Indoor Air Quality (IAQ) and Sick Buildings Syndrome (SBS) among Office Workers in New and Old Building in Universiti Putra Malaysia, Serdang

Nur Fadilah R, Juliana J*
Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia (43400), Serdang, Malaysia

*Corresponding author: Juliana@medic.upm.edu
Published 1 July 2012

ABSTRACT: This study aimed to determine the association between indoor air quality and the prevalence of sick building syndrome (SBS) among office workers in new and old buildings in Universiti Putra Malaysia, Serdang. A cross-sectional comparative study was conducted among 139 office workers from new buildings (The Faculty of Medicine and Health Sciences and Faculty of Engineering) and old building (administrative building of UPM). The SBS symptoms were assessed by using the questionnaires of Indoor Air Quality and Work Environment Symptoms Survey, NIOSH Indoor Environment Quality Survey (1991) while for the IAQ and IAP they were monitored by using the instruments. The results showed that ventilation rate was significantly higher in new buildings compared to old building with median 21.28 cfm/person and 15.16 cfm/person, respectively (z= -2.722, p<0.05). The temperature in the old building was significantly higher compared to new building with the median 24.2 ºC and 22.5 ºC, respectively (z= -2.127, p<0.05). SBS prevalence for the reported cases was 47.5% for new building while 33.8% for old building, however, the difference was not significant (χ^2 = 2.126, p >0.05). The prevalence of SBS symptom i.e. stuffy or runny nose or sinus was significantly higher in new building compared to old building (χ^2 = 5.974, p < 0.05). The level of IAP for ultrafine particle in old building was significantly higher compared to new building (z = -2.449, p<0.05). The temperature humidity index also showed the same pattern (z= -2.038, p<0.05). Although there was no significant difference for SBS prevalence between new and old buildings, both buildings can be concluded as having SBS since more than 20% of building occupants had experienced SBS during this study. Prevalence of SBS in new building was 47.5% while for the old building was 33.8%, indicating that both buildings have high risk on SBS. Thus, regular housekeeping and proper ventilation system maintenance are recommended.

Keywords: Sick building syndrome (SBS), Indoor air quality (IAQ), Indoor air pollutants (IAP), Old and new buildings.

Introduction

The sick building syndrome (SBS) is generally characterized by the following criteria: people in the same building complaining of mucous membrane irritation (such as eye, nose, or throat irritation), headache, dizziness, and difficulty in concentrating; the symptoms are relieved soon after leaving the building and the cause of the symptoms is usually not really known (Jones, 1999). Some studies found that there were several related risk factors for these symptoms such as the number of person inside the workplace area, type of job performed, workplace area and conditions, building design and age (Bornehag *et al*., 2001; Gyntelberg *et al*., 1994; Teeuw *et al*., 1994; Mendell, 1993). The prevalence of SBS symptoms was associated with the level of indoor air pollutants (IAP) and the quality of indoor air inside of the building. Ideal indoor air quality (IAQ) means the air we breathe everyday inside the building does not contain any contaminant either in the form of biological (mould, fungi or bacteria), chemical (gaseous which might become poisoning if excessively present in the breathing air like Carbon Dioxide (CO_2), Carbon Monoxide (CO), or Volatile organic compounds (VOCs)) or physical contaminants like dust (particulate matter; PM_{10}, $PM_{2.5}$ or ultrafine particle). All of these contaminants could potentially cause adverse health effect to the exposed human when there was a contact to the skin or entering the respiratory system.

Indoor air quality level is one of the indicators to determine the air quality of the office environment in term of the ventilation efficiency and adequacy. Thus, to ensure that all the air pollutants are reduced to the acceptable level, the ASHRAE Standard 62 for Natural and Mechanical Ventilation states that the minimum allowable rate recommended for the office building is 20 cfm/person (ASHRAE, 2005). Following the observations of Banaszak *et al.* (1970), the attention of the medical profession was drawn to the development of an allergic respiratory disorder (allergic alveolitis) among the employees working in air-conditioned offices. Molina *et al*. (1989) in their study stated that:

"Apart from these allergic and infectious disorders, doctors are confronted every day with a number of complaints affecting mucous membranes of eyes, nose and throat, headache and lethargy. These symptoms appear to be benign and related to the building in which the individuals work or live and constitute the sick building syndrome."

A large number of people are living or working in premises where ventilation is regulated and involved air conditioning systems (Molina *et al.,* 1989). However, the problem was not limited to air conditioned buildings (Finnegan *et al.,* 1987). Molina *et al*. (1989) showed that 20% of the employees experience symptoms of SBS and most of them were convinced that this reduces their working efficiency.Other report estimates that up to 30% of new refurbished buildings throughout the world may be affected by this syndrome (WHO, 1986). Molina *et al*. (1989) also stated that in a study performed in UK on 4373 of office workers in 46 buildings, 29% of them experienced five or more of the characteristic symptoms of sick building syndrome.

Thus, this study was conducted to determine the association between IAQ as well as the IAP concentration level and the symptoms of SBS among office workers in new and old buildings in Universiti Putra Malaysia, Serdang.

Methodology

This is a cross-sectional comparative study conducted on 139 office workers who are registered as staff, have worked for at least four months, including males and females from both new and old buildings. The aim of this study was to determine the level of indoor air quality and its relationship with the increasing level of chemical indoor airborne pollutants and its association with sick building syndrome in two office buildings (which are categorised as new and old buildings) in Universiti Putra Malaysia, Serdang Selangor, Malaysia. The old building is an administrative building of Universiti Putra Malaysia while the new building provides space for the Faculty of Medicine and Health Sciences and the Faculty of Engineering. These locations were chosen because both of the new and old buildings used centralized air conditioning systems and the offices are completely depending on the ventilation providing sufficient air for the occupants in the buldings.

The prevalence of sick building syndrome (SBS) and its symptoms

The questionnaire was developed according to the modified Indoor Air Quality and Work Environment Symptoms Survey, NIOSH Indoor Environment Quality Survey (1991). This questionnaire consists of four sections including personal information, workplace information, information on current health and description of workplace conditions. The questionnaires were distributed to the selected office workers and they have to answer all questions as required. Interview session was performed to ensure the respondents understand what was needed wanted in the questionnaires.

The measurement of IAQ

The temperature was measured first inside both of the building at selected areas before assessing the level of indoor air quality. In order to determine the evenly distribution of the air and the consistency of the buildings, the measurement of the temperature was taken periodically using Q-Trak. Then, a Velocicalc was used to measure the humidity the air movement, air flow, ventilation, volume of air supply and velocity of the building. For the air quality assessment, the level of CO_2 was used as the main indicator. Air supplied, outside air and return air inside the Air Handling Unit (AHU) was measured.

The measurement of IAP

The layout plan of the office building was used to mark the location of sampling point. The concentration of TVOCs was measured using a handheld ppb monitor (PpbRAE 3000). The concentration of CO and CO_2 was measured simultaneously in the sampling location determined by the workstation of building occupants using Q-Trak. The indoor air pollutant was separated into two major types based on their characters i.e. the particulate matter and the ultrafine particle (UFP). Aerosol monitors (The Dust Trak and Side Pack) were used to measured PM_{10} and $PM_{2.5}$. The data was collected in real-time at each sample location. They sample location was determined randomly according to the workstation of the office workers using the standard procedure by Industry Code of Practice on Indoor Air Quality 2010 (Department of Occupational Safety and Health, 2010). The ultrafine particle counter then was used to measure the UFP in the working area. All the instruments were located at the same level of breathing areas.

Data analysis

The data was analysed using statistical package for social science (SPSS) version 18.0. Kolmogorov-Smirnov statistic was used to test the normality of the data variables. The analysis done at different level which $p<0.05$ is set as significant in this study. The Mann-Whitney U was performed to compare the level of IAQ and IAP concentration level in new and old buildings since the data was not normally distributed and the Chi-square was performed to compare the prevalence of sick building syndrome between new and old buildings.

Results

Table 1 shows the socio-demographic of respondents in new and old buildings.

TABLE 1: Socio-demographic data of respondents from new and old building

Variables	Study Groups n (%)			
	New Building (n=59)	**Old Building (n=80)**	χ^2	**p**
Gender				
Male	23 (39)	16 (20)	6.062	0.014*
Female	36 (61)	64 (80)		
Race				
Malays	58 (98.3)	79 (98.8)	2.094	0.351
Chinese	0 (0)	0 (0)		
Indian	1 (1.7)	0 (0)		
Others	0 (0)	1 (1.3)		
Marital Status				
Single	16 (27.1)	30 (37.5)	4.071	0.131
Married	41 (69.5)	50 (62.5)		
Divorced	2 (3.4)	0 (0)		
Education Level				
PMR	4 (6.8)	2 (2.5)	2.337	0.505
SPM	15 (25.4)	26 (32.5)		
Diploma/STPM/Certificate	26 (44.1)	31 (38.8)		
Degree	14 (23.7)	21 (26.3)		
Smoking Status				
Never smoked	46 (78)	70 (87.5)	4.502	0.105
Former smoker	8 (13.6)	3 (3.8)		
Current smoker	5 (8.5)	7 (8.8)		

*Significant at $p < 0.05$
N = 139

The indoor air quality supplied air assessments

The comparison between the levels of IAQ in both buildings was made and the normality test was performed to find the normality of the data distribution for both buildings. Both data were not normally distributed and **TABLE 2** showed the result of Mann-Whitney U test. The difference between the levels of IAQ for ventilation and temperature in new building and old building was statistically significant.

TABLE 2: Comparisons of the IAQ in both buildings (new and old building)

Variables	New Building (n=59)	Old Building (n=80)	z	P
	Median (IQR)	Median (IQR)		
Ventilation (cfm/person)	21.285 (17.79 – 24.13)	15.16 (14.9 – 15.67)	-2.722	0.006*
Temperature (°C)	22.50 (21.25 – 23.60)	24.20 (23.48 – 25.08)	-2.127	0.033*
Relative Humidity (RH%)	60.80 (58.83 – 69.80)	59.10 (58.28 – 62.10)	-0.849	0.396

*Significant at $p < 0.05$
N = 139

Results of IAP for both new and old buildings

Normality test showed that all the parameters from both building were not normally distributed. Results of Mann-Whitney U test in **TABLE 3** showed that the difference of indoor air pollutants in new building was not significantly higher compared to old building but the UFP concentration was significantly higher for the old building.

The ultrafine particle was sampled using the ultrafine particle counter (UPC) P-Trak Model 8525. The concentration of UFP in both new and old buildings was higher than 1000 pt/cm^3. Mann-Whitney U test showed that the concentration of UFP in old building was significantly higher. The median of UFP in old building was 11655 pt/cm^3 with the Interquartile range (IQR), 10611 – 12728 pt/cm^3 while the new building has a lower concentration compared to old building with the median, 5019 pt/cm^3 and the IQR, 4292.50–6668.50 pt/cm^3.

TABLE 3: Comparison of the concentration of indoor air pollutants between new building and old building

Parameter	Median (IQR)		z	p
	New Building (n=59)	Old Building (IQR)		
UFP (pt/cm^3)	5019 (4292.50 – 6668.50)	11655 (10611 – 12728)	-2.717	0.007*
$PM_{2.5}$ (µg/m^3)	24 (98.25 – 68.75)	11 (8.00 – 22.25)	-0.682	0.495
PM_{10} (µg/m^3)	171 (120.50 – 189.75)	123.5 (105.00 – 127.00)	-1.701	0.089
TVOC (ppm)	330.50 (262.75 – 447.50)	234.00 (215.00 – 481.75)	-1.191	0.234
CO_2 (ppm)	576 (504.50 – 716.00)	536.5 (494.00 – 594.75)	-1.106	0.269

CO (ppm)	1.55 (0.875 – 1.950)	1.65 (0.625 – 1.925)	-1.70	0.865
THI (ºC/RH %)	36.14 (33.22 – 38.22)	41.84 (37.93 – 45.22)	-2.038	0.042*

*Significant at $p < 0.05$, N = 139

The prevalence of SBS

TABLE 4 showed the number of respondents who were categorized as SBS using the criteria by Ooi *et al*., (1998). Chi square test was performed on the prevalence of SBS for both buildings, the difference between new and old buildings was found statistically not significant.

TABLE 4: Comparison of the prevalence of sick building syndrome (SBS) between office workers of new building and office workers of old building

Variables	**Prevalence of SBS N=139 (100%)**		**χ^2**	**p**
	Yes	**No**		
New Building n = 59	28 (47.5)	31 (52.5)	2.126[a]	0.145
Old Building n = 80	27 (33.8)	53 (66.3)		

a. continuity correction since >20% have the expected count less than 5
N = 139

The prevalence of sick building syndrome (SBS) symptoms

TABLE 5 showed the comparison of the prevelance of SBS symptoms from both buildings. Headache, stuffy or runny nose or sinus, tired or strained eyes and dizziness or lighted headed recorded the highest percentage for new building with 37.3% for each symptoms. While for the old building, the dizziness or light headed recorded the highest percentage which was 36.3% followed by headache with 31.3%, and tired or strained eyes with 30%. The lowest SBS symptom for both buildings is chest tightness which was 8.5% and 11.3% for new and old building, respectively. Chi-Square test was performed for all of the symptoms and the results showed that there was statistically significant difference for stuffy. However, runny nose or sinus between new and old buildings and there was no significant difference for the other symptoms between new and old buildings.

TABLE 5: Comparison of the prevalence of sick building syndrome (SBS) symptoms among office workers between new and old building

Symptoms	Study groups		χ^2	p
	New Building (n=59)	Old Building (n=80)		
	Yes	Yes		

Dry, itching or irritated eyes	9 (15.3)	13 (16.3)	0.025	0.874
Headache	22 (37.3)	25 (31.3)	0.553	0.457
Sore or dry throat	14 (23.7)	15 (18.8)	0.510	0.475
Unusual tiredness fatigue	16 (27.1)	14 (17.5)	1.856	0.173
Chest tightness	5 (8.5)	9 (11.3)	0.289	0.591
Stuffy or runny nose or sinus	22 (37.3)	15 (18.8)	5.974	0.015*
Cough	20 (33.9)	18 (22.5)	2.221	0.136
Tired or strained eyes	22 (37.3)	24 (30.0)	0.815	0.367
Tension or irritability or nervousness	12 (20.3)	13 (16.3)	0.385	0.535
Difficulty remembering	11 (18.6)	12 (15.0)	0.327	0.568
Dizziness or light headed	22 (37.3)	29 (36.3)	0.016	0.900
Dry or itchy skin	11 (18.6)	14 (17.5)	0.030	0.862

*Significant at $p < 0.05$
N = 139

Discussions

Socio-demographic of respondents in new and old building

Over the past two decades, numerous field studies on indoor air quality and the sick building syndrome (SBS) have been conducted, mostly in office environments (Jones, 1999). The office workers involved in this study were of both genders with more women than men working in the office. Study by Stenberg and Wall (1995) found that women usually reported work-related and environmental symptoms more often than men, which may explain the relatively high frequencies of complaints among the respondents.

Sick building syndrome (SBS) describes a situation in which building occupants experience acute health and/or comfort effects that appear to be linked to time spent in a particular building, but where no specific illness or cause can be identified (DOSH, 2010). Our survey found that most of the workers seem not aware about sick building syndrome because they thought it was nothing to do with their health since they got better after leaving the workplace or the building. This is probably related to the education level of the office workers since majority of them have Diploma/STPM/Certificate or SPM as their highest education qualifications. From the simple interview session with the workers, data showed that the Degree holder respondents were aware of their health in their work environment. Some of them knew about sick building syndrome issues and its relationship with the quality of indoor air. It is therefore evident that the higher the education level, more aware the workers are about their health condition related to their workplace environment especially when it was in a poor indoor air environment. This however is contradicing with an earlier study that found by Burr and Alderfer (1991) no clear trend and no statistical association between the prevalence of SBS and the education levels among the office workers.

There were not many smoking workers in either new building or old building. Thus, the smoking status of the respondents might not be a major contributor to the relationship with the development of SBS among the office workers in UPM. A study done by Jones (1999) found out that the smoking status can be a major contributor to the prevalence of sick building syndrome. The SBS also tends to be worsening when the age of the worker increases, especially for people with 40 to 56 years-old. Nevertheless, since the office workers in UPM were in between the age of 25 to 40 years old, the age was not a main factor of getting SBS in this study. Burr and Alderfer (1991) also stated that there was no apparent trend and no statistical association between SBS and age of the workers.

The indoor air quality supplied air assessments

The indoor air quality level is one of the indicators to determine the air quality of the office environment in term of the ventilation efficiency and adequacy which consist of the supplied air, returned air and outside air supplied into the building. Shaw (1997) stated that the most frequent identified causes of poor indoor air quality are related to the building design and operation, presence of air contaminants and inadequate ventilation. Study by Apter *et al*., (1994) showed that inadequacy of ventilation supplied into the building failed to dilute the level of air pollutants that are generated and emitted indoors. In some cases, air contaminants generated outdoors can be brought into a building by the ventilation system. To ensure that all the air pollutants reduce to the acceptable level, the ASHRAE Standard 62 for Natural and Mechanical Ventilation states that the minimum allowable rates recommended for the office building is 20 cfm/person.

Based on the study done by Stolwijk (1991), the efficiency of ventilation could be reduced when the system provides the air which is supplied through the ceiling and return also in the ceiling. The system installed at the administrative building of Universiti Putra Malaysia is known as free return. This system might influence the IAQ for this building. Ventilation system of this kind allows pollutants to return freely to the ceiling of the office. Then, returned air was brought to the air handling unit (AHU) room where the air was filtered before being supplied back into the office building.

In this study, the administrative building was categorized as old building. Based on the result, the mean of IAQ level for this building was 15.33 cfm/person with the range of 14.90–15.67 cfm/person which was lower than the required level of IAQ as stated in the ASHRAE Standard 62. However, some locations of the sampling points in the old building had a value of IAQ supplied air exceeding ASHRAE standard. From the complaints by the workers of the old building, improper HVAC system caused poor distribution enough air supplied certain areas.Thus, the contaminants present on that particular area might be higher and have a possibility to cause health problem to the workplace.

The low level of IAQ in this old building might be related to high building occupancy with 20 -30 workers in an open space area compared to 4-15 workers for the new building. The mean of IAQ supplied air for new building was 21.22 cfm/person with the range 15.75–27.19 cfm/person and the mean showed a higher value of its IAQ supplied air compared to the ASHRAE Standard 62. Apter *et al.* (1994) found that the symptoms of sick building syndrome (SBS) would be reduced by increasing the outdoor air supply into the building. Median indoor air quality of supplied air was used for comparison normally distributed. The median of supplied air in the new building was 21.285 cfm/person and the IQR was 17.79–24.13 cfm/person while in the old building, the median of it was 15.42 cfm/person and the IQR was 14.9 – 15.67 cfm/person. Based on the results, the level of cfm/person in the new building was higher compared to the old building.

The level of indoor air quality in any building is influenced by the air handling unit (AHU), maintenance, cleaning procedures and the duration of inspection (Shaw, 1997). According to the engineer of HAVC system at the administrative building of UPM, the building has not been maintained for about three years since the last contract at early 2007. The maintenance of this old building was only started again at the end of 2010 when the new company took over the maintenance work. The maintenance for the indoor air quality was done once in a three months while the inspection of AHU room was done once in a month. The level of IAQ in this old building was influenced by the higher number of building occupancy which could contribute to the high level of CO_2 in most of the locations due to the breathing. The level of IAQ supplied in the new building was considered to be enough since it was higher than the ASHRAE Standard 62. This might be the result of maintenance done in both new buildings. The maintenance of indoor air quality of Faculty of Medicine and Health Sciences and Faculty of Engineering was done once in two months since the building was operated and there was also monthly inspection of AHU room and the HVAC system.

Burr and Alderfer (1991) stated that the perception of comfort was related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. The acceptable ranges of temperature and relative humidity inside the office environments are 23–26 ºC and 40–70% , respectively (DOSH, 2010). From this study, we found that both parameters in the new and old office buildings were acceptable.

The parameter results of IAP for both new and old buildings

Results on the level of indoor air pollutants showed that the old building had significant higher amount of ultrafine particles (UFP) compared to the new building. The ultrafine particle was sampled using the ultrafine particle counter (UPC) (P-Trak Model 8525). The concentration of UFP in both new and old building was higher than 1000 pt/cm^3. Mann-Whitney U test was performed and the concentration of UFP in old building was significantly higher compared to the new building. The median of UFP in old building was 11320 pt/cm^3 with the IQR, 11114 – 12906 pt/cm^3 while in the new building has median, 5019 pt/cm^3 and the IQR, 4292.50 – 6668.50 pt/cm^3.

Burr and Alderfer (1991) found that the sources of UFP in the office workplace could be from the laser printers, cleansers, photocopy activity, laminator, fragrant sprayers and even tobacco smoke. From the observation, the higher level of UFP in the old building could be due to the opened-area for photocopied machine and fax-machine, fragrant sprayers and carpet. Burr and Alderfer (1991) also found that the office workers who worked within 15 feet from a photocopy machine, painted wall, having new carpeting and also those workers who worked near the rearrange partitions in the preceding year have greater tendency to experience SBS than those who did not.

He *et al*. (2007) and Wang and Morawska (2008) found that the particles are usually produced during the operation of office equipment like printers Since the printer machines was not isolated from the workspace area in the old building, it could become the major contributor for indoor air pollutant.

On the contrary, the level of UFP concentration in new building was lower than the old building because the photocopied and printer machines were located in an isolated-area (in a specific room for photocopy activity) and there was no fragrant sprayers installed in this new building. However, the level of UFP was still high because the door of the photocopy room was opened from time to time during the photocopy activity. The toxicity effect of this ultrafine particle is greater than the PM_{10} and $PM_{2.5}$ because the smaller the size of particle, the narrower it can go through into the airways.

The prevalence of SBS

Syazwan *et al*., (2009) stated that the prevalence of sick building syndrome in the old building was significantly higher compared to the new building and the characteristics of the building was one of the factors that contributed to sick building syndrome among the office workers. However, no significant difference of the prevalence of sick building syndrome between the two buildings was reported by the authors.

There was no significant difference of SBS prevalence for both buildings with 47.5% for new building and 33.8% for the old building. Nonetheless, both buildings can be concluded as having SBS since there were more than 20% of building occupants experienced SBS during this study (Rosner, 2007).

The prevalence of SBS symptoms

Our results show that the new building shown the highest percentage of headache, stuffy or runny nose or sinus, tired or strained eyes, and dizziness or light headed which were 37.3% for each symptom, while for the old building, the highest percentage with 36.3% was dizziness or light headed, followed by headache with 31.3%, and tired or strained eyes with 30%.

There was one symptom showing significant different between new building and old building i.e. stuffy or runny nose or sinus, Bur and Alderfer (1991) found that the most frequent irritant was office chemical "fumes" like adhesives, glues, typewriter correction fluid (liquid) and rubber cement. Other such sources might include wall paint, carpet and other cleaners. To reduce the prevalence of SBS symptoms among the office workers minimization of the level of indoor air pollutants effectively through specifying the building materials and furnishings with low emission potentials, locating the outdoor-air intakes away from known outdoor sources, and using special exhaust system to remove localized contamination sources were suggested (Shaw, 1997).

Conclusion

The results obtained from this study can be used as the control measure of IAP source in the future for both new and old buildings by comparing the levels of air pollutants and air quality levels to the standard of Indoor Air Quality (DOSH, 2010). The findings may help the UPM's management to ensure that the health of all their workers are not affected by the indoor air problems or experienced any sick building syndrome (SBS) repeatedly in the future through the improvement of air quality levels. To maintain a good indoor air quality inside the buildings, occupants should practice good housekeeping, isolate fax-machines and printers have periodical the ventilation system maintenance. The most practicable control measures for indoor air problems are by controlling them at point of source. This is essential because the good indoor air quality can ensure that the health status of the office workers and the healthier the workers, the better their performance at work.

Acknowledgement

The author would like to express her gratitude to all the staff and the department at the Administrative of UPM, the Faculty of Engineering, the Faculty of Medicine and Health Sciences, and the Community Health Department staff as well as all the respondents who participated in this research.

References

1. Apter, A., Bracker, A., Hodgson, M., Sidman, J. and Leung, W.Y. (1994).Epidemiology of the sick building syndrome. *Journal of Allergy Clinical Immunology*, 94(2):277-288.

2. ASHRAE. (2003).Ventilation for acceptable indoor air quality. Atlanta GA: American Society of Heating, Refrigerating and Air Conditioning Engeneers.

3. Barnaszak, E.F., Thiede, W.H. and Fink, K.N. (1970).Hypersensitivity pneumonitis due to contamination of an air conditioner. *N. Engl. J. Med.*, 283(6):271-76.

4. Burr GA, Alderfer RJ. (1991). Health Hazard Evaluation (HHE) Report: HETA 89-065-2119. Available from: www.cdc.gov/niosh/hhe/reports/pdfs/1989-0065-2119.pdf. (*Retrieved on 18 March 2011*).

5. Department of Occupational Safety and Health. Ministry of Human Resources. Industry code of practice on indoor air quality 2010. JKKP DP (S) 127/379/4-39.

6. Finnegan, M.J. and Pickering, C.A.C. (1984) Work related asthma and humidifier fever in air conditioned buildings. Proceeding of the 3rd International Conference on Indoor Air Quality and Climate Eds. Berglund B, Lindvall T, Sundell J, Swedinsh Council for Building Research, Stockholm 1984, 1:256-262.

7. Gyntelberg, F., Suadicani, P.(1994). Dust and the sick building syndrome. *Indoor Air*, 4:223-38.

8. Harrison, J., Pickering, A.C., Finnegan, M.J. and Austwick, P.K.C. (1987). The sick building syndrome: further prevalence studies and investigation of possible causes. In: Vol. 2, Indoor Air '87: *Proc of the 4th International Conference on Indoor Air Quality and Climate, Berlin*, 487-491.

9. He, C. and Morawska, L. (2007).Particle emission characteristics of office printers. *Environment Science & Technology*, 41(17):6039-6045.

10. Jones, A.P. (1999). Indoor air quality and health. *Atmospheric Environment*, 33(28):4535-4564.

11. Mendell, M.J. (1993). Non-specific symptoms in office workers: A review and summary of the epidemiologic literature. *Indoor Air*, 3:227-36.

12. Molina, C., Pickering, C.A.C., Valbjorn, O., Bortoli, M.D. (1989). Indoor air quality and impact on man. Report No. 4 Sick Building Syndrome: A Practical Guide. http://www.buildingecology.com/publications/ECA_Report4.pdf. (*Retrieved on 18 March 2011*).

13. Ooi, P.L., Goh, K.T., Phoon, M.H., Foo, S.C. and Yap, H.M. (1998). Epidemiology of sick building syndrome and its associated risk factors in Singapore. *Occup Environ Med.* 55(3):188-193.

14. Rosner, D. (2007) Sick building syndrome and the problem of

uncertainty. *Journal Historical Medicine All Science*, 62(3): 376 – 378.

15. Shaw, C.Y. (1997). Construction technology update No. 3: Maintaining acceptable air quality in office buildings through ventilation. National Research Council's Institute for Research in Construction 1997.

16. Stenberg, B. and Wall, S. (1995). Why do women report "sick building symptoms" more often than men? *Soc Sci Med.*, 40:491-502.

17. Stolwijk, J.A. (1992). Risk assessment of acute health and comfort effects of indoor air pollution. *Annals of the New York Academy of Sciences*, 641:56-62.

18. Syazwan Aizat, I., Juliana, J., Norhafizalina, O., Azman, Z.A., Kamaruzaman, J. (2009). Indoor air quality and sick building syndrome in malaysian buildings. *Global Journal of Health Science*, 1(2):126-136.

19. Teeuw, K.B., Vandenbroucke-Grauls, C.M. (1994). Airborne gram-negative bacteria and endotoxin in sick building syndrome. A study in Dutch governmental office buildings. *Arch Intern Med.*, 154(20):2339-45.

20. Wang, L. and Morawska, L. (2008). Characterizing and predicting ultrafine particle number concentration in an office by CFD method. In Proceedings First International Conference on Building Energy and Environment COBEE, Dalian, China. 2107-2111.

21. World Health Organization. (WHO) (1986).Indoor air pollutants: exposure and health effects. Copenhagen: WHO Regional Office for Europe. (*EURO Reports and Studies No. 78*).