

ASSESSMENT OF INDOOR AIR QUALITY LEVEL AND SICK BUILDING SYNDROME ACCORDING TO THE AGES OF BUILDING IN UNIVERSITI TEKNOLOGI MALAYSIA

Article history

Received
22 January 2015
Received in revised form
5 April 2015
Accepted
1 August 2015

Norhidayah Ahmad, Mimi H. Hassim*

*Corresponding author
mimi@cheme.edu.my

Institute of Hydrogen Economy, Department of Chemical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

Abstract

This study was conducted to assess the indoor air quality (IAQ) level of buildings in Universiti Teknologi Malaysia (UTM). The buildings were randomly selected and represent the old building (>10years) and new building (<10 years). The IAQ physical parameters assessed are temperature, relative humidity and air velocity. Meanwhile, the IAQ chemical contaminants studied are carbon dioxide (CO₂), carbon monoxide (CO), formaldehyde (HCHO) and total volatile organic compound (TVOC). The results indicate that the old building has good IAQ level compared to the new buildings. The statistical test shows, there is an association between some IAQ physical parameters and the buildings' ages ($p < 0.05$). On the chemical contaminants, the measurement shows that the concentration of CO₂ and HCHO for all studied buildings exceeds the Malaysian acceptable exposure limits. The results also show there is no association between demographic factors and sick building syndrome (SBS) symptoms. The level of workplace condition and SBS symptoms existed in each selected faculty's buildings was also analyzed. The recommendations for the minimum number of years for maintenance of the indoor conditions have also been suggested based on the indoor air quality guidelines from Malaysia and Singapore. Finally, the appropriate technical and management approach has been suggested based on the some concepts.

Keywords: Indoor air quality, new building, old building, sick building syndrome, workplace assessment

Abstrak

Kajian ini telah dijalankan untuk menilai tahap kualiti udara dalaman bangunan-bangunan di Universiti Teknologi Malaysia (UTM). Bangunan-bangunan ini dipilih secara rawak dan mewakili bangunan lama (> 10 tahun) dan bangunan baru (< 10 tahun). Parameter fizikal kualiti udara dalaman yang dinilai adalah suhu, kelembapan relatif dan kelajuan udara. Manakala, pencemar kimia kualiti udara dalaman adalah karbon dioksida (CO₂), karbon monoksida (CO), fomaldehid (HCHO) dan jumlah kompaun organik meruap (TVOC). Keputusan menunjukkan bangunan lama mempunyai kualiti udara dalaman yang lebih baik berbanding bangunan baru. Ujian statistik menunjukkan terdapat perkaitan antara parameter yang diukur seperti suhu, kelembapan relatif, CO₂ dan HCHO terhadap umur bangunan ($p < 0.05$). Bagi pencemar kimia, bacaan menunjukkan kepekatan CO₂ dan HCHO bagi semua bangunan yang dikaji adalah melebihi had pendedahan yang boleh diterima di Malaysia. Keputusan juga menunjukkan tiada perkaitan antara faktor demografik dan simptom-simptom sindrom bangunan sakit (SBS). Tahap keadaan tempat kerja dan juga simptom SBS yang hadir di bangunan fakulti juga telah dianalisis. Penambahbaikan untuk tempoh minimum penyelenggaraan juga telah dicadangkan berdasarkan garis panduan kualiti udara dalaman daripada Malaysia dan Singapura. Akhir sekali, pendekatan teknikal dan pengurusan yang sesuai juga dicadangkan berdasarkan beberapa konsep.

Kata kunci: Kualiti udara dalaman, bangunan baru, bangunan lama, sindrom bangunan sakit, penilaian tempat kerja

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1.0 INTRODUCTION

Recently, the occupational hazards associated with indoor air quality (IAQ) in workplace are being discussed constantly and have caught attentions of the public and researchers. The growing attention on this issue is due to the increasing number of cases reported on health problems involving workers in indoor facilities since most of them are spending 90% of their works time in indoors environment (Jones, 1999; Lee and Chang, 2000). The IAQ within the age of building of schools or higher institutions has become the main public concerns today. Being exposed to various contaminants in an environment with poor IAQ may contribute to the possibility of getting short and long-term health problems. These problems are not only concerned to the students, but also to the academic and non-academic staffs since most of them are working in the enclosed environment throughout their working hours (8h). Moreover, the United State Environmental Protection Agency (US-EPA) had revealed that lung is the common target organ of injury due to indoor pollutants (US-EPA, 2013). Other than that, poor IAQ level in schools or other learning centers will decrease the productivity and effectiveness of learning session and learning environment (Shaughnessy et al., 2006). According to Abdel Hameed (2000), the age of building is one of the factors that influence the air quality in a building. Therefore the assessment of IAQ level according to the age of building in schools or higher institutions is crucial in understanding the conditions of IAQ in a building. Subsequently an appropriate counter measures can be taken to improve the indoor conditions as well as improvements in quality of life.

In Malaysia, studies on IAQ in schools or universities are still lacking and are not considered as top priority compared to others developed countries such as Hong Kong, Japan, United States and United Kingdom. Based on the study conducted by University of Minnesota in United States, IAQ in school buildings may affect the health of the students and it is directly affecting their learning performance (Daisey et al., 2003). Statistically, students are approximately spending 30% of their daytime in schools and it may be regarded as particularly vulnerable to potential health

hazard if they are exposed to poor IAQ everyday (Fromme et al., 2007). Similar study in Korea shows that poor IAQ can increase the risk of health problem among students and it may increase the potential of sick school syndrome (Lee and Chang, 2000). Sneezing, coughing, minor eye and skin irritation are among the symptoms due to exposure of poor IAQ (Saraga et al., 2011). One of the studies conducted in Malaysia shows the age of building in Universiti Putra Malaysia (UPM) is a pivotal role in contributing to the sick-building syndrome (SBS) symptoms among the building tenants (Rosli and Jalaluddin, 2012). This has somehow become the motivation to pursue with the study presented in this paper. Also, there is a critical need to conduct such study for Universiti Teknologi Malaysia (UTM). The study is challenging since UTM Skudai campus has been around since 1985 and there are continuous constructions of new buildings from time to time within the campus area, yet the earlier aged buildings are not maintained especially from the IAQ aspect.

2.0 METHODOLOGY

2.1 Study Background

This study involves experimental based work - that is to measure the indoor air quality (IAQ) parameters in selected buildings in Universiti Teknologi Malaysia (UTM) according to the age of the building. The study started with the selection of buildings based on the year it was constructed. There are six faculty buildings selected for this study, which can be categorized as new building and old building as presented in Table 1. The 'old building' refers to the building that was constructed more than 10 years whereas for the 'new building', it must not exceed 10 years. This criteria of building selection is adapted from the study by Jalaludin et al., (2014). There were two area sampling locations for each building – one in general office and another one in tutorial/lecture room. The selection of the sampling locations was made based on the Industry Code of Practice on Indoor Air Quality (ICOP- IAQ) 2010 guideline published by the Department of Occupational Safety and Health (DOSH) Malaysia.

Table 1 Selected faculty buildings

Category	Building	Year of Construction
Old	Faculty of Chemical Engineering (FKK)	1995
	Faculty of Civil Engineering (FKA)	1989
	Faculty of Petroleum and Renewable Energy Engineering (FPREE)	1995
New	Faculty of Islamic Civilization (FTI)	2011
	Faculty of Geoinformation and Real Estate (FGHT)	2011
	Faculty of Management (FM)	2010

(Source: Universiti Teknologi Malaysia, 2013)

2.2 IAQ Sampling Devices

The IAQ level was determined based on the measured level of IAQ physical parameter (temperature, relative humidity, air velocity) and the concentration of IAQ chemical contaminants (CO₂, CO, HCHO, TVOC). All physical parameters as well as the concentration of the chemical contaminants were measured using the direct-reading instruments. For example, the formaldehyde thermo-hygrometer was used to measure the level of temperature, relative humidity and concentration of HCHO. The hot-wire anemometer (Model TES-1341) was used to measure air velocity in the studied buildings. The IAQ meter (Model 1010a) was used to measure the concentration of CO and CO₂ in the same facilities besides its capability of measuring the temperature and humidity in indoor environment. Lastly, the portable VOC Monitor (Model MiniRAE 2000) was used to measure the level of TVOC.

2.3 IAQ and SBS Assessment

The study on the association between the IAQ and sick building syndrome (SBS) symptoms was also performed in this study by using the IAQ questionnaires adopted from the ICOP- IAQ 2010 guideline published by DOSH (2010). The study basically aims to find the association between demographic factors and SBS symptoms present among the building tenants. In order to strengthen this study, the level of workplace condition and SBS symptoms present in each selected faculty's buildings was also obtained in this assessment. The total numbers of respondents involved in this assessment were 53 and all selected participants are the administration office staffs only. This selection is justified by the fact that majority of the administration office staffs are working in the same workplace environment for 8-h working days. The selected participants in this study have different job scope and job environment compared to lecturers or students. Lecturers or students have higher tendency to be more frequently mobile from one area to another, hence makes it more difficult to get a consistent sampling environment for the participants.

3.0 RESULTS AND DISCUSSIONS

3.1 IAQ Level of Selected Building in UTM

In assessing the IAQ level of each selected building in this study, two main criteria need to be taken into account, which were measurement of IAQ physical parameters and IAQ chemical contaminants. Table 2 represents the level of IAQ parameters and IAQ contaminants of selected building in UTM.

3.1.1 IAQ Physical Parameter

a) Temperature

The FGHT (new building) was recorded with the highest temperature level compared to other faculties' buildings. The comparison of level of temperature was also been done to compare the level of temperature for all the faculties. The results show that the FM had lower level of temperature compare than the others. It is due to the usage of the heating, ventilation and air conditioning (HVAC) system in a building and assisted by the usage of fan to circulate the air inside the building and hence will decrease the temperature level. As for other faculties' buildings, the trend is similar to FM except for FGHT building. So, by looking at the trend, the temperature level of a particular building can be controlled by using the HVAC system in complement with the usage of fan to circulate the air. Averagely, the temperature level is within a range of 26.0 to 28.5(°C). Basically all the temperature levels in the selected building were exceeding the ICOP-IAQ 2010 guideline that has been published by DOSH. For international standards such as ASHRAE and IDPH, the standard of temperature level is quite higher which is within a range of 23°C to 28°C.

b) Relative Humidity

The FPREE (old building) recorded the highest level of relative humidity (72.1%) compared to other buildings and it shows a slightly higher value when comparing it to local (DOSH) and international standards (ASHRAE and IDPH). According to Arundel *et al.*, (1986), the temperature is inversely proportional with relative humidity. By referring to the temperature level of FPREE building, the temperature of this building is relatively lower compared to other buildings. It is the main reason for the highest relative humidity level in this building.

c) Air Velocity

According to ICOP-IAQ (2010) guideline, the level of air velocity in an indoor environment must be in a range of 0.15m/s to 0.5m/s. However, this study shows that the level of air velocity for all selected buildings was not complying with the IAQ guideline. All buildings except FIC (new building), have lower air velocity compared to minimum limit of air velocity in the indoor environment (average: 0.032 m/s). FIC building has shown good level of air velocity, which is 0.25m/s in the sampling area within the general office but poor level of air velocity in tutorial-lecture room (0.02m/s).

3.1.2 IAQ Chemical Contaminants

There were four IAQ chemical contaminants measured in this study i.e. carbon dioxide (CO₂), carbon monoxide (CO), formaldehyde (HCHO) and total volatile organic compounds (TVOC). However, only CO₂ and HCHO can be detected in all six buildings under study. The other substances such as CO and

TVOC were recorded at 0ppm, indicating their absence in the indoor environment of all six buildings. In order to ensure the results are reliable, the measurements of IAQ chemical contaminants were taken three times per day for a total of three days.

a) Carbon Dioxide (CO₂)

The CO₂ level in all selected faculty buildings (old and new) exceeds the limit set forth by ICOP-IAQ 2010 and ASHRAE guideline. Based on both guidelines, the CO₂ level must not exceed 1000ppm in non-industrial workplace because high concentration of CO₂ will cause asphyxiation to the building tenants. However, by referring to other guidelines such as from US Occupational, Safety and Health Administration (OSHA) and American Conference of Governmental Industrial Hygiene (ACGIH), the CO₂ level in all selected buildings did not exceed the limit. These two guidelines have limited 5000ppm of CO₂ as a maximum level in eight-hour (8h) time weighted average. The result of CO₂ level in all selected building shows that, FIC (new building) recorded the highest level of CO₂ (2176.50ppm) compared to other buildings. According to Prill (2000), there are some external factors that can give influence to the CO₂ level in an enclosed building such as from the vehicle traffic area, industry area and as well as the sources of combustion. This finding from Prill (2000) reinforces the results that have been obtained in this study because the location of FIC (new building) is located near the highway. The factors of vehicle traffic may become a factor in increasing level of CO₂ in this building. Other than that, Sulaiman and Muhammad (2011) revealed the high concentration of CO₂ is due to the number of occupants in an enclosed building. As a matter of fact, the CO₂ is a by-product of human respiration. A high level of CO₂ shows that the building has lack of fresh air supply and at the same time it can be also linked to the HVAC system of the building. The lack of HVAC system maintenance may result in inadequate ventilation of the space. Thus, the CO₂ will accumulate in an enclosed building because CO₂ generated by the building's tenants cannot be diluted

and removed excellently hence increasing the level of CO₂ in that particular building.

b) Formaldehyde (HCHO)

The HCHO level for each building involved in this study exceeded the standard limit set up by the Malaysian DOSH and Illinois Department of Public Health (IDPH) (0.10ppm). However, the HCHO levels in the selected faculty buildings in this study were not exceeding the standard established by ASHRAE and OSHA (0.75ppm). Besides, ACGIH has also published a special standard regarding the HCHO level in an indoor environment, which is not more than 0.30ppm. Only two faculties, which are FKK (0.2492ppm) and FPREE (0.2233ppm), comply with the HCHO standard level that has been published by ACGIH. Both of these faculties' buildings were categorized as an old building, which have been constructed more than 10 years. According to Abdel Hameed (2000), the age of building is one of the factors that influence the HCHO level in a particular building instead of air temperature and relative humidity. Abdul Hameed's study revealed that the concentration of HCHO would decrease when the building age is increased. The negative correlation was found on these two variables. In other words, this statement strengthens the result that has been obtained in this study. Based on this study, FKK and FPREE (old building) show the lowest concentration level of HCHO compared to other buildings. However, FKA building, which is also an old building, recorded a high level of HCHO (0.4208) in the indoor environment. It might be due to other factors such as air temperature and relative humidity. By looking at the data, the temperature level of FKA building was also exceeding the standard, especially the temperature in a general office. Abdel Hameed (2000) described that there is a positive correlation between HCHO concentration and air temperature. Therefore, it might be a factor that contributes to the increasing level of HCHO in FKA building even though it is an old building.

Table 2 Level of IAQ parameters of selected building

IAQ Parameter	Malaysian Standard	Mean of IAQ contaminants					
		FKK	FKA	FPREE	FIC	FGHT	FM
Temperature (°C)	23-26	28.1	27.4	27.6	27.6	29.7	27.8
R. Humidity (%)	40-70	66.7	66.9	72.1	68.7	63.1	63.8
Air Velocity (m/s)	0.15-0.50	0.025	0.045	0.030	0.135	0.035	0.025
Carbon dioxide (ppm)	1000	1752.75	1908.33	1750.58	2176.50	1899.92	2078.75
Carbon monoxide (ppm)	10	0	0	0	0	0	0
Formaldehyde (ppm)	0.10	0.2492	0.4208	0.2233	0.3893	0.3918	0.3467
TVOC (ppm)	3	0	0	0	0	0	0

*Malaysian Standard refers to ICOP IAQ 2010 (DOSH)

3.2 Comparison of the IAQ Level for Old and New Buildings

The comparison of the IAQ level (IAQ physical parameters and IAQ chemical contaminants) for both building categories (old and new buildings) has been done in this study by calculating the mean of each IAQ level and the results are summarized in Table 3. Since the data of this study is normally distributed, the independent t-test has been carried out to compare

the level of IAQ physical parameters and IAQ chemical contaminants level in both old and new buildings. In this study, the independent t-test indicates that there is a significant difference between the temperature, relative humidity, CO₂ level and HCHO level in old buildings and new buildings ($p < 0.05$). This means that, the age of building does have influences on the IAQ level in an enclosed building.

Table 3 Comparison of the IAQ level in both building's category (old and new)

Variables	OB (n=36)	NB (n=36)	t statistics (df)	P
	Mean	Mean		
T(°C)	27.6611	28.3583	(-2.177) 70	0.033
RH (%)	68.5611	65.0806	(2.293) 70	0.025
AV (m/s)	0.0311	0.0619	(-1506) 70	0.136
CO ₂ (ppm)	1803.9	2051.7	(-3.626) 70	0.001
CO (ppm)	-	-	-	-
HCHO (ppm)	0.2978	0.3767	(-2.195) 70	0.031
TVOC (ppm)	-	-	-	-

* Significant at $P < 0.05$ (OB= Old Building, NB= New Building)

3.3 IAQ and SBS Assessment

As mentioned earlier, the IAQ and SBS assessment is intended to find out the workplace condition and SBS symptoms that present in each selected faculties' buildings. This assessment is initiated by finding the association between demographic factors and SBS symptoms among building tenants. Other than that, in order to support this study, the level of workplace condition and SBS symptoms have been analyzed by using the Bloom's cut-off point. This cut-off point has been used to group and code scores based on the level of workplace condition and SBS symptoms as retorted by the respondents.

3.3.1 Association of Demographic Factors and SBS Symptoms

In this study, the association of demographic data and SBS symptoms has also been determined by using the statistical test analysis (chi-square test). There are some demographic factors that have been queried in this study such as gender, age, marital status, job category and years of service. However, the statistical test shows that there is no association between all demographic data and the SBS symptoms present. Hence, all demographic data that were shown above were not affecting the level of IAQ and SBS symptoms for all the selected faculties' buildings in this study.

3.3.2 Workplace Condition Level

The result of workplace condition level is shown in Table 4. Based on the survey form, there are a few aspects that have been asked to indicate the workplace condition of building tenants. Among the aspects were dirtiness or unsanitary conditions, extreme temperature in the workplace, blocked vents, unpleasant odors, passive smokers, presence of dust and dirt, presence of hazardous chemical substances and the maintenance of air filters or HVAC system. Based on the result, it shows that majority which is 52.8% of the respondents categorized their workplace condition level as a high level of pollutants presence, 45.3% categorized as moderate level and only 1.9% categorized their workplace condition as low level. The percentage obtained in this study indicates that majority of the respondents (52.8%) highly experienced the workplace conditions that were asked in the IAQ and SBS symptoms survey form. Based on the responses given, the working conditions in the faculties' buildings can be categorized as "high level of pollutant presence". Based on these circumstances, the improvements and control measures of indoor air condition at all faculties' buildings in UTM are very crucial.

3.3.3 SBS Symptoms Level

The SBS symptoms level has also been measured in this study by adapting the same methodology as workplace condition level. Based on the study, the SBS symptoms that were asked in the IAQ and SBS symptoms surveys were headache, fatigue and lethargy, drowsiness, dizziness, nausea and vomiting, coughing, irritated and stuffy nose, hoarse and dry throat, eye irritation and as well as skin rashes and itchiness. Table 5 shows the SBS symptoms level that have been obtained in this study. Based on the results, 49.1% of the respondents have moderately experienced SBS symptoms while 47.2% of total respondents are in a high level. Only 3.8% have experienced low level of SBS symptoms, which

indicates that they never distracted by, or experienced the SBS symptoms. The largest percentage of responses (high and moderate level) received in this assessment indicates most of these respondents often felt disturbed or affected with the SBS symptoms in the workplace. The experiences of the SBS symptoms by respondents in the faculty's building are in line with the IAQ level that has been obtained in this study. Most of IAQ physical parameter and IAQ contaminants exceed the IAQ standard that has been set up by local and international authorities. Thus, it is not surprising if most of them were distracted by the SBS symptoms. The improvements and control measures of IAQ level and workplace condition in faculties' buildings in UTM need to be proposed and implemented as soon as possible.

Table 4 Distribution of workplace condition level

Level	Number (n=53)	Percentage (%)
High level (19-24 scores)	28	52.8
Moderate level (14-18 scores)	24	45.3
Low level (0-13 scores)	1	1.9

*N= 53

Table 5 Distribution of SBS symptoms level

Level	Number (n=53)	Percentage (%)
High level (24-30 scores)	25	47.2
Moderate level (18-23 scores)	26	49.1
Low level (0-17 scores)	2	3.8

*N= 53

3.4 Recommendation of the Maintenance in Indoor Environment

In order to maintain a good IAQ in an enclosed building, there are many aspects that need to be considered, especially the maintenance aspect. The maintenance in this context refers to the maintenance of the ventilation system (HVAC) in a building. The main purpose of this maintenance is to ensure the ventilation system will run as effectively as possible. As a matter of fact, the main function of ventilation system is to dilute or/and remove the contaminants from the work area. Therefore, if the ventilation system is not working properly, the IAQ contaminants in an indoor environment will not be diluted or/and removed from the work area. It will increase building tenants' exposure to hazardous work environment. According to "Malaysian ICOP-IAQ 2010" and "Singaporean Guidelines for good IAQ in office premises", the minimum period for maintenance of ventilation system must be suggested by the manufacturers of the system. However, the

government has proposed that the ventilation system should be inspected every six months to ensure and maintain good IAQ level in an enclosed building. Apart from emphasizing the minimum maintenance period, this maintenance must also be done when there are complaints or experiences of SBS symptoms among the building tenants. The management of each building needs to be addressed of these problems according to the proper procedure on a guideline and the control measures need to be implemented as soon as possible. To avoid any unexpected damage and excessive cost in operations, the inspection and maintenance procedure must be carried out by a competent person.

3.5 Control Measures to Reduce Exposure of Harmful Pollutants

There are many initiatives that can be implemented to reduce the exposure of excessive indoor air contaminants. Based on this study, there are two

suggested control measures that can be applied to reduce the harmful pollutants in a building environment, such as the adaptation of "hierarchy of control" concept and taking into account the suggestion from building's designer and owner.

3.5.1 Hierarchy of Control

The concept of "hierarchy of control" suggests a six-step prevention method where it can be adopted to control the exposure of harmful pollutants in indoor environment as low as reasonably practicable (ALARP) and as low as reasonably achievable (ALARA). This concept has been widely accepted around the world including by the Malaysian DOSH in the hazard identification, risk assessment and risk control (HIRARC) guideline in 2008. It consists of six elements of elimination, substitution, isolation, engineering control, administrative control and personal protective equipment (PPE). Among these elements, isolation seems the best approach to control the risk of exposure to harmful pollutants in the indoor environment. The isolation can be done by keeping away the building tenants from the source of hazards such as during the renovation works at their work building. For certain activities such as paint stripping, replacement of office equipment and furniture must be done after working hours to minimize the release of IAQ contaminants to the environment as well as to reduce the exposure of hazardous pollutants to the building tenants. The barriers and signal warnings should be provided near the renovated area to minimize the entrance of personnel to the area and to reduce the exposure to hazardous condition. Other than that, the building occupants are strictly prohibited to smoke inside the building area, especially in the university environment. The tobacco released from cigarette will contribute to the presence of thousands of indoor pollutants, which will worsen the IAQ level.

3.5.2 Building's Designer and Owner Perspectives

In order to achieve the ideal IAQ level in an enclosed building, the concept of "Cradle to the Grave" can be implemented. This concept refers to the consideration of building's designer and owner input in every stage of the building's lifecycle, starting from the design stage and progresses into the construction, operation and finally the maintenance phase. According to Levin (2014), there are some IAQ best practices that can be used by the building's designer and owner to create a good IAQ in a commercial building. Firstly, the building's designer and owner need to understand the relationship between exposure, dose and occupant susceptibility starting from the early stage (planning and strategies stage). During this stage, the selection of building materials, building fabrics, building equipment must strictly follow the IAQ's best guidelines practices. Realistically, there are no "non-toxic" building products or chemicals exist

in the market at the moment; the only option available is less toxic or less hazardous chemicals. But such products are already considered very well towards achieving a more sustainable and healthier indoor air environment compared to the previous conditions. Other than that, the building's designer and owner also need to understand the relationships between indoor air pollutants sources, ventilation and concentrations. The concentration of indoor pollutants in enclosed buildings is actually deepening on several factors such as pollutants source rate, pollutant removal rate and ventilation rate of the HVAC system in a particular building. By understanding this relationship, the concentration of air pollutants in a building environment can be controlled in a much better and healthier way.

4.0 CONCLUSION

In conclusion, this study has successfully achieved the aim and objective that have been discussed earlier. The assessment of the indoor air quality (IAQ) level according to the ages of building in Universiti Teknologi Malaysia (UTM) has successfully provided the useful information regarding IAQ level among the building tenants of faculties' buildings. Finally, this study has been carried out with the hopes of raising the awareness and can be used as a reference in improving the IAQ in indoor environments at the workplace, particularly in universities or other similar institutions for the benefits and health being of the occupants.

Acknowledgement

The author would like to convey the heartfelt appreciation to the Faculty Chemical Engineering, Universiti Teknologi Malaysia (UTM), which has provided the facilities, instruments and material to conduct this research project under grant scheme entitled "Comprehensive Health Risk Assessment and Environmental Assessment for the Production of New Green Diesel Formulation (Q.J130000.2444.00G55)".

References

- [1] Abdel Hameed, A. A. 2000. Indoor and Outdoor Formaldehyde Concentrations in Homes in Residential Areas in Greater Cairo. *Journal of Environmental Monitoring*. 2(2): 123-126.
- [2] Arundel, A. V., Sterling, E. M., Biggin, J. H., and Sterling, T. D. 1986. Indirect Health Effects of Relative Humidity in Indoor Environments. *Environmental Health Perspectives*. 65: 351.
- [3] Daisey, J. M., Angell, W. J. and Apte, M. G. 2003. Indoor Air Quality, Ventilation and Health Symptoms in Schools: An Analysis of Existing Information. *Indoor Air*. 13, 53-64.
- [4] Fromme, H., Twardella, D., Dietrich, S., Heitmann, D., Schierl, R., Liebl, B. and Ruden, H. 2007. Particulate Matter in the Indoor Air of Classrooms – Exploratory Results from Munich

- and Surrounding Area. *Atmospheric Environment*. 41: 854-856.
- [5] Jalaludin, J., Nordiyana, M. S., and Suhaimi, N. F. 2014. Exposure to Indoor Air Pollutants (Formaldehyde, VOCs, Ultrafine Particles) and Respiratory Health Symptoms among Office Workers in Old and New Buildings in Universiti Putra Malaysia. *International Journal of Applied and Natural Sciences*. 3(1): 69-80.
- [6] Jones, A. P. 1999. Indoor Air Quality and Health. *Atmospheric Environment*. 33(28): 4535-4564.
- [7] Lee, S. C. and Chang, M. 2000. Indoor and Outdoor Air Quality Investigation at Schools in Hong Kong. *Chemosphere*. 41: 109-113.
- [8] Levin, H. Practical Ways Building Designers Address Indoor Air Quality Issues?
- [9] Montgomery, D. D., and Kalman, D. A. 1989. Indoor and Outdoor Air Quality: Reference Concentrations in Complaint Free Residences. *Application Industrial Hygiene*. 4: 17-20.
- [10] Malaysia. 2005. Code of Practice on Indoor Air Quality. GP (1)05/2005.
- [11] Malaysia. 2010. Industry Code of Practice on Indoor Air Quality 2010. JKPP DP(S) 127/379/4-39.
- [12] Malaysia. 2008. Guideline for Hazard Identification, Risk Assessment and Risk Control (HIRARC). JKPP DP 127/789/4-47.
- [13] Prill, R. 2000. Why Measure Carbon Dioxide Inside Buildings? Washington State University Extension Energy Program.
- [14] Rosli, N. F. and Jalaluddin, J. 2012. Indoor Air Quality (IAQ) and Sick Building Syndrome (SBS) among Office Workers in New and Old Building in Universiti Putra Malaysia, Serdang. *Health and the Environmental Journal*. 3(2): 98-109.
- [15] Saraga, D., Pateraki, S., Papadopoulus, A., Vasilakos, C., and Maggos. 2011. Studying the Indoor Air Quality in Three Non-Residential Environments of Different Use: A Museum, a Printer Industry and an Office. *Building and Environment*. 46: 2333-2341.
- [16] Shaughnessy, R. J., Shaughnessy, U. H., Nevalainen, A., and Moschandreas, D. 2006. A Preliminary Study on the Association between Ventilation Rates in Classrooms and Student Performance. *Indoor Air*. 16: 465-468.
- [17] Singapore. 1996. Guidelines for Good Indoor Air Quality in Office Premises.
- [18] Sulaiman, Z., and Mohamed, M. 2011. Indoor Air Quality and Sick Building Syndrome Study at Two Selected Libraries in Johor Bahru, Malaysia. *Environment Asia*. 4(1): 67-74.
- [19] US-EPA-Indoor Air Quality (2013) [Online]. From: <http://www.epa.gov/iaq/>. [Accessed on 18th March 2013].