683-88.

Ooi P, Goh K, Phoon M, Foo S, Yap H. Epidemiology of sick building syndrome and its associated risk factors in Singapore. Occupational and environmental medicine 1998; 55(3): 188-93.

Passarelli GR. Sick building syndrome: An overview to raise awareness. Journal of Building Appraisal 2009; 5(1): 55-66.

Persily AK. Evaluating building IAQ and ventilation with indoor carbon dioxide. Transactions-American society of heating refrigerating and air conditioning engineers 1997; 103: 193-204.

Portnoy JM, Barnes CS, Kennedy K. Sampling for indoor fungi. Journal of Allergy and Clinical Immunology 2004; 113(2): 189-98.

Public Works Department. Ministry of Works Malaysia. Guidelines On Indoor Environmental Quality For Government Office Building 2013.

Raub JA, Mathieu-Nolf M, Hampson NB, Thom SR. Carbon monoxide poisoning - a public health perspective. Toxicology 2000; 145(1): 1-14.

Rollins JA. Evidence-based hospital design improves health care outcomes for patients, families, and staff. Pediatric nursing 2004; 30(4): 338.

Sarıca S, Asan A, Otkun MT, Ture M. Monitoring indoor airborne fungi and bacteria in the different areas of Trakya University Hospital, Edirne, Turkey. Indoor and built Environment 2002; 11(5): 285-92.

Satish U, Mendell MJ, Shekhar K, Hotchi T, Sullivan D, Streufert S, Fisk W J. Is CO_2 an indoor pollutant? Direct effects of low-to-moderate CO_2 concentrations on human decision-making performance. Environmental health perspectives 2012; 120(12): 1671.

Sautour M, Sixt N, Dalle F, L'Ollivier C, Calinon C, Fourquenet V, Thibaut C, Jury H, Lafon I, Aho S. Prospective survey of indoor fungal contamination in hospital during a period of building construction. Journal of Hospital infection 2007; 67(4) ; 367-73.

Sautour M, Sixt N, Dalle F, L'Ollivier C, Fourquenet V, Calinon C, Paul K, Valvin S, Maurel A, Aho S. Profiles and seasonal distribution of airborne fungi in indoor and outdoor environments at a French hospital. Science of the total environment 2009; 407(12): 3766-71.

Seppänen OA, Fisk WJ, Mendell MJ. Association of ventilation rates and CO_2 concentrations with health andother responses in commercial and institutional buildings. Indoor air 1999; 9(4): 226-252.

Seppänen OA, Fisk WJ. Association of ventilation system type with SBS symptoms in office workers. Indoor Air 2002; 12(2): 98-112.

Syazwan Aizat I, Juliana J, Norhafizalina O, Azman Z, Kamaruzaman J. Indoor air quality and sick building syndrome in Malaysian buildings. Glob J Health Sci 2009; 1(2): 126-36.

Tang J, Li Y, Eames I, Chan P, Ridgway G. Factors involved in the aerosol transmission of infection and control of ventilation in healthcare premises. Journal of Hospital Infection 2006; 64(2): 100-14.

Godish T. Ventilation In, Indoor Environmental Quality. Lewis Publishers, Washington, DC. 2000; 333.

Ulrich RS, Zimring C, Zhu X, DuBose J, Seo H-B, Choi Y-S, Quan X, Joseph A. A review of the research literature on evidence-based healthcare design. HERD: Health Environments Research & Design Journal 2008; 1(3): 61-125.

United States Environmental Protection Agency. Air Emissions Inventories: Air Emissions Sources 2017. Retrieved from:https://www.epa.gov/air-emissions-inventories/air-emissions-sources [Accessed August 9, 2017].

Whitehouse S, Varni JW, Seid M, Cooper-Marcus C, Ensberg MJ, Jacobs JR, Mehlenbeck RS. Evaluating a children's hospital garden environment: Utilization and consumer satisfaction. Journal of environmental psychology 2001; 21(3): 301-14.

Wong NH, Huang B. Comparative study of the indoor air quality of naturally ventilated and air-conditioned bedrooms of residential buildings in Singapore. Building and Environment 2004; 39(9): 1115-23.

Wood RA, Burchett MD, Alquezar R, Orwell RL, Tarran J, Torpy F. The potted-plant microcosm substantially reduces indoor air VOC pollution: I. Office field-study. Water, Air, & Soil Pollution 2006; 175(1): 163-80.

Zaini Ujang. Pengenalan Pencemaran Udara. Dewan Bahasa dan Pustaka, Kuala Lumpur, Malaysia. 2000.