INFLUENCE OF INDOOR AIR QUALITY (IAQ) ON THE SICK BUILDING SYNDROME (SBS) AT TWO SELECTED HOSPITALS

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ABSTRACT

Attention on buildings' Indoor Air Quality (IAQ) tend to show an increased due to time spending indoors is relatively higher than workers being outdoors. One major problem often associated with IAQ is Sick Building Syndrome (SBS). This study has its objectives of identifying current status of IAQ and investigating its relationship with SBS inside of the building served by the mechanical ventilation and air-conditioning (MVAC) system in two selected hospitals in Selangor and Pahang. The findings of study are useful as they provide data to ensure that the health, comfort and well-being of workers are not to be affected or continuously affected by problems associated to IAQ. Self-administered questionnaire was used to obtain current SBS symptoms experienced by workers. Then, technical assessments comprised of walkthrough survey and measurements of IAQ parameters were carried out to understand the current status of IAQ in building. The important IAQ parameters considered in this study were air temperature, relative humidity, air changes per hour (ACH), carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), formaldehyde (HCHO) and respirable particulate (RP). Measurements were performed using calibrated IAQ equipment. A questionnaire was distributed to workers in selected departments and a 76% response rate was achieved, giving a sample of 76 workers. The prevalence of SBS was significantly higher at hospital in Selangor (38.9%) compared to Pahang (7.5%) and of all the reported symptoms, irritated, stuffy or runny nose was the most reported symptoms in this study (11.1%). The average results for IAQ parameters at both hospitals were well below the acceptable limits or within recommended acceptable range of Malaysian Industry Code of Practice on Indoor Air Quality 2010 (MICOP IAQ 2010). Meanwhile, the average results for ACH have failed to achieve the minimum limit of 10 as stated in the Factories and Machineries (Safety, Health and Welfare) Regulations 1970 (FMA(SHW) 1970). Nevertheless, there were no direct causal link and no significant association between IAQ parameters and SBS symptoms. Further study with wider scope including personal and psychosocial factors should be conducted especially within healthcare facilities in order to obtain more accurate results.

Keywords: Indoor air quality (IAQ), sick building syndrome (SBS), building, air changes per hour

ABSTRAK

Pada masa kini, kebimbangan terhadap kualiti udara dalaman (IAQ) di bangunan-bangunan cenderung menunjukkan peningkatan kerana kebanyakan pekerja menghabiskan masa mereka di dalam bangunan berbanding di luar bangunan. Satu masalah yang sering dikaitkan dengan IAQ adalah Sindrom Bangunan Sakit (SBS). Kajian ini dijalankan untuk mengenal pasti status semasa IAQ dan menyiasat hubungannya dengan SBS di dalam bangunan yang menggunakan sistem pengudaraan mekanikal dan penghawa dingin (MVAC) di dua buah hospital di Selangor dan Pahang. Dapatan kajian adalah berguna untuk memastikan bahawa kesihatan, keselesaan dan kesejahteraan pekerja tidak terjejas atau terus terjejas oleh masalah yang berpunca daripada IAQ. Soal selidik yang ditadbir sendiri telah digunakan untuk mendapatkan gejala SBS semasa yang dialami oleh pekerja. Kemudian, penilaian teknikal yang terdiri daripada kajian secara langsung dan ukuran parameter IAQ telah dijalankan untuk memahami status semasa IAQ di dalam bangunan. Parameter penting IAQ yang dikaji dalam kajian ini ialah suhu udara, kelembapan relatif, pertukaran udara sejam (ACH), karbon dioksida (CO2), karbon monoksida (CO), jumlah sebatian organik meruap (TVOC), formaldehid (HCHO) dan habuk boleh terhirup (RP). Ukuran telah dijalankan menggunakan peralatan IAQ yang telah ditentukur. Soal selidik telah diedarkan kepada pekerja-pekerja di jabatan-jabatan terpilih dan kadar maklumbalas yang diterima ialah 76%, iaitu bersamaan dengan jumlah pekerja seramai 76 orang. Kes SBS adalah jauh lebih tinggi di hospital yang terletak di Selangor (38.9%) berbanding Pahang (7.5%) dan di antara semua gejala yang dilaporkan, gatal-gatal, tersumbat atau hidung berair adalah gejala yang paling tinggi dilaporkan di dalam kajian ini (11.1%). Keputusan bacaan purata bagi setiap parameter IAQ di kedua-dua hospital adalah di bawah had yang boleh diterima atau dalam julat yang boleh diterima seperti dinyatakan dalam Kod Amalan Industri Kualiti Udara Dalaman 2010 (MICOP IAQ 2010). Sementara itu, keputusan bacaan purata untuk ACH telah gagal mencapai had minimum 10 seperti yang dinyatakan dalam Akta Kilang dan Jentera (Keselamatan, Kesihatan dan Kebajikan) Peraturan- peraturan 1970 (FMA (SHW) 1970). Walau bagaimanapun, tiada hubungan kaitan secara langsung dan tiada hubungan yang signifikan di antara setiap parameter IAQ dan gejala SBS. Kajian lanjut dengan skop yang lebih luas termasuk faktor peribadi dan psikososial perlu dijalankan terutamanya untuk kemudahan penjagaan kesihatan bagi mendapatkan keputusan yang lebih tepat.

Kata kunci: Kualiti udara dalaman (IAQ), sindrom bangunan sakit (SBS), bangunan, pertukaran udara sejam (ACH)

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LIST OF ABBREVIATION/ NOTATIONS/ GLOSSARY OF TERMS

ACH	- Air changes per hour
CO_2	- Carbon dioxide
CO	- Carbon monoxide
FMA(SHW)	- Factories and Machineries (Safety, Health and Welfare) Regulations 1970
HCHO	- Formaldehyde
IAQ	- Indoor air quality
mg/m^3	- Milligram per cubic meter
MICOP IAQ	- Malaysia Industry Code of Practice on Indoor Air Quality
MVAC	- Mechanical ventilation and air conditioning
n	- Sample size
ppb	- Parts per billion
ppm	- Parts per million
RP	- Respirable particulates
SBS	- Sick building syndrome
TVOC	- Total volatile organic compound
%RH	- Percentage of relative humidity
°C	- Degree celcius
$\chi 2$	- Chi square
$<$	- Not less than

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

One of the important elements to ensure the health and comfort level of people in the physical environment especially in a building is Indoor Air Quality (IAQ). IAQ refers to the quality of air within and around a particular building and its structure. It highly relates to the health of its occupants. Poor IAQ can certainly lead to a variety of environmental health problems and potentially affect comfort and well-being.

According to the United States Environmental Protection Agency (US EPA), poor IAQ can be associated with many known environmental health problems such as Sick Building Syndrome (SBS), Building Related Illness (BRI), and Multiple Chemical Sensitivity (MCS). However, the most well-known environmental health problem associated with poor IAQ is SBS (U.S EPA, 2016). SBS describes situations in which people employed in building experience acute health and comfort effects that seem to be linked to time spent in a building. Even though there is yet specific illness or cause to be strongly associated to SBS, common symptoms of SBS may include headache, fatigue, irritated throat, itchy skin, eyes and nose, coughing and nausea (Godish, 1995). These symptoms are generic and varied where most of them are found to be temporary as the SBS complainants report relief soon after leaving the building.

According to Berardil, Leoni, Marchesini, Cascella and Raffil (1991), SBS is a known issue in Malaysia due to the construction of buildings designed to be energyefficient with air-conditioning system, yet poor maintenance and services of MVAC system resulting the increase of indoor air pollutants. Malaysia is a tropical country with high humidity and temperatures. As such, most of buildings in this country are tightly designed and use mechanical ventilating and air conditioning (MVAC) systems to maintain a thermally comfortable indoors and provide sufficient air within them. When buildings fail to do what they are intended to do, indoor environmental problems in the form of indoor air pollutions cause occupant to be discomfort and lead to health problems thus resulting in poor performance (Levin, 1995).

In order to ensure occupants of building are protected from poor IAQ, the Malaysian Industry Code of Practice on Indoor Air Quality 2010 (MICOP IAQ 2010) has been established by Department of Occupational Safety and Health (DOSH) under Malaysian Ministry of Human Resources. The establishment of this MICOP IAQ 2010 have generally created awareness among building occupants on the importance of IAQ and to acknowledge the needs to ensure good IAQ.

There are many guidelines, standards and policies pertaining to IAQ have been developed at certain developed and developing countries to systematically manage IAQ other than what is available in Malaysia. Although Malaysia has its own guidelines, IAQ still has not been given much attention compare to developed countries due to lack of assessment activities and studies (Norhidayah & Mimi, 2015; Siti Hamimah, Baba & Abd Mutalib, 2010).

1.2 Problem Statement

According to the US EPA (2000), people spend almost 90% of their time indoors than outdoors and indoor air concentrations of pollutants are 2 to 5 times greater than those found outdoors. Thus, to ensure the good quality of air in indoors environment is essential and warrants further deep examination. Furthermore, the risks for people to be exposed to health problems due to indoor air pollutions may be greater than risks from outdoor pollutions as stated in Healthy Housing Reference Manual. Atlanta: US Department of Health and Human Services (2006).

In developing countries, such as Malaysia, IAQ has not been given much attention compare to developed countries due to lack of assessment activities and studies (Norhidayah & Mimi, 2015; Siti Hamimah, Baba & Abd Mutalib, 2010). Nevertheless, several studies have been conducted over selected buildings of specific functions to examine relationship between symptoms of SBS and measured physical environment. Among them are libraries (Sulaiman and Mohamed, 2011), offices (Nur Fadilah & Juliana, 2012) and laboratories (Zuliza, Irniza & Emilia, 2016). This thus highlights lack of study pertaining to IAQ and SBS for hospitals and healthcare facilities in Malaysia as no study is yet to be found.

From previous studies, there are many reasons contributing to the main causes of SBS. Some studies suggest indoor air pollutants are the main cause, while another suggest environmental physical factors such as temperature and relative humidity. US EPA (2016) has listed many causes of SBS which can be connected to poor IAQ but the most common causes are indoor air pollutants and inadequate ventilation.

Despite many reasons that have been derived from existing studies, it is consistent to claim that IAQ indeed has significant relationship with SBS especially in air-conditioning buildings (Khushbu & Rushabh, 2016). Burge (2004) has previously supported the relationship as most of the complaints pertaining to SBS were raised by occupants at buildings equipped with air-conditioning system.

Nur Fadilah et al. (2012) stated that the quality of indoor air and the level of indoor air pollutants inside of the building were associated to the prevalence of SBS among workers. Thus, it is essential to ensure the good quality of air in indoors environment. Good quality of air can simply refer to the air human breath daily that does not contain any indoor air pollutants and could potentially cause adverse health effect to the exposed human when it enters respiratory system or there is a contact to the skin or eye. Since SBS is also included as one of the environmental health problems due to poor IAQ by MICOP IAQ 2010, the IAQ parameters that require to be monitored in order to check the IAQ status whether it is good or not are as follows:

1. indoor air pollutants (carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), formaldehyde (HCHO), respirable particulates (RP))
2. environmental physical factors (temperature and relative humidity)
3. biological agents

Without proper study and understanding on the current status of IAQ according to MICOP IAQ 2010, the quality of indoor air in a building will reduce significantly from day to day and if this IAQ problem is overlooked, complaints will raise and SBS will worsen.

Besides the IAQ parameters that have been discussed earlier, poor IAQ is also often to be related to poor distribution of fresh air over the space or the ventilation rate of the space (Gomzi et al., 2009; Michael, William & Joan, 2000; Siti Hamimah et al., 2010). Basically, IAQ can be improved in most of the buildings by operating the MVAC system to its design requirement (Khushbu et al., 2016). The main connection between MVAC system and IAQ parameters inside of the building is the function of MVAC system to dilute or remove the indoor air pollutants from the space by providing an adequate quantity of ventilation air. If the system does not properly work, this may allow indoor air pollutants to be built-up within space and increase occupants' exposure to hazardous air pollutants. This justifies the need to inspect and maintain the system frequently to ensure it operates with much efficiency. Occasionally, it is easy to find an explanation and solution for the complaints especially if the MVAC system in building is not functioning. However, some problems may require detailed investigation by an experienced professional that include measuring IAQ parameters to ensure good quality of air is maintained.

Therefore, this research is designed to identify the current status of IAQ and its relationship with SBS in air-conditioning buildings served by the MVAC system. Hospitals were selected as primary research area of study since they are one of the most critical buildings that requires a good IAQ due to housing many people with heightened susceptibility to problems associated with indoor air pollutants.

1.3 Research Questions

The research questions for this study are as the following:

1. What is the current status of IAQ inside the buildings?
2. Does existing MVAC system adequate to maintain good IAQ?
3. What are the common symptoms of SBS among hospital workers?
4. What is the difference in the reporting of SBS symptoms by workers between Hospital Selangor and Hospital Pahang?
5. What is the difference in the prevalence of SBS among workers between Hospital Selangor and Hospital Pahang?
6. Is there any relationship between IAQ and symptoms of SBS experienced by workers?

1.4 Research Objectives

The introduction, problem statement and research questions led to the following research objectives:

1. To study the current status of IAQ in hospitals
    - To measure the IAQ parameters (indoor air pollutants and physical environment factors) of carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), formaldehyde (HCHO), respirable particulates (RP), air temperature and air humidity
    - To compare the results with acceptable limits or range as stipulated in the MICOP IAQ 2010
2. To determine the adequacy of the existing MVAC system in maintaining good IAQ
    - To measure air changes per hour, ACH (how many times the air enters and exits a space from the MVAC in one hour) and compare the results

with acceptable limit as stipulated in the Factories and Machineries (Safety, Health and Welfare) Regulations 1970 (FMA(SHW) 1970)

- To measure CO_2 and compare the results with acceptable limit as stipulated in the MICOP IAQ 2010

3. To identify the common symptoms of SBS among workers in hospitals
4. To compare reported SBS symptoms by workers in different hospitals
5. To compare the prevalence of SBS among workers in different hospitals
6. To identify relationship between IAQ and symptoms of SBS experienced by workers

1.5 Scope and Limitations of the Study

1.5.1 Scope

The study includes two (2) hospitals at two (2) different states, Selangor and Pahang. Hospital Selangor has operated for almost 10 years, meanwhile Hospital Pahang has operated for more than 22 years. These hospitals were selected based on the years of operation and long history of occupancy, which can be considered as old and new building and both are under the same external company who is responsible for their facility engineering maintenance services.

Both hospitals have many departments with different functions. Thus, it is impossible to cover all areas due to cost and time constraints. For this study, the selection of departments to be studied was based on the type of ventilation, type of workstation and average of time workers spend in the workplace. On top of that, the requirement from the hospitals and several complaints received by the workers were also considered. According to MICOP IAQ 2010, the building management should conduct an IAQ assessment when complaints are received where the problem cannot be resolved. Therefore, the study areas are restricted to area served by the individual MVAC system and workers from the following five (5) departments in Hospital Selangor and Pahang:

1. Surgical Outpatient Department (SOPD)- SOPD provides a comprehensive outpatient service for patients across a large range of specialties. Many clinicians, including dieticians and specialist nurses, run clinics within the department. The role of the SOPD is to admit and prepare all patients for the Operating Room.
2. Pediatric Department (PD) - PD specializes in the care of infants and children. The roles of the staff in this department are broken down into medical, nursing and administrative support. The pediatrician directs the medical care of a child who is ill or injured, and provides care for healthy children.
3. Medical Records Department (MRD)- MRD maintains and safeguard the confidentiality of medical record information in accordance with the patient's right to privacy and legal requirements.
4. Obstetrics and Gynecology Department (OGD) - OGD is involved with teaching, patient care, and research in the areas of normal and abnormal human reproduction, growth and development of the fetus, normal and complicated obstetrics, and surgical and medical diseases of the female reproductive system, including reproductive endocrinology and infertility, oncology, urogynecology, global women's health, genetics, infectious disease, psychosocial problems, preventive health care, and ethics.

5. Orthopaedic Department (OD) - OD provides diagnosis and treatment of orthopaedic diseases and injuries of the musculoskeletal system, including the bones and joints of the arms, legs, and spine, and nerves, ligaments, tendons, and muscles. It also provides expert treatment for all aspects of musculoskeletal injuries including inpatient and outpatient surgical care, rehabilitation, and orthotics and prosthetics.

Principally, this cross-sectional study involved the measurement of IAQ parameters at those five departments. The IAQ parameters are divided into two (2) categories namely indoor air pollutants and physical environment factors. Concurrently, a self-administered questionnaire adopted from MM40 questionnaire, developed by Department of Occupational Health in Orebro Sweden and MICOP IAQ 2010 is used to gather data on commonly reported symptoms of SBS. Both inputs from measurement of IAQ parameters and self-administered questionnaire will help to identify the current status of IAQ and the prevalence of SBS at these two hospitals and also to confirm findings from previous studies.

1.5.2 Limitation

Limitations that arise in a study which are out of the researcher's control are as follow:

- Less number of respondents- Limited numbers of participants for the study is expected as permission from the supervisors or voluntary participation probably will be declined due to busy schedules of those in the targeted departments.

- Self-administered Questionnaire- Little interest by participants and the data from the questionnaires is significantly influenced by the reliability of the respondent. Honesty of participants and dealing with participants who are not cooperative to respond to questionnaires and might not correspond with the real situation.
- Non-probability sampling (convenience sampling) - Due to busy schedules of staff working in hospitals, this sampling technique will be used to ensure the availability and the quickness way to gather information. However, the information might not represent the population as a whole and it might be biased by participants

1.6 Definition of Key Terms

1.6.1 Sick Building Syndrome (SBS)

According to Burge (2004), the SBS comprises a group of symptoms of unclear aetiology divided into mucous membrane symptoms related to the eyes, nose, and throat; dry skin; together with what are often called general symptoms of headache and lethargy. There is no specific illness or cause can be identified but the developed symptoms seem to be linked to time spent in a particular building.

1.6.2 Indoor Air Quality (IAQ)

IAQ is the quality of the air inside buildings as represented by concentrations of pollutants and thermal comfort (temperature and relative humidity) conditions that affect the health, comfort, and well- being of buildings occupants (US EPA, 2016). According to the American Society of Heating, Refrigerating and Air-Conditioning

Engineers (ASHRAE) (1999), IAQ is viewed as acceptable if the indoor air contains no known pollutants at harmful concentrations as determined by cognizant authorities and if a substantial majority (80% or more) of people exposed to the air do not express dissatisfaction.

1.7 Organization of the Thesis

The research intends to determine the current status of Indoor Air Quality (IAQ) in buildings, compare the results with acceptable limits or range as stipulated in the recognized standards and determine if there is a relationship between IAQ and Sick Building Syndrome (SBS) symptoms experienced by workers in hospitals. Basically, this research is organized in five chapters as follows:

i) **Chapter 1: Introduction to the Research Project**

This chapter forms the introductory part of the research, and explains about the background of the study and statement of the problem. The chapter also highlights the objectives and significance of the study followed by the scope and limitations of the study and introduces the concept of IAQ and SBS, in terms of their definitions and characteristics.

ii) **Chapter 2: Literature Review**

This chapter presents relevant literature and studies that have been reviewed and comprehended in order to guide current study to its right direction. The current knowledge about the particular study areas is also being captured to make connections between the literature and research project and to see the strengths and weaknesses of the theories, arguments, methodology and findings of the literature.

iii) Chapter 3: Methodology

In this chapter, research framework of the study is described together with the research questions and hypothesis to be tested. The research design followed with selection of measurement variables and sampling and discussion on the methods used for the data collection were also described. The data are collected through various research techniques from three phases which include worker’s questionnaire, walkthrough survey and environmental measurements. Last but not least, this chapter also discusses the technique for analyzing the data.

iv) Chapter 4: Results and Discussion

Chapter 4 discusses the findings of the study. It starts with a summary of the results from the worker’s questionnaire and followed by a walkthrough survey and the environmental measurements results. The final section of the chapter provides a detailed discussion relating to the prevalence of SBS, status of IAQ and association between SBS and IAQ in different hospitals.

v) Chapter 5: Conclusion and Recommendation

This final chapter concludes the research. Several important issues that are discussed in this chapter include the implications, limitations and the contribution of the study. Possible future research areas are also discussed.

1.8 Conclusion

Health complaints among workers in buildings have increased in the recent years, in relation to the SBS as most of them spend their time indoors. The developed symptoms of SBS seem to be linked to time spent in a building, thus many studies revealed that poor IAQ may led to these complaints. SBS problems must be solved immediately as they may lead to increased absenteeism, reduced work efficiency and worsening workers' morale.

Properly diagnosing the health complaints starts with investigating the level of IAQ parameters in buildings, including indoor air pollutants, thermal comfort and ventilation system as they are the most likely causes of problems that threaten IAQ. Concurrently, a questionnaire is used to collect information on symptoms of SBS. The MICOP IAQ 2010 will be used as the main reference for questionnaire, sampling strategies and procedures. Thus, all IAQ parameters in this study are measured using calibrated IAQ instruments by IAQ assessor registered with DOSH. The results of IAQ parameters are compared with the acceptable limits or range as stipulated in the MICOP IAQ 2010 and FMA (SHW) 1970.

Both inputs from measurement of IAQ parameters and questionnaire will help to answer all research questions including hypothesis and, to confirm what already has been discovered in the previous studies. This study is also important as it is useful to be used as a reference to improve IAQ level in buildings by improving control measures in order to ensure that all workers are safe, healthy and not affected or continuously affected by the poor IAQ or experienced any SBS in the future.

In Malaysia, studies on IAQ and its connection with SBS by measuring IAQ parameters are still lacking especially for healthcare facilities as there is no published study in the area was found to date. Thus, hospitals are selected as the main study areas with the hopes of providing useful information regarding IAQ and SBS and as a reference to improve IAQ particularly in hospitals or other similar healthcare facilities.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature in seven (7) major topics: (1) Sick Building Syndrome (SBS), (2) The prevalence of SBS symptoms, (3) Factors associated with SBS, (4) Indoor Air Quality (IAQ), (5) IAQ Parameters, (6) Ways to improve IAQ and (7) IAQ and SBS Study.

2.2 Sick Building Syndrome (SBS)

Malaysia is a tropical country with temperature and humidity levels higher than other parts of the world and this happens because of the evaporative effects of the sun. Therefore, many buildings in Malaysia utilize mechanical ventilation and air-conditioning (MVAC) system to maintain their indoor air quality (IAQ). Although the buildings are well equipped with MVAC system, building occupants can still be exposed to risks from having environmental health problems such as Sick Building Syndrome (SBS) especially when maintenance and services of MVAC system are poor.

According to MICOP IAQ 2010, SBS describes situations in which building occupants experience acute health and comfort effects that seem to be linked to time spent in a building, but no specific illness or cause can be identified. Often this condition is temporary as the complainants report relief soon after leaving the building, but some may lead to long-term problems. Many extensive studies have documented common symptoms of SBS to include headache, fatigue, irritated throat, itchy skin, eyes and nose, coughing and nausea.

2.3 The Prevalence of Sick Building Syndrome (SBS) Symptoms

In 1983, the World Health Organization (WHO) has recognized SBS to exist in buildings and associated symptoms are identified as eye, nose and throat irritation, sensation of dry mucous membranes and skin, erythema as well as mental fatigue. According to Burroughs and Hansen (1991), when at least 20% of the building's occupants show symptoms of illness for more than 2 weeks with unknown source, it can be determined that a building had experienced of SBS. Although the symptoms of SBS are generic and varied, which makes it difficult to pinpoint SBS as the cause, Raw (1992) has summarized the symptoms and effects as given in Table 2.1.

Table 2.1

Symptoms and Effects due to SBS

Organ Involved	Symptoms	Effects
Eyes	Irritated, dry/ watering	Itching, tiredness, smarting, redness, burning or has difficulty in wearing contact lenses
Nose	Irritated, runny/ blocked	Congestion, nosebleeds, itchy or stuffy nose
Throat	Dry or sore	Irritation or pharyngeal symptoms, upper airway irritation or difficulty swallowing
Skin	Dryness, itching or irritation	Rash or specific clinical terms such as erythema, rosacea, urticarial, pruritis and xerodermia
Others	Headache, irritability, lethargy and poor concentration	Others

Source: HSE Contract Research Report No. 42/1992, Health Safety and Executive, UK

In addition, according to Godish (1995), building occupants that experienced with SBS symptoms frequently complaint the following:

- Nose and throat: dryness, stuffiness, irritation of the mucous membrane, runny nose, sneezing, odour, taste sensations.
- Eyes: dryness, itching, irritation, watery eyes.
- Skin: dryness and irritation, rash, itching, eczema, erythematic, localized swelling.
- General: tight-chest, abnormal fatigue, malaise, headache, feeling heavy-headed, lethargy, sluggishness, dizziness, nausea.
- Headaches, high frequency of airway infections and cough.
- Hoarseness, wheezing, itching, and unspecific hypersensitivity.
- Nausea & dizziness.

Michael et al. (2000) also mentioned that SBS symptoms can be on lower respiratory (cough, tight chest, wheeze, or difficulty in breathing) and the other symptoms are upper respiratory and mucous membrane symptoms (irritated eyes, nose, sinus, or throat). Zuliza et al. (2016) found that the most prevalent reported symptoms in their study are drowsiness (18.5%), followed by irritated stuffy runny nose (13.4%), headache (10.9%) and skin rashes or itchiness (10.1%).

2.4 Factors Associated with Sick Building Syndrome (SBS)

There are many factors for SBS to occur and among them include lack of fresh air, poorly maintained or operated ventilation systems, disruption of air circulation throughout the occupied spaces, poorly regulated temperature and relative humidity levels and indoor and outdoor sources of contamination. According to study conducted by Armstrong Laboratory (1992), the most frequent causes of IAQ problems are inadequate design or maintenance of the heating, ventilation and air conditioning (HVAC) systems and lack of fresh air and humidity control inside the building. Since Malaysia is a tropical country, heating is not included in the system, thus it has been standardized to MVAC.

Many studies have been conducted previously to show possible risk factors for SBS in buildings where it involves symptoms such as irritation to the eyes, skin and upper airways, headache and fatigue (Godish, 1995). Early in 1990s, Nordstrom, Norback and Akselsson have examined a relation between symptoms of SBS and personal and environmental factors in a hospital. Although this study was done among hospital workers, it had supported earlier findings found in office workers that showed both personal and environmental factors influenced the prevalence of symptoms of SBS. Personal factors may include gender, age and smoking status. Lu Aye, Charters, Chiazor and Robinson (2005) stated that complaint by female was higher than male. In addition, smoking status (Nordstrom et al., 1995) and age of worker which is between 40- 56 years old (Nur Fadilah et al., 2012) were major contributor to the prevalence of SBS among workers.

Environmental factors can be either via human perception or technical measurements. Selected technical measurements are performed to identify the environmental factors causing the symptoms. There are many possible environmental factors that have been suggested such as IAQ, noise, lighting and ergonomics (Apter, Bracker, Hodgson, Sidman & Wing- Yan, 1994; Magnavita, 2013).

IAQ can be defined as the quality of the air inside buildings as represented by concentrations of pollutants and thermal comfort (temperature and relative humidity) conditions that affect the health, comfort, and well- being of buildings occupants. Arya and Rajput (2011) supported that the main factor that generally affecting the IAQ is either from physical or chemical parameters such as temperature, relative humidity, air velocity, amount of fresh air, carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), formaldehyde (HCHO) and respirable particulates (RP).

2.5 Indoor Air Quality (IAQ)

According to Bluyssen (2009), the definition of IAQ can be approached from three points of view: the human, the indoor air of the space and the sources contributing to indoor air pollution. Most standards currently in use mainly address the indoor air of the space and the sources contributing to indoor air pollution. As an example, the MICOP IAQ 2010 has specified that IAQ refers to the air inside a building, including air which is within a room and air which is removed from a room through mechanical means.

The US EPA acknowledges that about 30% of new or renovated buildings have serious IAQ problems, and ranks IAQ as the most prominent environmental problem (Roodman & Lenssen, 1995). Besides, age of the building may significantly affect the level of IAQ inside building. Syazwan et al. (2009) suggested that the poor level of IAQ in old building was higher compared to new building.

Whenever there is complaint on poor IAQ, it can be considered that there is a disturbance in the indoor environment. According to Apter et al. (1994), headache, eye, nose and throat irritation, lethargy and fatigue symptoms have been attributed to indoor air pollutants. Some people can be affected by indoor air pollutants for the longest periods of time but some of them may be more susceptible than others especially those older adults and those who have chronic respiratory or cardiovascular disease.

2.6 IAQ Parameters- Indoor Air Pollutants and Physical Environment Factors

Indoor air problems have increasingly been associated with air quality and must be addressed properly to avoid adverse impact on building occupant’s health, comfort and well-being (Levin, 1995). The quality of indoor air in a building will reduce significantly from day to day if many air pollutants are introduced without being efficiently removed from the building. Michael et al. (2000) supported that elevated level of indoor air pollutants lead to SBS. In general, indoor air pollutants fall into two sources of categories; those that enter the building from the outside and those generated within the building itself. Few examples are as the following:

(a) Biological

Bacteria, fungi, virus, mold, pollen, animal hair, dander and excrement.

(b) Chemical

Household cleaning agents, solvents, adhesives and emissions from furnishings and vehicles

(c) Particles and Aerosols

Solids or liquids that is light enough to be suspended in air. These particles are derived from dust, construction activities, printing, photocopying, smoking, combustion and dust that are brought in together from the visitors' and workers' work clothes and shoes.

2.6.1 Indoor Air Pollutants

Many studies (Norhidayah et al., 2015; Nur Fadilah et al., 2012; Sulaiman et al., 2011; Zuliza et al., 2016) have been conducted to determine the association between IAQ and the symptoms of SBS at developed and developing countries including Malaysia and the most common sources of indoor air pollutants are carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), respirable particulates (RP), formaldehyde (HCHO), air temperature, air humidity and also, ventilation rate (MICOP IAQ 2010).

2.6.1.1 Carbon Dioxide (CO_2)

CO_2 is produced during human respiration, combustion or smoking but the primary indoor source of CO_2 in buildings is human respiration. The indoor concentration of CO_2 is primarily based on the number of occupants in a building and the rate of CO_2 production based on human activities. Though CO_2 is not toxic itself, the amount found in the indoor environment is used as an indicator for human comfort and adequate ventilation. High levels of CO_2 indicate that an insufficient amount of fresh air is being delivered to the occupied areas of the building. According to Michael et al. (2000), elevated level of CO_2 in building may indicate inadequate ventilation.

CO_2 is mostly a threat to health when the concentration is high enough to displace the oxygen, which can lead to discomfort or health complaints. Syazwan et al. (2009) supported that the CO_2 concentration on certain level was major factor contributing to SBS complaints among office workers. Micheal et al. (2000) also added that there is no direct causal link between exposure to CO_2 and SBS symptoms, but relatively CO_2 is nearly correlated with other indoor air pollutants that may cause other symptoms. Meanwhile, the findings from Sulaiman et al. (2011) indicated that CO_2 has strong relationship with other indoor pollutants that cause SBS symptoms.

2.6.1.2 Carbon Monoxide (CO)

CO is normally generated from incomplete combustion. CO is an odourless, colourless, tasteless, and no irritating gas. It is produced whenever carbon-based fuels are burned such as gas, oil, kerosene, wood, or charcoal. CO may accumulate indoors because of smoking, vehicle exhaust and poorly ventilated appliances. Thus, CO level is usually high in a building if the working space is near to the traffic, parking area and cafeteria. CO is a threat to health as it is capable to harm the oxygen binding capacity of haemoglobin which can cause headache, nausea, dizziness, breathlessness, fatigue and death if expose to high level of CO (Weaver et al., 2002).

Although Syazwan et al. (2009) concluded that the SBS was not influenced mainly by CO exposure, many other researchers such as Samet (1993) and Mohd Ezman, Juliana and Nafiz (2013) believe that the CO concentration at higher level (mostly above 10 ppm) was significantly associated with SBS symptoms (dizziness, fatigue and headache).

2.6.1.3 Total Volatile Organic Compounds (TVOC)

TVOCs are emitted as gases from certain solids or liquids. TVOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. TVOCs are emitted by a wide array of products numbering in the thousands. Examples include inks, paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions (Source: US EPA). Non-proven adverse health effects caused by TVOCs in indoor environments include mucous membrane irritation (strongest association), fatigue and difficulty to concentrate and possibility for cancer (Cometto-Muniz, Cain & Abraham, 2004; Pouli et al., 2003; Wolkoff, Wilkins, Clausen & Nielsen, 2006).

Norback et al. (1995) suggested that indoor TVOCs may cause asthma-like symptoms. Sulaiman et al. (2011) supported that TVOCs are important indoor air factors that can influence the prevalence of SBS. Thus, the emission of TVOCs should be lower than acceptable limits of 3 ppm (MICOP IAQ 2010), to minimize symptoms related to SBS.

2.6.1.4 Formaldehyde (HCHO)

The most familiar volatile organic compound to the researchers that has been associated with indoor air pollution is HCHO. HCHO is used in numerous building and furnishing materials such as bonding/laminating agents, printing inks, adhesives, paper/ textiles, foam insulation, carpets and fabrics. It is also a by-product of combustion and certain other natural processes. Thus, it may be present in substantial concentrations both indoors and outdoors.

HCHO, a colourless, pungent-smelling gas, can cause watery eyes, burning sensations in the eyes and throat, nausea, and difficulty in breathing in some humans exposed at elevated levels (above 0.1 ppm). High concentrations may trigger attacks in people with asthma. There is evidence that some people can develop sensitivity to HCHO. It has also been shown to cause cancer in animals and may also cause cancer in humans. Health effects include eye, nose, and throat irritation as well as lower airway and pulmonary effects (Samet, Marbury & Spengler, 1988).

Findings from study by Norback, Bjornsson, Janson, Widstrom and Boman (1995) suggested that indoor TVOCs and HCHO may cause asthma-like symptoms. Thus, the emission of both should be as low as reasonably achievable to minimize symptoms related to asthma due to indoor air pollution.

2.6.1.5 Respirable Particulates (RP)

Respirable particulates refer to dust particles that are small enough to penetrate the nose and upper respiratory system and deep into the lungs. Particles that penetrate deep into the respiratory system are generally beyond the body's natural clearance mechanisms of cilia and mucous and are more likely to be retained. The amount of dust emitted by these activities depends on the physical characteristics of the material and the way in which the material is handled. The adverse effect of respirable particulates is normally associated with increased respiratory symptoms (Simoni et al., 2002).

The main indoor respirable particulates are outdoor air, environmental tobacco smoke (ETS), fibres (presence from carpets, curtains, insulation and asbestos), printing, photocopying and dust that is brought in together from the worker's or visitor's work clothes and shoes. According to Mohd Ezman et al. (2013), SBS symptoms are significantly associated with high level of respirable particulates.

2.6.2 Physical Environment Factors

There are many physical environmental factors such as thermal factors, noise, vibration and light were considered as important physical factors (Levin, 1995). However, the most common factors are type of ventilation system, high room temperature, low supply of outdoor air, and low air humidity. These factors have been shown to influence the prevalence of SBS symptoms (Apter et al. 1994; Hodgson, 1995).

2.6.2.1 Temperature and Relative Humidity

Most study has stated that the extreme high or low temperature and humidity levels in the building will dissatisfy its occupants and make them uncomfortable. Thus, uniformity of temperature and relative humidity is important to provide comfort. Relative humidity refers to the amount of water vapours in the air. Most people work comfortably at temperature between 23-26°C and the optimum comfort range for relative humidity is 40 % to 70% as recommended in the MICOP IAQ 2010. Based on this MICOP IAQ 2010, it was stated that:

- Low humidity can cause dryness of the eyes, nose and throat and may also increase the frequency of static electricity shocks.

- High humidity, above 80%, can be associated with fatigue and report of stuffiness.

Sulaiman et al. (2011) concluded that the temperature and humidity are important indoor factors that can influence prevalence of SBS. The conclusion observed in this research is also similar to study by Syazwan et al. (2009).

2.6.2.2 Ventilation Rate (Air change per hour, ACH)

According to Michael et al. 2000, inadequate ventilation per person in buildings can significantly lead to the SBS prevalence. Burge (2004) has mentioned that many studies have disclosed that the prevalence of SBS is higher in buildings with mechanical ventilation system compared to normal ventilation system as SBS is influenced by the type of ventilation system. Air changes per hour (ACH) will be used to measure the ventilation rate. According to Factories and Machineries (Safety, Health and Welfare) Regulations 1970, the number of ACH for areas which generate little or no heat, smoke or fume (office) shall not be less than 10. The ACH recommended in ASHRAE for typical office environment is between the range of 6 to 20.

Increasing ventilation rate or improvements in ventilation effectiveness basically help dilute pollutants generated within the building itself and would be expected to decrease the prevalence of selected SBS symptoms by up to 70-85% (Michael et al. 2000). Syazwan et al. (2009) suggested that increases in the ventilation rates per person among typical office buildings will, on average, significantly reduce prevalence of SBS, even when these buildings meet the existing ASHRAE ventilation standards for office buildings.

2.7 Mechanisms for IAQ Improvement

From the literatures review, it can be concluded that there are three major ways to create a healthy or further improve indoor environment. These include:

- acceptably low levels of indoor air pollutants (chemical and biological pollutants) (Nur Fadilah et al., 2012)
- proper ventilation system maintenance and adequate ventilation of fresh air supply (Nur Fadilah et al., 2012; Syazwan et al., 2009)
- adequate temperature and relative humidity (Syazwan et al., 2009)

Thus, it is very important to ensure that buildings are designed to meet basic human requirements for a healthy and comfortable indoor environment by referring to any established standards or guidelines while at the same time ensuring low energy consumption.

2.8 IAQ and SBS Study

SBS is set out to become more prevalent as companies continue to expand, with more people working in indoor environments. With the fact that most people spend 90% of their time indoor, a good IAQ is really important to ensure that SBS does not occur in the future.

Existing literatures have shown many factors associated with SBS relate to indoor air pollutants, MVAC system, temperature and humidity inside buildings. Norhidayah et al. (2013) suggested that both accumulation of indoor air pollutants and ventilation system within indoors were important factors of SBS. Thus, measurement and analysis of indoor air pollutants and other physical parameters are used to understand the current status of IAQ and its relationship with SBS in the buildings served by a MVAC system.

Despite of many factors derived from existing studies, there were generally consistent findings that show IAQ has significant relationship with SBS especially in air-conditioning buildings (Khushbu & Rushabh, 2016). Burge (2004) has previously supported the relationship as most of the complaints pertaining to SBS were raised by occupants at buildings equipped with air-conditioning system. Buildings can be defined as having SBS if 20% of the occupants show symptoms of SBS (Burroughs & Hansen, 1991). According to Apter et al. (1994), headache, eye, nose and throat irritation, lethargy and fatigue symptoms have been attributed to indoor air pollutants.

In 2015, a study was conducted to assess the association of SBS with individual factors and indoor air pollutions among workers in two office buildings in Tehran, Iran (Jafari et al., 2015). The association between individual factors and SBS symptoms was examined using a valid questionnaire meanwhile the association between indoor air pollutions were measured using calibrated instruments. Their study showed that malaise and headache were the most common SBS symptoms whereas throat dryness, cough, sputum, and wheezing were less prevalent among workers in both offices. A relationship was found between the office temperature and some of SBS symptoms (sneezing, skin redness, itchy eyes, and headache), throat dryness, dyspnoea, and malaise and relative humidity showed a significant association with sneezing, skin redness, and pain of the eyes and exposure to CO_2 may cause dizziness, headache, nausea and nasal irritation.

In Malaysia, several studies were conducted to find a significant relationship between IAQ parameters and SBS symptoms. These studies reported that CO_2, temperature, RH, TVOC (Sulaiman et al., 2011), RP, CO (Mohd Ezman et al., 2013) and HCHO (Norback et al., 1995) relate to the prevalence of SBS symptoms.

Although literature tends to suggest that the level of IAQ parameters in buildings is one of the good indicators to determine the prevalence of SBS symptoms, there were some researchers that claimed the opposite. Ooi et al. (1998) and Norhidayah et al. (2013) found that the measurements of IAQ or ventilation were not significantly associated with SBS symptoms. Most of the IAQ parameters monitored by them in the area with health complaints remained within acceptable limits. Arya and Rajput (2011) also believed that lower level (below the applicable limits) of physical environmental factors were significantly associated with SBS symptoms.

More study is thus needed especially in Malaysia to increase understanding of SBS and whether or not it is influence by IAQ (Norhidayah et al., 2013). This will allow adequate actions to be successfully planned and implemented which will help to reduce symptoms related to SBS, ensuring a comfort and healthy working environment thus improving the quality of life. In addition, the findings could also help to increase the level of awareness on IAQ and at the same time, to confirm what already has been discovered in the previous studies. If IAQ problems are to be taken with less attention, this could escalate more problems in the future where workers will start to report symptoms of SBS and may lead to increased absenteeism, reduced work efficiency and worsening employee morale.

CHAPTER 3: METHODOLOGY

3.1 Introduction

Chapter 3 describes the research framework of the study together with the research questions and hypothesis to be tested. The research design followed with selection of measurement variables. Sampling and discussion on the methods used for the data collection were also described. The data are collected through three data collection techniques namely questionnaire, walkthrough survey and environmental measurements. In this chapter also, the techniques of data analysis were further discussed and elaborated.

3.2 Research Framework

The data collection methods were identified to determine the current status of IAQ in buildings, compare the results with acceptable limits or range as stipulated in the recognized standards and determine if there is a relationship between IAQ and SBS symptoms experienced by workers. The proposed research model as shown in figure 3.1 was developed to show the linkage of relationship between the independent and dependent variables.

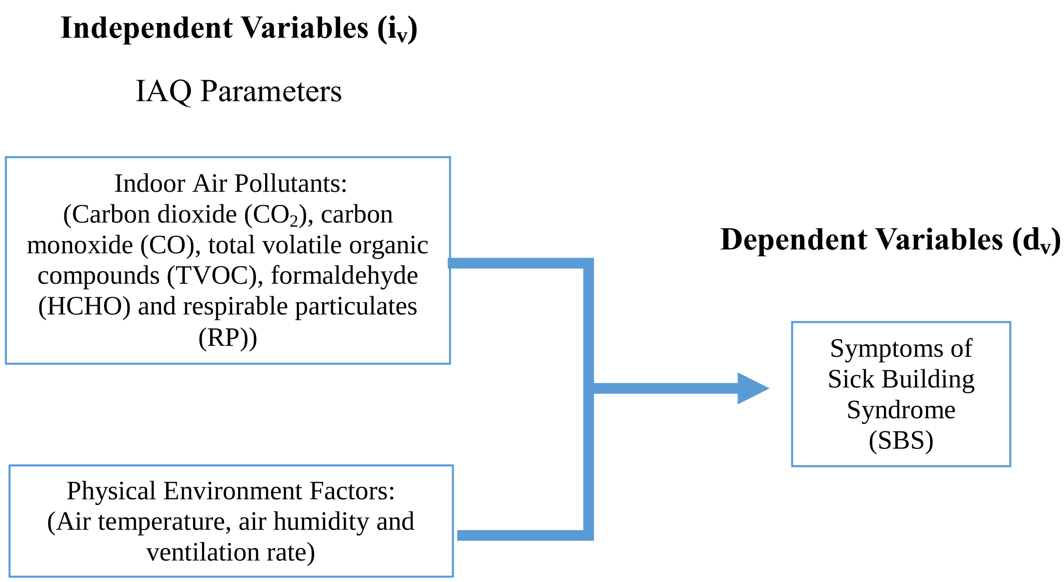

Figure 3.1. The relationship between independent variables and dependent variables in the research.

The study involved two (2) hospitals in two (2) different states, Selangor and Pahang. They were chosen as there was no “Prescribed Activities” that had taken place in both hospitals during the study. In the MICOP IAQ 2010, the “Prescribed Activities” means any activity that could pose health hazard to the occupants, including but not limited to:

a) applying or removing floor coverings including carpeting, floor tiles and other surfaces
b) applying wall coverings
c) painting or the application of similar coatings;
d) cleaning carpets
e) applying floor finishing and stripping products
f) applying pest control products
g) applying caulking, sealing, or glazing compounds

The researcher was not allowed to disclose information on the actual name and location of these two hospitals by both project owner and building management. For the purpose of this study, these hospitals were identified as Hospital Selangor and Hospital Pahang. Hospital Selangor has operated for almost 10 years, while Hospital Pahang has operated for more than 22 years. These hospitals were selected based on the years of operation and long history of occupancy, which can be considered as old and new building and both are under the same external company who is responsible for their facility engineering maintenance services.

Both hospitals have many departments with different functions. It is thus impossible to cover all areas due to cost and time constraints. For this study, the selection of departments to be studied was based on the type of ventilation, type of workstation and average of time workers spend in the workplace. On top of that, the requirement from the hospitals and several complaints received by the workers were also considered. According to MICOP IAQ 2010, the building management should conduct an IAQ assessment when complaints are received where the problem cannot be resolved. Therefore, the study areas are restricted to area served by the individual MVAC system and workers from five (5) departments; Surgical Outpatient Department (SOPD), Paediatric Department (PD), Medical Records Department (MRD), Obstetrics and Gynaecology Department (OGD) and Orthopaedic Department (OD).

In order to achieve the objective which is to study the symptoms of SBS, a standardized self-administered questionnaire was distributed to workers in the five (5) listed departments. On the other hand, the current status of IAQ inside of the building was determined by measuring both indoor air pollutants and physical environment factors consist of CO_2, CO, TVOC, HCHO, RP, air temperature, air humidity and ventilation rate.

3.3 Hypotheses/ Propositions Development

The research questions for this study are as follows:

1. What is the current status of IAQ inside the buildings?
2. Does existing MVAC system adequate to maintain good IAQ?
3. What are the common symptoms of SBS among workers in hospitals?
4. What is the difference in the reporting of SBS symptoms by workers between Hospital Selangor and Hospital Pahang?
5. What is the difference in the prevalence of SBS among workers between Hospital Selangor and Hospital Pahang?
6. Is there any relationship between IAQ and symptoms of SBS experienced by workers?

The above research questions will be answered together with the following hypothesis:

H_{1A}: There is a significant relationship between the prevalence of symptoms of SBS and indoor air quality (IAQ)

3.4 Research Design

This study specifically examines the influence of IAQ on SBS among workers in the hospitals. The study was designed within quantitative research paradigm. A quantitative approach was observed in the following aspects of study:

1. A questionnaire was used as a tool to collect information on symptoms of SBS
2. Measurement of IAQ parameters through calibrated equipment

Symptoms of SBS are the dependent variable (d_v) for this study while IAQ parameters are the study's independent variables (i_v). The IAQ parameters are represented by the measurement of both indoor air pollutants (CO_2, CO, TVOC, HCHO and RP) and physical environment factors (air temperature, air humidity and ventilation rate).

3.5 Operational Definition

3.5.1 Building

Refers to hospital building served by mechanical and ventilation air conditioning (MVAC) system (Malaysian Industry Code of Practice on Indoor Air Quality, MICOP IAQ 2010)

3.5.2 Sick Building Syndrome (SBS)

The SBS comprises a group of symptoms of unclear etiology (Burge, 2004). Common medical symptoms associated with SBS include fatigue, headache, nausea, dizziness, poor concentration, irritated eyes or nose, dry skin or throat and coughing (Godish, 1995; Michael et al., 2000; Raw, 1992). Any individual will be defined as having SBS if they had at least one symptom of SBS symptoms which appear at least once in a week (Nordstrom et al., 1995; Syazwan et al., 2009).

3.5.3 Environmental Factors

In this study, environmental factors refer to indoor air pollutants, physical environmental factors and ventilation performance indicator (Norback, 2009).

3.5.4 Physical Environment Factors

Refers to thermal environment, the surrounding environment within which the occupants work. In this study, physical parameters are measured by monitoring the level of air temperature and humidity (MICOP IAQ 2010) and ventilation performance indicator (Norback, 2009).

3.5.5 Indoor Air Pollutants

Refers to the toxic emissions either from indoor (e.g carpets, housekeeping chemicals) or outdoor (e.g nearby construction, factory) sources. In this study, indoor air pollutants are measured by monitoring the level of CO_2, CO, TVOC, HCHO and RP (MICOP IAQ 2010).

3.5.6 Ventilation Performance Indicator (VPI)

VPI refers to the process of supplying or removing air from any enclosed space by mechanical means. In this study, VPI is measured by monitoring the level of CO_2 in the building (MICOP IAQ 2010) and ventilation rate (Michael et al., 2000). Air changes per hour (ACH) will be used to measure the ventilation rate (ASHRAE, 2001) and all results will be compared with acceptable limit of 10 ACH as stipulated under Factories and Machineries (Safety, Health and Welfare) Regulations 1970.

3.5.7 Air Changes per Hour (ACH)

Air changes per hour (ACH) is generally used as a way to measure the dilution ventilation rate. According to US Occupational Safety and Health Administration (OSHA), the ACH is the number of times one volume of air is replaced in the space per hour.

3.5.8 Acceptable Limits or Range

IAQ status in buildings is acceptable if the value of one or more physical parameters is within the range for specific physical parameters and/ or the concentration of one or more indoor air pollutants are well below the maximum limits as specified in the MICOP IAQ 2010.

3.6 Measurement of Variables/ Instrumentation

Cross-sectional study was chosen as research design, whereby it was carried out at a particular time in three (3) phases. These phases are:

3.6.1 First Phase: Self-administered Questionnaire

In the first phase, a standardized self-administered questionnaire was utilized to gather data on prevalence of the SBS symptoms. This questionnaire was distributed to the selected workers. This questionnaire is actually adopted from MICOP IAQ

2010, which originally developed by the Department of Occupational Health in Orebro Sweden and well-known as MM40. This questionnaire has been used in Sweden for some years and most of the questions have been validated by many researchers (Andersson & Stridh, 1991; Nordstrom et al., 1995; Zuliza et al., 2016). The MM40 is a common used tool for investigating indoor air problems at workplaces and it is used worldwide including Malaysia who has adopted and adapted the questionnaire to be included in the MICOP IAQ 2010. The content of the questionnaire from MICOP IAQ 2010 was tested in term of clarity of the questions by expert from the Faculty of Medicine and Health Science, Universiti Putra Malaysia (UPM). A pilot study was done to 30 laboratory workers in the UPM where the reliability was found to be good as the value of Cronbach's alpha is 0.72 (Zuliza et al., 2016).

The original questionnaire, MM40 composed of closed-ended questions and contained questions on personal factors, indoor air complaints, symptoms included in the SBS and the psychosocial climate at the workplace. However, only questions on symptoms included in the SBS were assessed as the main objective is to find a relationship between IAQ (by means of the technical measurements, not by human perceptions) and symptoms of SBS experienced by workers. There are twelve (12) questions on symptoms included in the SBS. Appendix A shows survey form used by this study.

3.6.2 Second Phase: Walkthrough Survey

In the study's second phase, a walkthrough survey to the entire space of study areas was conducted with the aim to collect available basic information on the potential factors which affect IAQ (e.g. number of occupants, MVAC system, pollution pathways and potential pollutant sources). A short discussion with the maintenance team and the workers was done to obtain their general feedback related to indoor air quality issues at the study areas. The workplace inspection was carried out by referring to the given checklist. The checklist was adopted from the MICOP IAQ 2010 to support in providing any relevant information pertaining to the findings of the study.

3.6.3 Third Phase: Environmental Measurements

Finally, the third phase which involves technical measurements using direct reading equipment was carried out. The following IAQ parameters were covered in this study:

(a) 5 indoor air pollutants (CO_2, CO, TVOC, HCHO and RP)

(b) 3 physical environment factors (Air temperature, relative humidity and ventilation rate)

All direct reading equipment to monitor the IAQ parameters are shown in Table 3.1 and all of them are calibrated according to the manufacturer specifications to minimize any measurement uncertainty by ensuring the accuracy of those equipment.

Table 3.1

IAQ Direct Reading Equipment

	IAQ Parameters	Analytical Equipment	Brand/ Model No.	Detection Range (Accuracy)
1.	Carbon Dioxide (CO_2) and Carbon Monoxide (CO) (including Temperature (°C) and Relative Humidity (RH))	Portable TSI IAQ Meter	TSI 7565- X, and TSI 982	CO_2: 0 to 5000 ppm (± 3% of reading or ± 50 ppm) CO: 0 to 500 ppm (± 3% reading or ± 3 ppm) °C: 0 to 60 °C (± 0.6 °C) RH: 5 to 95% (± 3%)
		Portable Multi-gas Meter	Gray Wolf TG501	CO: 0 to 750 ppm °C: -10 to 70 °C (± 0.3 °C)
2.	Total volatile organic compounds	Handheld VOC Detector	Ion Science ProCheck Tiger	1 ppb to 20,000 ppm (± 5% of reading)
		ppbRAE 3000 Portable Gas Detector	RAE	1 ppb to 10,000 ppm (± 3% of reading)
3.	Formaldehyde	Portable Environmental Sensor's Formaldehyde Meter	PPM Technology	0 to 10 ppm (10% at 2 ppm)
4.	Respirable Particulates	TSI Dust Track Particle Monitor	Dusttrak II TSI 8534	0.001 to 150 mg/m^3
5.	Air Flow	Portable TSI IAQ Meter	TSI 960	Flow: 0 to 9,999 ft/min (±3% of reading or ±3 ft/min) °C: -18 to 93 °C (± 0.3 °C)
		TSI Air Flow Hood	TSI Accubalance Air Capture Hood 8380	25 to 5,000 ft/min (±3% of reading ±7 ft/min)

All results from the environmental measurement were compared with the acceptable limits or range as stipulated in the Malaysian Industry Code of Practice on Indoor Air Quality 2010 (MICOP IAQ 2010) and Factories and Machineries (Safety, Health and Welfare) Regulations 1970 (FMA(SHW) 1970). Table 3.2 and 3.3 summarized the acceptable limits or range for indoor air pollutants and physical environment factors.

Table 3.2

MICOP- IAQ 2010: List of Indoor Air Pollutants and the Acceptable Limits

Indoor Air Pollutants	Acceptable limits		
	ppm	**mg/m^3**	**cfu/m^3**
Chemical Pollutants			
a) Carbon Monoxide	10	-	-
b) Formaldehyde	0.1	-	-
c) Respirable Particulate	-	0.15	-
d) Total Volatile Organic Compounds (TVOC)	3	-	-
Ventilation performance indicator			
Carbon Dioxide	C1000	-	-

Table 3.3

Acceptable Range for Specific Physical Environment Factors

Parameter	Acceptable Range	Standard
Temperature	23 – 26 °C	MICOP- IAQ 2010
Relative Humidity	40 – 70%	MICOP- IAQ 2010
Ventilation Rate (air changes per hour, ACH)	Not less than 10	FMA(SHW) 1970

As a summary, the results of the questionnaire facilitated to identify the common SBS symptoms for the workers, which were expected based on the walkthrough and the environmental measurement results.

3.7 Sampling

3.7.1 Questionnaire

For this study, only workers from SOPD, PD, MRD, OGD and OD were considered. The required sample size was determined based on the proximity of the worker's workstations (according to the zoning area) to the IAQ parameters sampling locations. Worker closest to the sampling location was selected first and the selection continued, concentric circles from the sampling location. The required sample size is determined using Krejcie and Morgan (1970)'s table as shown in Table 3.4

Table 3.4

Required Sample Size

Building (only for SOPD, PD, MRD, OGD & OD)	**No. of Workers Available During Measurement Day**	**Required Sample Size (Confidence 95%) Margin of error 5%**
Hospital Selangor	50	44
Hospital Pahang	55	48

In line with Roscoe's rules of thumb that indicated a sample size larger than 30 and less than 500 are appropriate for most research, 50 questionnaires were distributed to workers at each hospital during working hours (8.00 am until 5.00 pm). Non-probability sampling (convenience sampling) was used to ensure the availability and the quickness way to gather information due to busy schedule of staff working at those targeted departments.

3.7.2 Environmental measurements

At minimum, the required numbers of sampling point are given in Table 3.5. This recommended minimum number of sampling points is in accordance with MICOP IAQ 2010.

Table 3.5

Minimum Number of Sampling Points

Total floor area (served by MVAC system) (m2)	Minimum number of sampling points
< 3,000	1 per 500 m^2
3,000 - < 5,000	8
5,000 - < 10,000	12
10,000 - < 15,000	15
15,000 - < 20,000	18
20,000 - < 30,000	21
≥ 30,000	1 per 500 m^2

An intermittent measurement strategy based on eight (8) hours of exposure representing normal business hours (8.00 am until 5.00 pm) was practiced. The average of half-hour measurements conducted at four time-slots was conducted where the operation pattern of the hospitals was taken into account. Thus, the four time-slots selected are morning, afternoon before lunch, afternoon after lunch and evening as shown in Table 3.6.

Table 3.6

Sampling Slots vs. Time Interval

Sampling Slot	Time Interval
Slot 1- Morning	0800- 1000
Slot 2- Afternoon (before lunch)	1000- 1200
Slot 3- Afternoon (after lunch)	1300- 1500
Slot 4- Evening	1500- 1700

For this study, the selections of sampling points were based on the requirement from the hospitals and segregation places such as main offices rooms, working area and surrounding of the incoming and outgoing patients' area. Besides, the design of MVAC system and the study of pollutant pathways were also considered.

3.8 Data Collection Procedures

The self-administered questionnaire was distributed to the selected workers. Originally, this questionnaire (MM40) is developed by the Department of Occupational Health in Orebro Sweden and then adopted by DOSH to be included in the MICOP IAQ 2010. On the other hand, environmental measurements were conducted using appropriate equipment (Table 3.1) and all of them were calibrated according to the manufacturer specifications to minimize any measurement uncertainty. Standard Operating Procedures (SOP) was followed strictly and method of calculation for the IAQ was guided by the IAQ assessor to ensure quality of the data taken.

During the measurement day, all of equipment were set to run simultaneously using specific procedure by MICOP IAQ 2010 and ventilation measurement using guideline given by ASHRAE. Duration of sampling is 30 minutes for each time slot (morning, afternoon- before lunch, afternoon after lunch and evening) from 8.00 am until 5.00 pm to represent the IAQ status inside the selected study areas for the whole day. The zoning areas were determined by the IAQ assessor and equipment were basically located in the centre of the location in the study areas at 75cm- 120cm above the floor.

The simplified process of an integrated IAQ study was summarized in Figure 3.2.

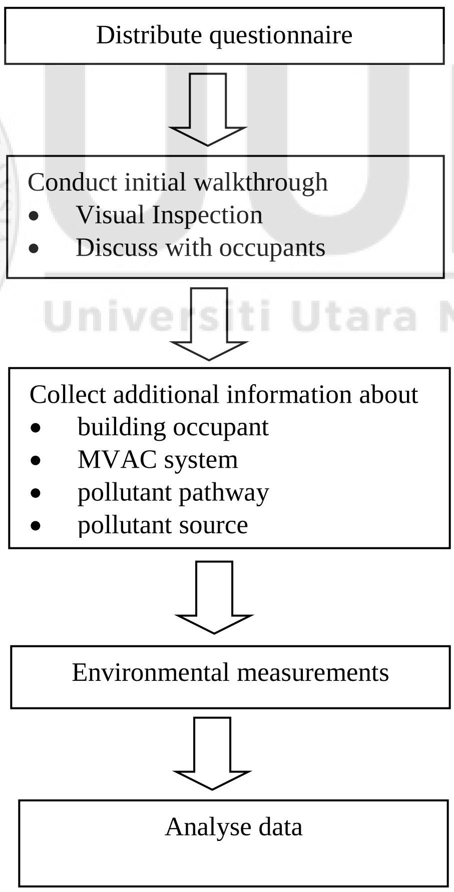

Figure 3.2. Flowchart on Data Collection Procedures

In general, the explanation for the above flowchart is as follows:

1) Distribute worker's questionnaire with the main objective to study prevalence of the SBS symptoms (Phase 1)
2) Conduct initial walkthrough and site investigations to gain basic information on the factors which affect IAQ such as MVAC system, number of occupants, air pollutant pathways and potential pollutant sources. A simple checklist will be used to assist in collection information (Phase 2)
3) Conduct environmental measurements during normal business activity (Phase 3) with the following considerations:
    a) Sources of indoor air pollutants
    b) Worker's exposure to air pollutants, either from indoor or outdoor sources
    c) Any activity that could pose health hazards to the occupants such as renovation and construction-related work including housekeeping
    d) Adequacy of mechanical ventilation at the place of work
4) Analyse all raw data obtained from the phase 1, 2 and 3 using various techniques as discussed in Section 3.9

3.9 Data Analysis Techniques

The questionnaire contains twelve (12) questions on symptoms included in the SBS that occurred during the last three (3) months, where two of them deal with dermal symptoms and the rest covers eye irritation, nasal, throat, facial dermal and general symptoms. For each symptom, an answer was given according to one of three options namely as "yes often (every week), "yes sometimes" and "no never". The individual worker was defined as having SBS if they had at least one symptom of SBS symptoms and the symptoms appear at least once in a week (Nordstrom et al., 1995; Syazwan et al., 2009).

All technical measurements for IAQ parameters (indoor air pollutants and physical environment factors) were averaged and compared either with the acceptable limits or ranges of MICOP IAQ 2010 or acceptable limit of Factories and Machineries (Safety, Health and Welfare) Regulations 1970.

Results of both questionnaire and environmental measurements were recorded in an excel sheet in order to generate the required graphs and pie charts to ensure that all the tested parameters are appropriately compared, and that any trend in the results is noted and clearly elaborated. A basic Statistical Package for Social Science (SPSS) software was used to analyse the raw data in order:

1. to make a comparison of reported SBS symptoms by workers in different hospitals
2. to make a comparison of the prevalence of SBS among workers in different hospitals
3. to find a relationship between symptoms of SBS and measured physical environment.

The value of $p < 0.05$ is set as a significant level for data analyses. One (1) hypothesis is generated in this research, thus chi-square test (χ 2) was used to test for it.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This research tries to determine the current status of IAQ in buildings compares the results with acceptable limits or range as stipulated in the MICOP IAQ 2010 and determines whether there is positive relationship between IAQ and SBS symptoms experienced by workers.

This chapter will elaborate more on the findings gathered of this study. In general, this chapter is comprised of seven major sections. The first section addresses the current status of IAQ in hospitals. The second section details the adequacy of the MVAC system in maintaining good IAQ. The third section of this chapter reports the common symptoms of SBS in hospitals. This is followed by the fourth and fifth section, which discuss the comparison of reported SBS symptoms and the comparison of the prevalence of SBS in hospitals. The association between IAQ and SBS is presented in the sixth section. Finally, the last section covers the significance of findings in light of what was already has been discovered about the research problem being investigated, and to explain any new understanding or insights about the research problem.

4.2 The Current Status of IAQ in Hospitals

4.2.1 Sampling Points Overview

The environmental measurements were completed for Hospital Selangor and Hospital Pahang in November and December, where the selected five departments from each hospital are located. Hospital Selangor has started its operation in 2006 and it is considered as new hospital compared to Pahang (old hospital) which has started its operation in 1985. The objectives of the environmental measurements are as follows:

a) To determine and quantify the five (5) commonly encountered indoor contaminants for CO_2, CO, RP, HCHO and TVOC and to compare with maximum exposure limits listed in the MICOP IAQ 2010

b) To determine the temperature and relative humidity in the building and to compare with the MICOP IAQ 2010

c) To determine the air changes per hour (ACH) and to compare with the Malaysian Factories and Machinery (Safety, Health and Welfare) Regulations 1970

Basically, sampling points were based on requirement from the hospitals, findings from the walkthrough survey and short interview with the personnel. Besides, the segregated places such as main offices rooms, working area and surrounding of the incoming and outgoing patients' area, the design of MVAC system and the study of pollutant pathways were also considered. As a summary, all sampling points were described in Table 4.1 until 4.4.

Table 4.1 and 4.2 described all sampling points for IAQ parameters at Hospital Selangor meanwhile Table 4.3 and 4.4 described all sampling points for IAQ parameters at Hospital Pahang.

Table 4.1

List of Sampling Points Description (indoor air pollutants, temperature and relative humidity) for Hospital Selangor

Point	**Department**				
	SOPD	**PD**	**MRD**	**OGD**	**OD**
1	Waiting Area	Waiting Area	Waiting Area	Waiting Area	Waiting Area
2	Room 1	Head of Nurse's Room	Room 1	Examination Room 1	Procedure Room
3	Supervisor's Room	Assessment Room	Room 2	Examination Room 2	Plaster Room
4	Room 2	Room 1	Room 3	Examination Room 3	Room 1
5	Room 3	Room 2	Room 5	Examination Room 4	Room 2
6	Room 4	Room 3	Room 7	Examination Room 5	Room 3
7	Room 5	Room 4	Room 9	Examination Room 6	Room 5
8	Room 10 (TR 2)	Room 5	Waiting Area 2	Examination Room 7	Room 6
9	Room 9 (TR 1)	Room 6	Room 10	Examination Room 8	Room 7
10	Waiting Area 2	Room 7	Room 11	Assessment Room	Room 8
11	Room 6	Room 8	Room 12	Health Education Room	Room 10
12	Room 7	Room 9	Room 13	PACs Area	
13	PAC Room	Room 10	Room 14	Treatment Room 1	
14	Staff Room		Room 16	Staff Room	

Table 4.1 (Continued)

Point	Department				
	SOPD	PD	MRD	OGD	OD
15	Counter 1		Nebulizer Room	Head of Nurse's Room	
16	Counter 2			Examination Room 9	
17	Room 8			Breastfeeding Room	
18				Interview Room	
19				Blood Pressure and Weight Management Room	

Table 4.2

List of Sampling Points Description (air changes per hour, ACH) for Hospital Selangor

Point	Department				
	SOPD	PD	MRD	OGD	OD
1	Room 8	Waiting Area (Behind)	Room 3	Room 4	Room 10
2	Room 7	Head of Nurse's Room	Room 4	Procedure Room	Treatment Room
3	Room 6	Room 1	Room 6	Room 5	Medical Officer's Room
4	Waiting Area (Behind)	Injection Room	Room 2	Room 6	Plaster Room
5	Room 10	Room 10	Room 1	Room 3	Room 8
6	Room 9	Assessment Room 1	Supervisor's Room	Room 7	Room 7
7	Room 5	Assessment Room 2	Room 8	Room 2	Room 6
8	Room 4	Room 2	Room 9	Room 8	Room 5

Table 4.2 (Continued)

Point	Department				
	SOPD	PD	MRD	OGD	OD
9	Room 3	Room 3	Waiting Area (Behind)	Room 10	Room 4
10	Room 2	Room 4	Medical Officer's Room	Waiting Area	Room 3
11	PACs Room	Room 6	Room 16	Weighing Room	Room 2
12	Room 1	Room 7		Interview Room	Room 1
13	Waiting Area (Front)	Room 8		Breastfeeding Room	Room 9
14	Supervisor's Room	Waiting Area (Front)		Room 9	Waiting Room
15				Treatment Room 1	
16				Assessment Room	

Table 4.3

List of Sampling Points Description (indoor air pollutants, temperature and relative humidity) for Hospital Pahang

Point	Department				
	SOPD	PD	MRD	OGD	OD
1	Waiting Area	Waiting Area	Reception	Procedure Room	Room 6
2	Research Room	Examination Room	Office	Ultrasound Room	Room 7
3	Room 3	Head of Nurse's Room	File Room (report)	Treatment Room	Room 8
4	Room 4	Room 1	File Room (ML)	Counselling Room	Room 9
5	Room 5	Room 2	Office 2	Room 9	Meeting Room
6	Room 6	Room 4	File Room 1	Room 8	Room 10

Table 4.3 (Continued)

Point	Department				
	SOPD	PD	MRD	OGD	OD
7	Room 7	Room 3	Manager's Office	Room 7	Room 11
8	Room 8	Room 6	File Room 2	Room 6	Office
9	Head of Nurse's Room	Room 5	Stationery Store	Room 5	Waiting Area
10	Room 9	Room 8	Record Received Area	Room 4	Room 1
11	Room 10		Chief Clerk's Room	Waiting Area	Room 2
12	Room 11		File Room 3	Head of Nurse's room	Room 3
13			Middle Halfway	Room 3	Room 4
14			Active File Room	Room 2	Pantry
15			File Room 4	Interview Room	Room 5
16			Pantry	Room 1	
17				Seminar Room	17
18				Treatment Room	18
19				Room 7	19
20				Echo Room	20

Table 4.4

List of Sampling Points Description (air changes per hour, ACH) for Hospital Pahang

Point	Department				
	SOPD	PD	MRD	OGD	OD
1	Staff Records Room	Waiting Area	Waiting Area	Waiting Area	Seminar Room

Table 4.4 (Continued)

Point	Department				
	SOPD	PD	MRD	OGD	OD
2	Discussion Room	Physical Assessment Room	General Office	Examination Room 1	Treatment Room
3	Examination Room 11	Examination Room 1	Management Office Assistant's Room 1	Examination Room 2	Examination Room 9
4	Examination Room 10	Examination Room 3	Record Received Room	Examination Room 3	Examination Room 8
5	Examination Room 9	Examination Room 5	File Room (report)	Examination Room 4	Examination Room 7
6	Head of Nurse's Room	Examination Room 8	Stationary Room	Examination Room 6	Examination Room 6
7	Examination Room 6	Examination Room 7	Head of Nurse's Room	Examination Room 8	Examination Room 5
8	Waiting Area	ECHO Room	File Room	Counselling Room	Examination Room 4
9	Health Education Room	Staff Room	Management Office Assistant's Room 2	Ultrasound Room	Examination Room 3
10	Physical Assessment Room		Research Room	Treatment Room	Examination Room 2
11	Treatment Room			Examination Room 9	Examination Room 1
12	Examination Room 3			Examination Room 7	Waiting Area
13	Examination Room 4			Examination Room 5	
14	Examination Room 5			Head of Nurse's Room	
15	Examination Room 7			Treatment Room	
16	Examination Room 8			Seminar Room	

4.2.2 Environmental Measurement Results

The zoning measurement areas were determined and IAQ equipment was basically located in the centre of the location in the study areas at 75 - 120 cm above the floor. Direct monitoring data were obtained to determine the concentrations of indoor air pollutants (CO_2, CO, HCHO, TVOC and RP), temperature, relative humidity and air change per hour (ACH) at the studied area. An intermittent measurement strategy based on eight (8) hours exposure representing normal business hours (8.00 am until 5.00 pm) was practiced. The strategy was, the average of half-hour measurements conducted at four time-slots (morning, afternoon before lunch, afternoon after lunch and evening) was conducted where the operational pattern of the hospitals was taken into account. Then, results from these four time-slots were averaged. The direct reading monitoring results for each sampling points from the selected department at Hospital Selangor and Hospital Pahang are shown in Table 4.5 until 4.14. The average results for each IAQ parameters were also included in the table and they are compared with the acceptable limits or range from the established standards in Malaysia, namely as MICOP IAQ 2010 and FMA(SHW) 1970. As a summary:

1) Table 4.5 and 4.10 - IAQ Measurement Results for SOPD, Hospital Selangor and Hospital Pahang respectively
2) Table 4.6 and 4.11 - IAQ Measurement Results for PD, Hospital Selangor and Hospital Pahang respectively
3) Table 4.7 and 4.12 - IAQ Measurement Results for MRD, Hospital Selangor and Hospital Pahang respectively
4) Table 4.8 and 4.13 - IAQ Measurement Results for OGD, Hospital Selangor and Hospital Pahang respectively

5) Table 4.9 and 4.14 - IAQ Measurement Results for OD, Hospital Selangor and Hospital Pahang respectively

These results are further simplified in charts shown in Figure 4.1 until 4.16:

1) Figure 4.1 and 4.9 - CO_2 Concentration Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively
2) Figure 4.2 and 4.10 - CO Concentration Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively
3) Figure 4.3 and 4.11 - TVOC Concentration Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively
4) Figure 4.4 and 4.12 - HCHO Concentration Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively
5) Figure 4.5 and 4.13 - RP Concentration Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively
6) Figure 4.6 and 4.14 - Temperature Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively
7) Figure 4.7 and 4.15 – Relative Humidity Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively
8) Figure 4.8 and 4.16 - ACH Vs. Sampling Points at Hospital Selangor and Hospital Pahang respectively

During the environmental measurements day, there were no outdoor air contaminants that may contribute to poor IAQ as the direct monitoring results for outdoor areas were low and well below the acceptable limits for indoor air contaminants. Basically, the direct monitoring results showed that the outdoor air is relatively clean and capable to improve IAQ by diluting indoor pollutants. However, this acceptable IAQ could not be achieved if the building owner did not operate, inspect and maintain the ventilation system consistent with its design intent.

4.2.2.1 Hospital Selangor

Table 4.5 until 4.9 and Figure 4.1 until 4.8 shows the environmental measurement results and compares an average result for each IAQ parameters with the acceptable limits or range from the MICOP IAQ 2010 and FMA(SHW) 1970.

Table 4.5

IAQ Measurement Results for SOPD, Hospital Selangor

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
1	576	0.89	1.59	0.00	0.052	23.2	61.9	8
2	671	0.99	2.22	0.00	0.047	22.6	64.4	7
3	536	0.95	1.52	0.00	0.032	22.9	62.3	6
4	543	1.03	1.89	0.00	0.037	22.5	65.1	3
5	531	1.00	1.78	0.00	0.031	22.5	65.1	13
6	576	0.00	1.72	0.00	0.036	22.7	65.4	11
7	604	0.10	0.00	0.04	0.003	22.1	67.9	5
8	660	0.22	1.35	0.12	0.004	20.9	73.6	9
9	548	0.13	0.00	0.04	0.003	20.5	73.0	6
10	659	0.20	1.69	0.06	0.005	20.1	73.8	4
11	620	0.20	0.32	0.05	0.003	21.3	72.9	8
12	695	0.13	0.00	0.05	0.004	21.8	71.6	8
13	662	1.17	0.43	0.04	0.020	22.3	68.0	6
14	830	0.87	1.03	0.00	0.018	21.6	67.0	7

Table 4.5 (Continued)

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
15	1003	1.20	1.20	0.00	0.025	23.3	66.9	
16	620	0.67	0.31	0.02	0.015	21.0	72.9	
17	765	1.39	0.28	0.29	0.015	21.8	72.5	
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40-70	<10
Mean	653	0.66	1.02	0.04	0.021	21.9	68.5	7
Standard Deviation	122	0.47	0.77	0.07	0.016	0.9	4.2	3

Table 4.5 shows there were 17 sampling points for all IAQ parameters except for ACH who had only 14 sampling points at SOPD, Hospital Selangor. The IAQ results (mean) for CO_2, CO, TVOC, HCHO, RP and RH are found to be satisfactory as they are well below the acceptable limits or range of MICOP IAQ 2010. However, the result (mean) for temperature (21.9°C) is lower than the recommended range of 23 - 26 °C (MICOP IAQ 2010) and ACH (7) has failed to achieve the minimum limit of 10 as stated in the FMA(SHW) 1970.

Table 4.6

IAQ Measurement Results for PD, Hospital Selangor

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
1	722	1.59	0.31	0.08	0.034	21.8	69.5	6
2	702	1.49	0.33	0.07	0.034	20.2	73.8	3
3	847	1.26	0.29	0.00	0.025	20.4	74.7	7

Table 4.6 (Continued)

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	**CO (ppm)**	**TVOC (ppm)**	**HCHO (ppm)**	**RP (mg/m^3)**	**Temperature (°C)**	**RH (%)**	**ACH**
4	739	1.42	0.28	0.07	0.038	20.2	75.0	8
5	772	1.51	0.28	0.06	0.037	20.5	74.4	6
6	765	1.39	0.28	0.07	0.042	21.8	72.5	8
7	708	1.44	0.25	0.06	0.039	21.1	74.1	17
8	748	1.46	0.26	0.07	0.039	20.9	72.6	7
9	752	2.19	0.26	0.07	0.040	21.0	72.0	8
10	676	1.61	0.29	0.06	0.039	21.7	71.6	8
11	698	1.57	0.28	0.07	0.040	22.0	71.7	7
12	758	1.58	0.67	0.09	0.038	20.4	75.3	8
13	785	2.23	0.31	0.06	0.045	20.1	75.6	12
14								1
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40- 70	<10
Mean	744	1.60	0.31	0.06	0.038	20.9	73.3	8
Standard Deviation	45	0.29	0.11	0.02	0.005	0.7	1.8	4

From Table 4.6, the average results for temperature, RH and ACH at PD, Hospital Selangor failed to achieve the recommended range of 23 - 26 °C and 40- 70% (MICOP IAQ 2010) and the minimum limit of 10 (FMA(SHW) 1970). All other results however are well below the acceptable limits (MICOP IAQ 2010).

Table 4.7

IAQ Measurement Results for MRD, Hospital Selangor

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
1	1018	1.40	0.90	0.00	0.059	22.3	56.9	11
2	974	1.50	0.88	0.00	0.053	21.5	57.2	2
3	758	0.16	0.00	0.06	0.002	20.6	61.3	9
4	801	0.31	0.00	0.02	0.004	20.5	64.9	7
5	919	0.24	0.00	0.04	0.007	20.4	64.6	12
6	792	0.20	0.00	0.04	0.003	19.4	66.0	13
7	763	0.21	0.02	0.04	0.005	19.1	68.3	7
8	950	0.16	0.01	0.05	0.004	19.4	68.4	6
9	991	0.30	0.17	0.06	0.004	20.2	66.1	6
10	1075	0.20	0.45	0.14	0.005	21.5	63.6	2
11	1006	0.16	0.12	0.08	0.005	20.6	65.4	6
12	1031	0.13	0.62	0.07	0.004	20.7	59.8	
13	1149	0.20	0.13	0.05	0.004	20.3	65.7	
14	985	1.50	0.98	0.00	0.062	23.4	58.9	
15	1005	1.20	1.90	0.00	0.030	21.1	59.8	
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40-70	<10
Mean	948	0.52	0.41	0.04	0.017	20.7	63.1	7
Standard Deviation	118	0.55	0.55	0.04	0.022	1.1	3.8	4

In MRD of Hospital Selangor, average results for temperature and ACH derived from Table 4.7 shows they have failed to meet the acceptable limit/ range.

Table 4.8

IAQ Measurement Results for OGD, Hospital Selangor

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
1	641	0.21	0.00	0.05	0.017	20.9	72.8	9
2	649	1.40	1.51	0.00	0.060	22.4	63.7	12
3	658	1.50	2.00	0.00	0.070	21.4	68.8	8
4	643	1.20	2.19	0.00	0.062	21.1	70.4	10
5	633	1.30	2.20	0.00	0.064	21.9	67.8	9
6	604	1.40	2.06	0.00	0.050	21.5	67.7	10
7	617	1.50	1.93	0.00	0.053	21.8	68.0	11
8	639	1.30	1.88	0.00	0.051	21.9	68.9	4
9	632	1.40	1.78	0.00	0.051	22.3	68.2	14
10	595	0.76	0.00	0.05	0.033	20.4	74.4	19
11	656	0.55	0.00	0.07	0.032	20.5	75.4	11
12	636	0.32	0.06	0.08	0.025	20.2	76.2	11
13	644	0.30	0.12	0.07	0.024	19.5	78.5	10
14	611	1.20	1.83	0.00	0.058	21.9	69.7	13
15	663	0.33	0.15	0.08	0.025	20.6	74.4	15
16	616	0.17	0.00	0.08	0.022	20.2	76.6	12
17	660	0.21	0.00	0.08	0.028	20.9	74.9	
18	681	0.18	0.00	0.07	0.027	20.6	76.6	
19	710	0.30	0.00	0.07	0.025	26.8	76.3	
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40-70	<10
Mean	641	0.52	0.93	0.04	0.041	21.4	72.1	11
Standard Deviation	27	0.55	0.98	0.04	0.017	1.5	4.2	3

At OGD of Hospital Selangor, both temperature and RH failed to achieve the recommended range of of 23 - 26 °C and 40- 70% (MICOP IAQ 2010) respectively. Besides ACH that has failed to achieve the minimum limit of 10, average results for CO_2 and HCHO from OD, Hospital Selangor (Table 4.9) also exceeded the acceptable limits of 1000 ppm (CO_2), and 0.1 ppm (HCHO).

Table 4.9

IAQ Measurement Results for OD, Hospital Selangor

Sampling Points	**IAQ Parameters**							
	CO_2 (ppm)	**CO (ppm)**	**TVOC (ppm)**	**HCHO (ppm)**	**RP (mg/m^3)**	**Temperature (°C)**	**RH (%)**	**ACH**
1	1542	1.44	0.31	0.07	0.013	21.0	68.9	2
2	1463	1.39	0.35	0.06	0.011	21.3	68.8	11
3	1301	1.45	0.31	0.04	0.017	21.5	69.4	2
4	1403	1.14	0.25	0.02	0.012	21.6	69.2	2
5	1389	2.41	0.42	0.02	0.017	23.7	68.9	4
6	1257	1.33	0.33	0.00	0.008	20.3	68.1	9
7	932	3.38	1.55	0.18	0.084	25.0	69.7	1
8	1022	1.57	0.33	0.09	0.014	23.7	69.7	2
9	941	1.48	0.30	0.14	0.012	21.2	68.8	2
10	933	2.47	0.30	0.66	0.041	28.6	77.0	2
11	1310	0.90	1.65	0.14	0.026	24.0	75.3	2
12								2
13								2
14								1
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40- 70	<10
Mean	1227	1.72	0.55	0.13	0.023	22.9	70.3	3

Table 4.9 (Continued)

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
Standard Deviation	229	0.73	0.52	0.19	0.022	2.4	2.9	3

Summary of the direct monitoring results for each IAQ parameters measured at Hospital Selangor is given in charts indicated through Figure 4.1 until 4.8. The individual acceptable limit or range for every IAQ parameter is also provided.

In general, the chart in Figure 4.1 shows that most of the results for CO_2 have exceeded the acceptable limit of 1000 ppm at OD and MRD. The results for other departments were satisfactory. Figure 4.2 and 4.3 clearly show that all results for CO and TVOC are well below the acceptable limit of 10 ppm (CO) and 3 ppm (TVOC). Meanwhile, most of the results for HCHO (Figure 4.4) are well below the acceptable limit of 0.1 ppm except for results taken at OD. Similar to results for CO and TVOC, majority of results for RP is well below the acceptable limit of 0.15 mg/m^3 as shown in Figure 4.5. In contrast with results for RP, figure 4.6 shows that majority results for temperature are not within the acceptable range of 23- 26 °C. Chart in figure 4.7 indicates the worst area with poor results of RH is at PD as most of the results are not within the acceptable range of 40- 70%. Meanwhile, the best area with good level of ACH is ODG as the results are above the minimum requirement of 10 (Figure 4.8).

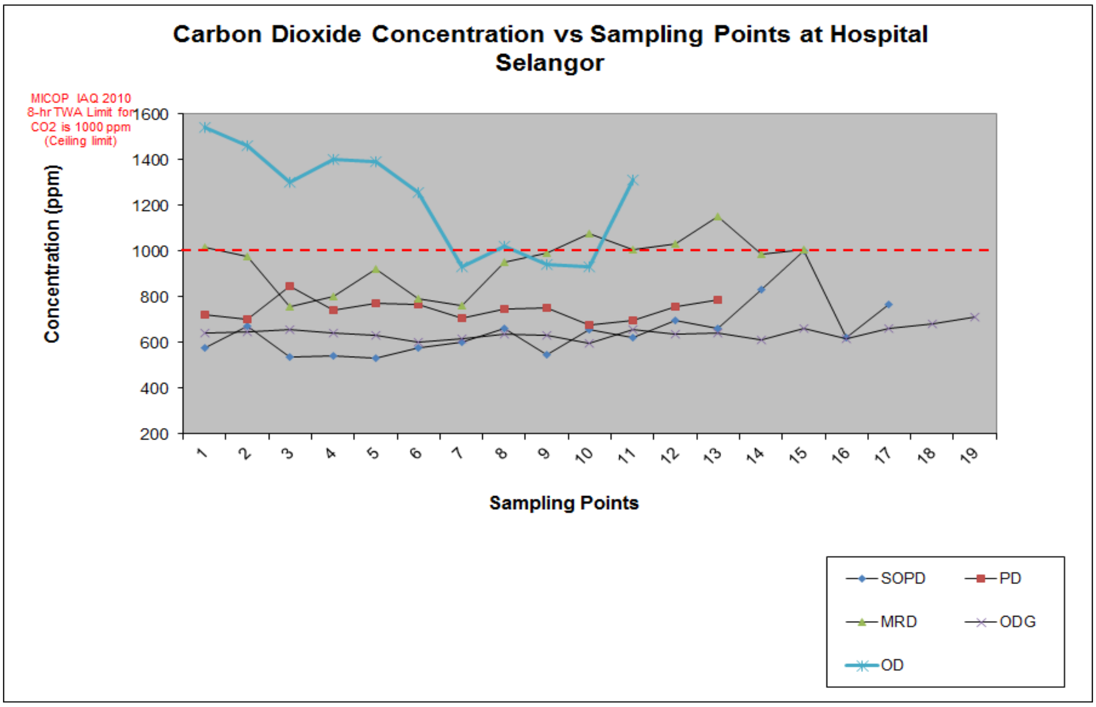

Figure 4.1. CO_2 Concentration Vs. Sampling Points at Hospital Selangor

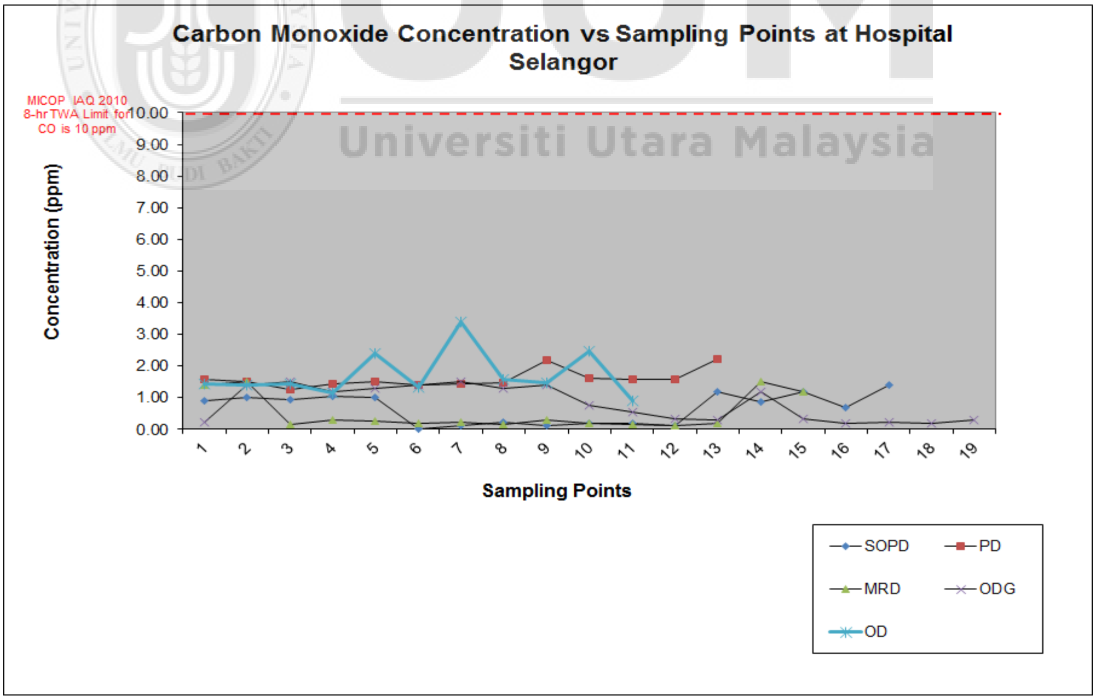

Figure 4.2. CO Concentration Vs. Sampling Points at Hospital Selangor

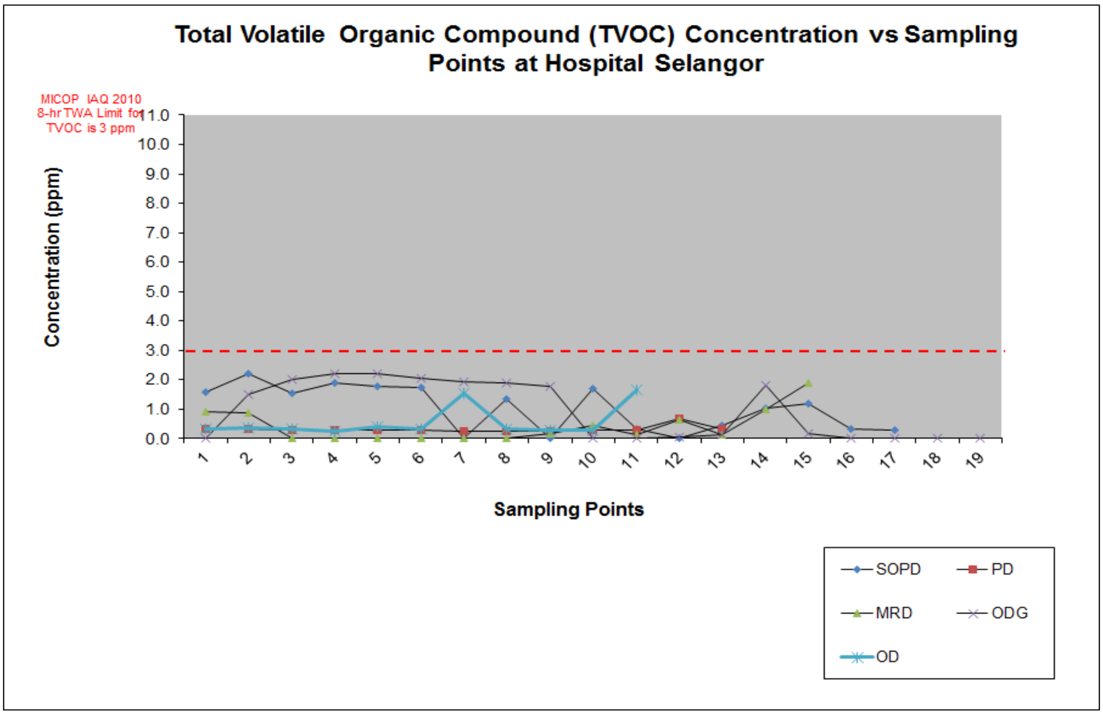

Figure 4.3. TVOC Concentration Vs. Sampling Points at Hospital Selangor

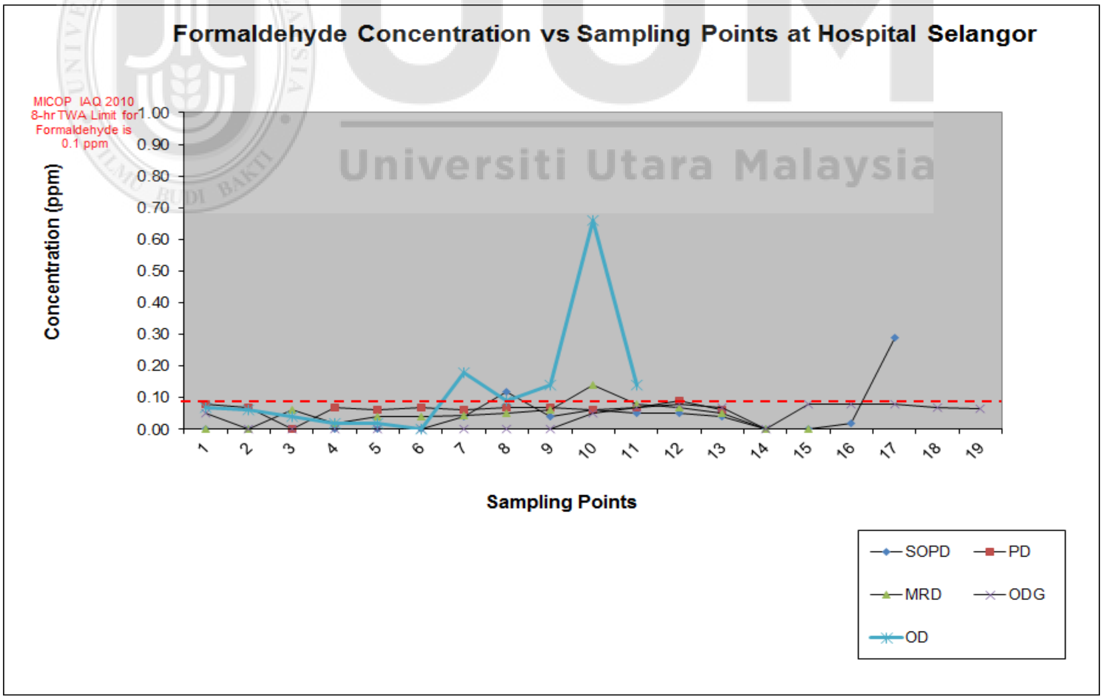

Figure 4.4. HCHO Concentration Vs. Sampling Points at Hospital Selangor

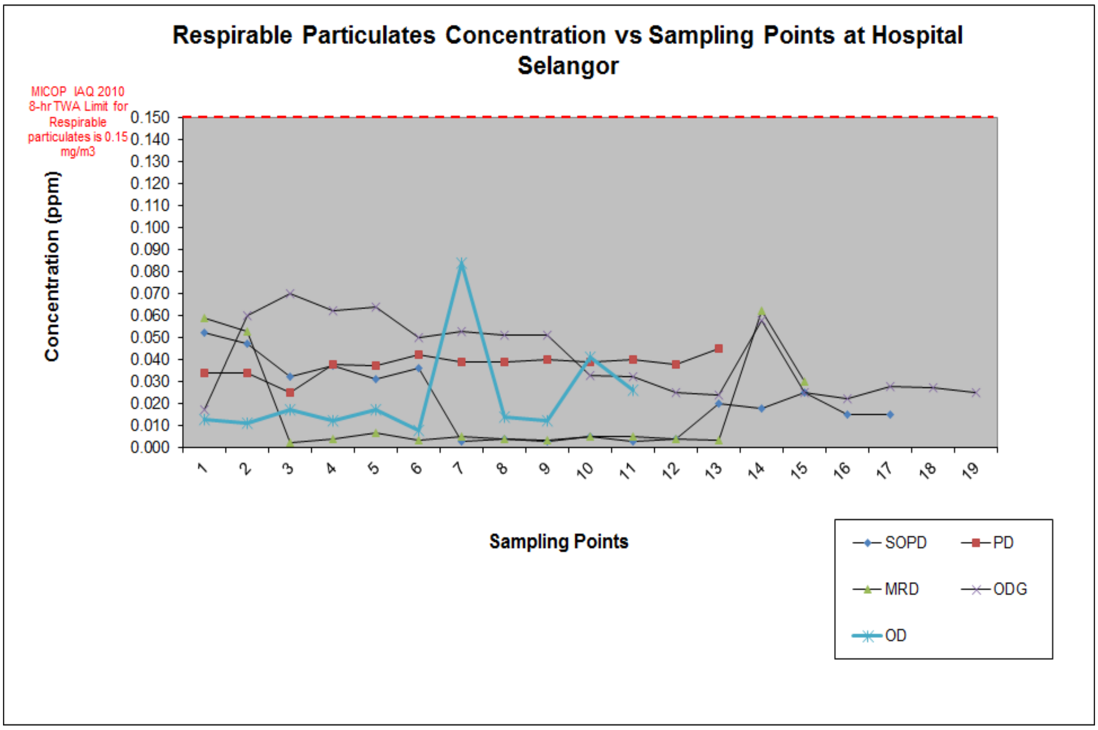

Figure 4.5. RP Concentration Vs. Sampling Points at Hospital Selangor

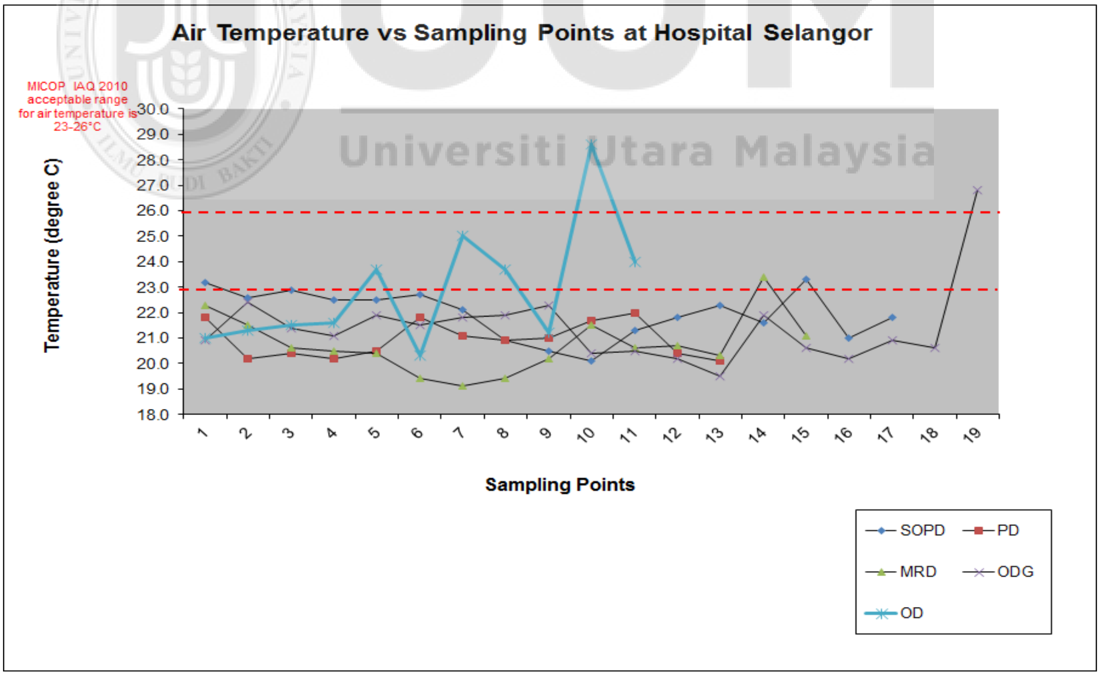

Figure 4.6. Temperature Vs. Sampling Points at Hospital Selangor

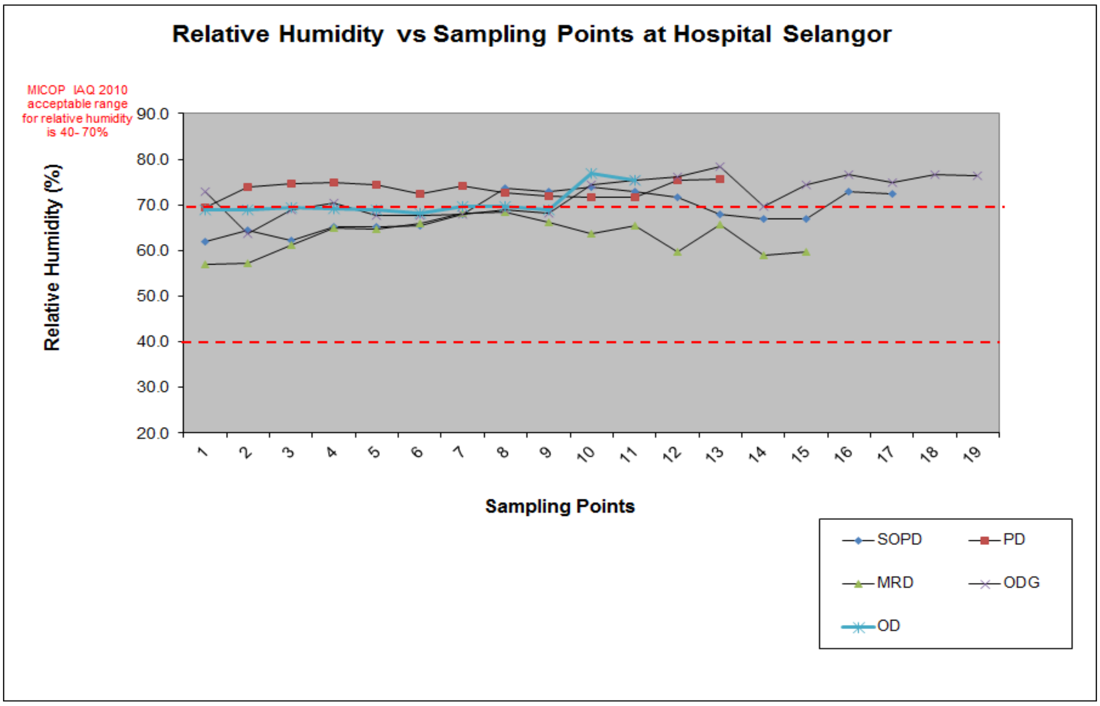

Figure 4.7. Relative Humidity Vs. Sampling Points at Hospital Selangor

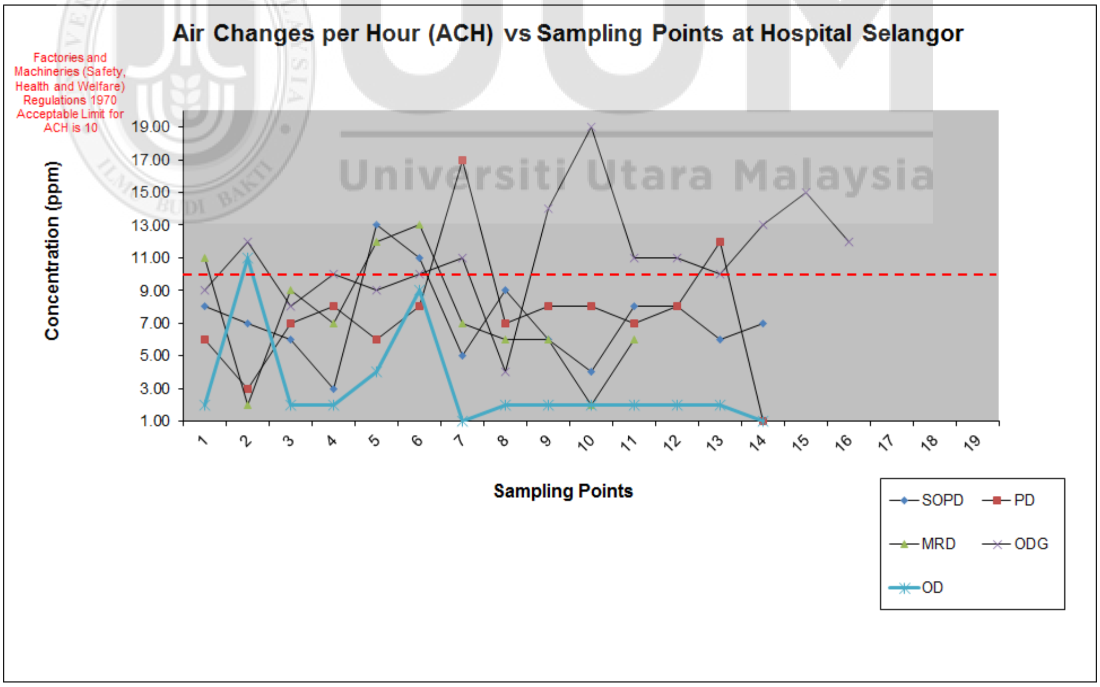

Figure 4.8. ACH Vs. Sampling Points at Hospital Selangor

4.2.2.2 Hospital Pahang

The environmental measurement results for five selected departments at Hospital Pahang are shown in Table 4.10 until 4.14 and Figure 4.9 until 4.16. The results for each sampling point were averaged and compared with the acceptable limits or range as specified in the MICOP IAQ 2010 and FMA(SHW) 1970.

At SOPD of Hospital Pahang, Table 4.10 shows the result (mean) for temperature is lower than the recommended range of 23 - 26°C (MICOP IAQ 2010). Meanwhile, the result (mean) for ACH has also failed to achieve the minimum limit of 10 as stated in the FMA(SHW) 1970.

Table 4.10

IAQ Measurement Results for SOPD, Hospital Pahang

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
1	842	0.18	0.00	0.01	0.003	21.6	72.7	10
2	807	0.10	0.00	0.04	0.002	22.7	71.4	5
3	899	0.28	0.00	0.05	0.019	22.7	72.9	11
4	948	0.18	0.00	0.09	0.002	21.3	69.4	10
5	931	0.03	0.00	0.08	0.017	23.1	70.4	11
6	925	0.01	0.00	0.10	0.002	23.1	72.9	11
7	1087	0.03	0.00	0.14	0.003	23.2	73.8	9
8	943	0.00	0.00	0.11	0.002	23.0	71.9	4
9	809	0.04	0.00	0.08	0.002	22.6	71.4	3
10	858	0.05	0.00	0.11	0.002	22.7	71.7	6
11	825	0.10	0.00	0.08	0.002	18.8	72.5	14

Table 4.10 (Continued)

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	**CO (ppm)**	**TVOC (ppm)**	**HCHO (ppm)**	**RP (mg/m^3)**	**Temperature (°C)**	**RH (%)**	**ACH**
12	706	0.00	0.00	0.09	0.002	22.6	58.4	12
13								7
14								8
15								9
16								8
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40-70	<10
Mean	882	0.08	0.00	0.08	0.005	22.3	70.8	9
Standard Deviation	96	0.09	0.00	0.03	0.006	1.2	4.1	3

Table 4.11

IAQ Measurement Results for PD, Hospital Pahang

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	**CO (ppm)**	**TVOC (ppm)**	**HCHO (ppm)**	**RP (mg/m^3)**	**Temperature (°C)**	**RH (%)**	**ACH**
1	650	1.60	1.90	0.00	0.022	24.7	66.5	8
2	741	1.60	1.89	0.00	0.027	24.8	67.4	6
3	698	1.60	2.04	0.00	0.020	22.8	68.8	5
4	759	1.60	1.66	0.00	0.020	24.8	67.6	9
5	669	1.50	1.74	0.00	0.026	24.7	66.8	9
6	654	1.36	1.78	0.00	0.024	24.9	64.5	11
7	649	1.50	1.77	0.00	0.020	24.2	66.7	10
8	629	1.30	1.74	0.00	0.025	24.6	67.3	7
9	685	1.20	1.56	0.00	0.022	24.5	67.2	14
10	707	1.20	1.84	0.00	0.018	22.8	71.4	

Table 4.11 (Continued)

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40- 70	10
Mean	684	1.45	1.79	0.00	0.022	24.3	67.4	9
Standard Deviation	42	0.17	0.13	0.00	0.003	0.8	1.8	3

From Table 4.11, basically all average results for CO_2, CO, TVOC, HCHO, RP, temperature and RH at PD, Hospital Pahang are satisfactory and well below the acceptable limits of MICOP IAQ 2010 except for ACH. Average result for ACH (9) is slightly lower than the minimum limit of 10.

Table 4.12

IAQ Measurement Results for MRD, Hospital Pahang

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
1	616	2.03	1.31	0.00	0.047	27.5	68.4	1
2	701	2.05	1.11	0.00	0.050	27.1	61.0	9
3	698	1.98	1.30	0.00	0.042	27.1	62.7	0
4	731	1.84	1.40	0.00	0.046	26.8	62.7	1
5	662	2.12	0.90	0.00	0.048	26.6	58.9	3
6	698	1.80	0.80	0.00	0.055	27.2	59.0	1
7	679	1.90	0.60	0.00	0.052	27.1	56.0	5
8	600	1.70	0.50	0.00	0.052	26.4	54.4	4
9	737	1.35	0.21	0.04	0.021	23.7	69.9	6

Table 4.12 (Continued)

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	**CO (ppm)**	**TVOC (ppm)**	**HCHO (ppm)**	**RP (mg/m^3)**	**Temperature (°C)**	**RH (%)**	**ACH**
10	700	1.52	0.21	0.04	0.021	24.7	69.6	10
11	712	1.43	0.21	0.04	0.018	24.9	69.4	
12	643	1.38	0.19	0.03	0.015	22.5	68.3	
13	671	0.94	0.18	0.03	0.016	22.3	69.0	
14	678	1.07	0.18	0.04	0.015	22.1	68.6	
15	615	1.28	0.18	0.03	0.013	22.1	68.7	
16	723	1.39	0.18	0.04	0.015	22.8	69.6	
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40-70	<10
Mean	679	1.61	0.59	0.02	0.033	25.1	64.8	4
Standard Deviation	42	0.37	0.47	0.02	0.017	2.1	5.4	3

Table 4.12 shows average result for ACH at MRD, Hospital Pahang is only 4, which clearly stays lower than the minimum limit of 10. Other IAQ parameters are satisfactory.

Table 4.13

IAQ Measurement Results for OGD, Hospital Pahang

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	**CO (ppm)**	**TVOC (ppm)**	**HCHO (ppm)**	**RP (mg/m^3)**	**Temperature (°C)**	**RH (%)**	**ACH**
1	797	1.43	0.21	0.00	0.011	22.3	68.8	7
2	846	1.49	0.23	0.00	0.012	22.3	68.8	8
3	708	1.33	0.20	0.00	0.013	21.3	68.8	7
4	677	1.35	0.20	0.00	0.011	21.8	69.0	9

Table 4.13 (Continued)

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	**CO (ppm)**	**TVOC (ppm)**	**HCHO (ppm)**	**RP (mg/m^3)**	**Temperature (°C)**	**RH (%)**	**ACH**
5	718	1.58	0.20	0.00	0.013	21.5	68.8	9
6	702	1.32	0.21	0.00	0.012	21.5	69.0	8
7	729	1.30	0.20	0.00	0.014	21.6	68.8	8
8	685	1.25	0.21	0.00	0.014	21.4	68.2	8
9	745	1.37	0.19	0.00	0.014	21.4	67.1	3
10	691	1.47	0.22	0.00	0.013	21.6	68.8	6
11	683	0.00	0.00	0.01	0.003	22.6	70.3	5
12	714	0.00	0.00	0.01	0.003	21.4	74.0	7
13	713	0.00	0.00	0.02	0.003	22.0	72.0	8
14	719	0.00	0.00	0.02	0.004	22.0	72.0	8
15	886	0.00	0.00	0.06	0.003	23.0	70.0	11
16	778	0.00	0.00	0.04	0.003	22.0	72.0	14
17	782	0.00	0.00	0.06	0.003	23.0	72.0	
18	729	0.01	0.00	0.50	0.002	23.0	70.0	
19	747	0.02	0.33	0.24	0.002	23.0	76.0	
20	718	0.01	0.15	0.15	0.001	24.0	75.0	
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40-70	<10
Mean	738	0.70	0.13	0.05	0.008	22.1	70.5	8
Standard Deviation	55	0.71	0.11	0.12	0.005	0.7	2.4	2

In OGD of Hospital Pahang, average results for temperature and ACH shown in Table 4.13 indicated they have failed to meet the acceptable limit/ range.

Table 4.14

IAQ Measurement Results for OD, Hospital Pahang

Sampling Points	IAQ Parameters							
	CO_2 (ppm)	CO (ppm)	TVOC (ppm)	HCHO (ppm)	RP (mg/m^3)	Temperature (°C)	RH (%)	ACH
1	655	2.20	1.72	0.00	0.027	22.4	63.4	11
2	673	2.10	1.56	0.00	0.028	23.0	63.0	2
3	683	2.10	1.31	0.00	0.029	22.9	61.9	9
4	666	2.10	1.07	0.00	0.027	22.6	60.4	7
5	640	1.90	0.99	0.00	0.027	22.3	60.2	10
6	669	1.90	1.36	0.00	0.026	18.2	62.2	21
7	648	2.40	1.56	0.00	0.029	23.0	60.1	8
8	707	3.20	1.18	0.00	0.029	22.9	60.9	8
9	739	0.08	0.01	0.09	0.016	22.5	69.0	7
10	769	0.04	0.00	0.06	0.013	22.1	67.8	4
11	800	0.09	0.00	0.05	0.013	21.9	67.8	5
12	767	0.03	0.00	0.06	0.013	21.7	67.8	7
13	730	0.00	0.00	0.07	0.013	22.1	69.6	
14	759	0.06	0.00	0.06	0.012	22.2	67.0	
15	713	0.02	0.00	0.05	0.010	21.5	67.5	
Acceptable limits/ range	1000	10	3	0.1	0.15	23- 26	40-70	<10
Mean	708	1.21	0.72	0.03	0.021	22.1	64.6	8
Standard Deviation	51	1.17	0.72	0.03	0.008	1.2	3.6	5

From Table 4.14, the average results for temperature and ACH at OD, Hospital Pahang failed to achieve the recommended range of 23 - 26°C (MICOP IAQ 2010) and the minimum limit of 10 (FMA(SHW) 1970). All other results are well below the acceptable limits (MICOP IAQ 2010).

Summary of the direct monitoring results for each IAQ parameters measured at Hospital Pahang are summarized in charts as shown in Figure 4.9 until 4.16. The individual acceptable limit or range for every IAQ parameter is also provided in charts.

In general, charts in Figure 4.9, 4.10, 4.11, 4.12 and 4.13 clearly indicate that most of the results for CO_2, CO, TVOC, HCHO and RP are satisfactory and they are well below the acceptable limits of the MICOP IAQ 2010. Meanwhile, the best area with good level of temperature is PD as the results are within the acceptable range of 23 - 26°C (Figure 4.14). The worse area with poor results of RH is at SOPD as most of the results are not within the acceptable range of 40 - 70%. This is shown in Figure 4.15. As contrast to results for CO_2, CO, TVOC, HCHO and RP, Figure 4.16 shows majority of results for ACH at Hospital Pahang is lower than the minimum requirement of 10.

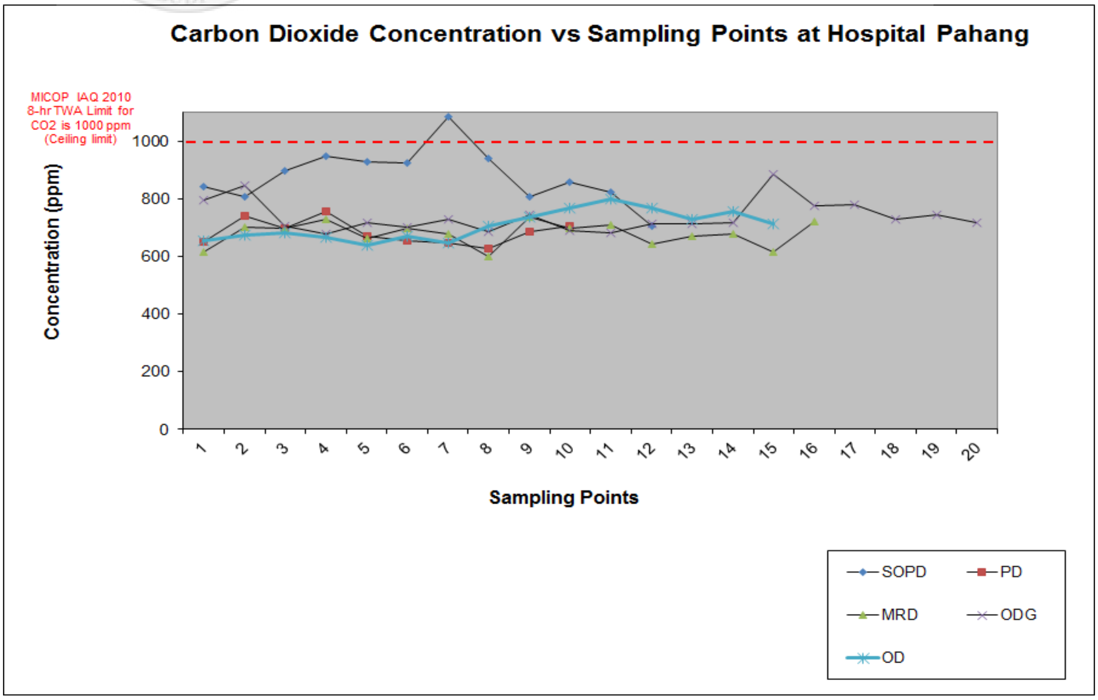

Figure 4.9. CO_2 Concentration Vs. Sampling Points at Hospital Pahang

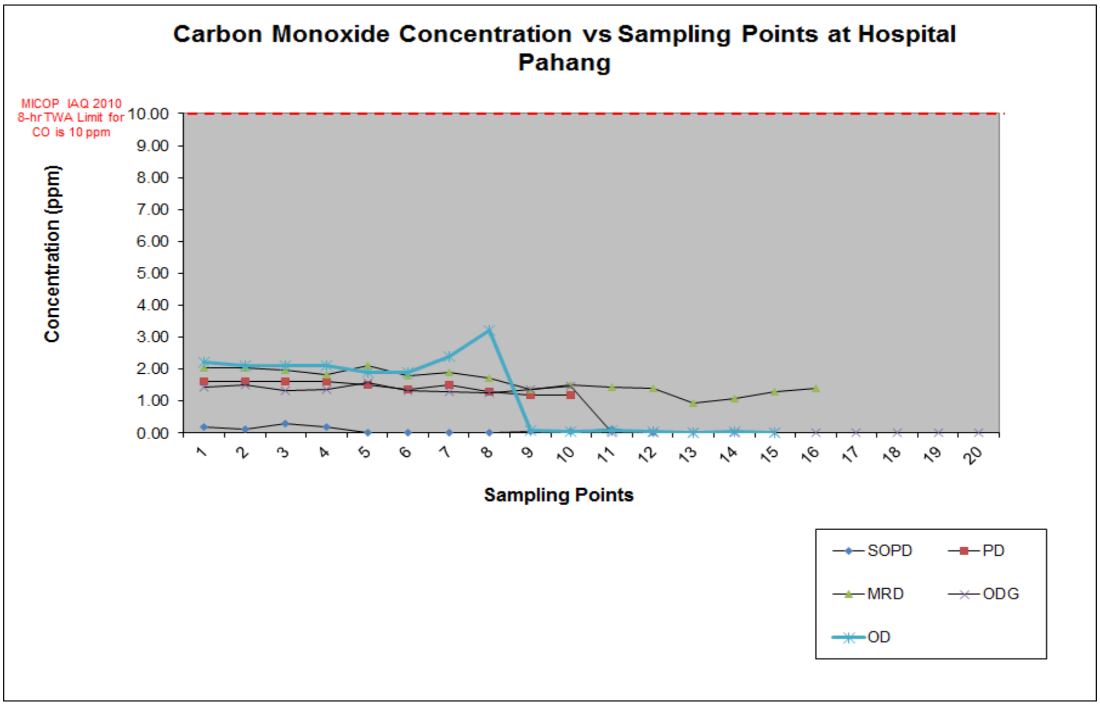

Figure 4.10. CO Concentration Vs. Sampling Points at Hospital Pahang

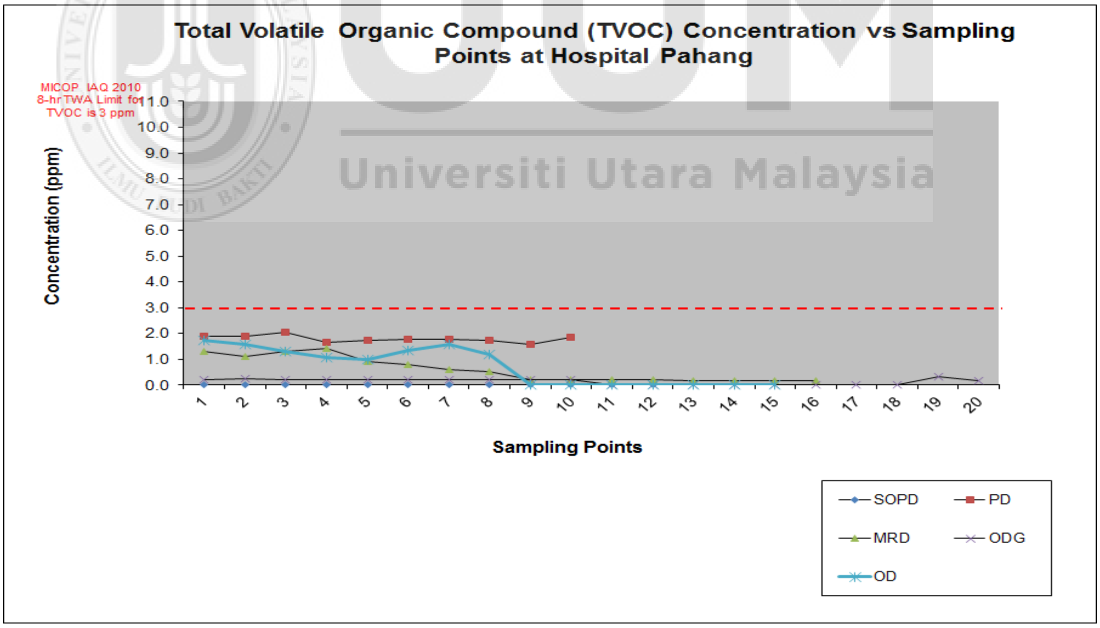

Figure 4.11. TVOC Concentration Vs. Sampling Points at Hospital Pahang

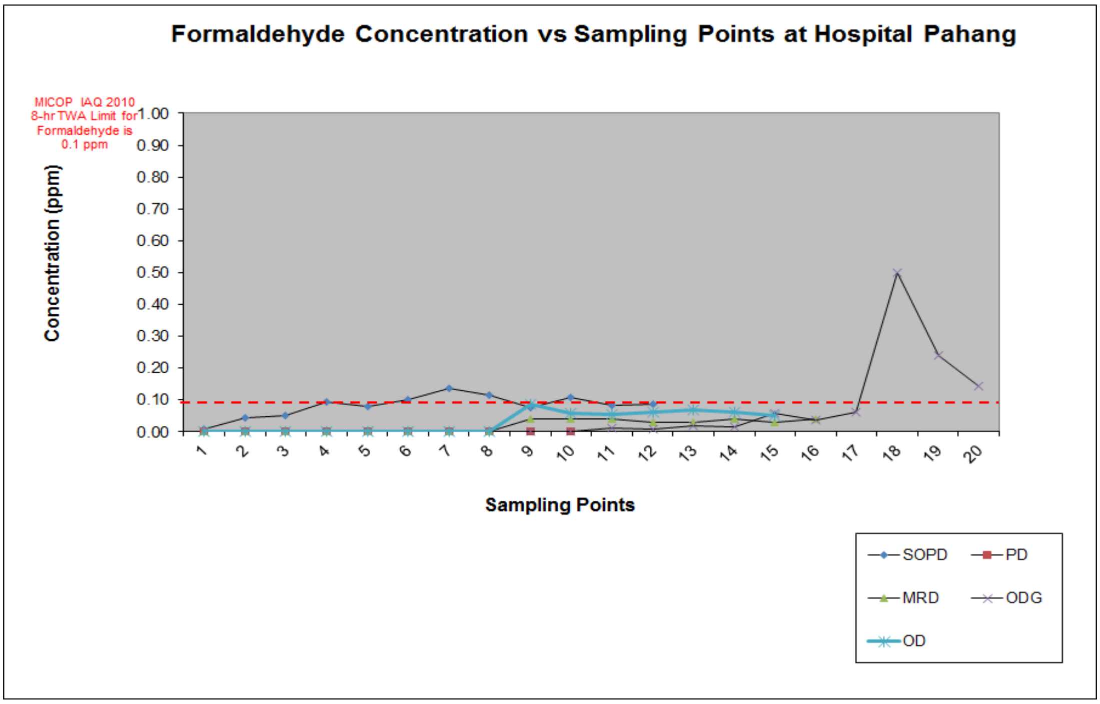

Figure 4.12. HCHO Concentration Vs. Sampling Points at Hospital Pahang

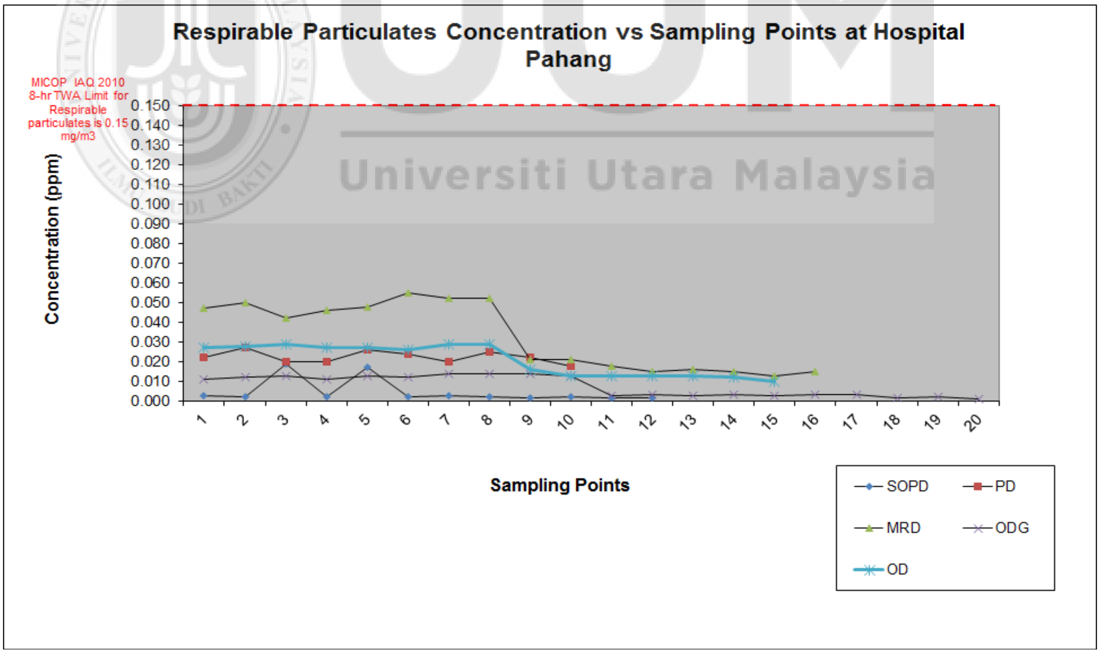

Figure 4.13. RP Concentration Vs. Sampling Points at Hospital Pahang

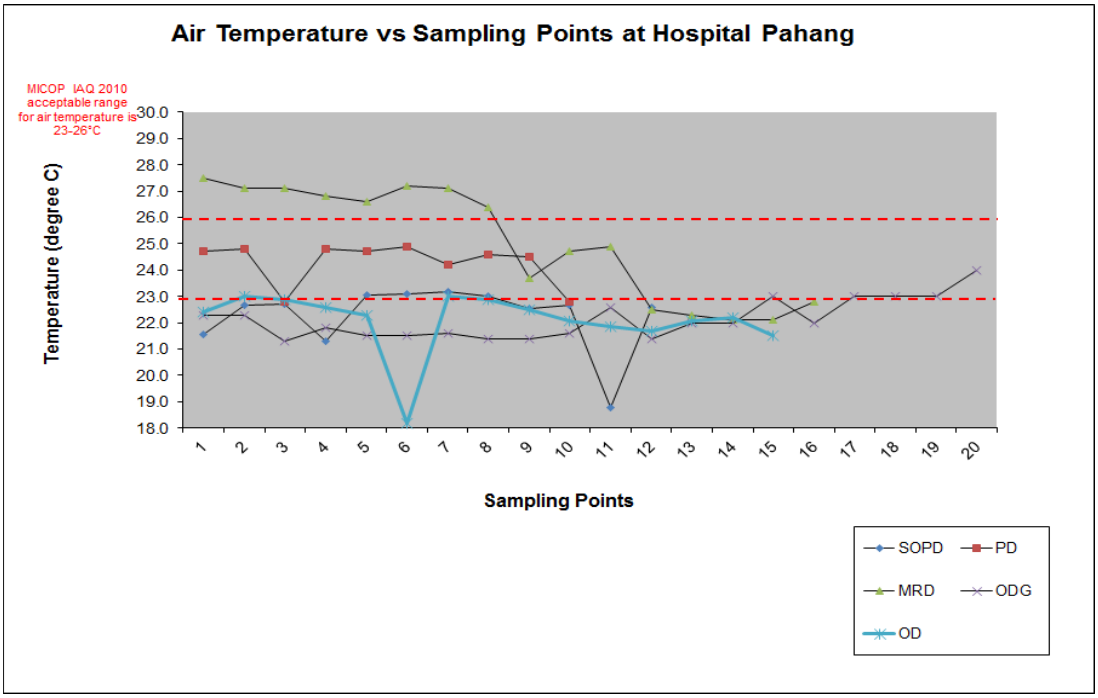

Figure 4.14. Temperature Vs. Sampling Points at Hospital Pahang

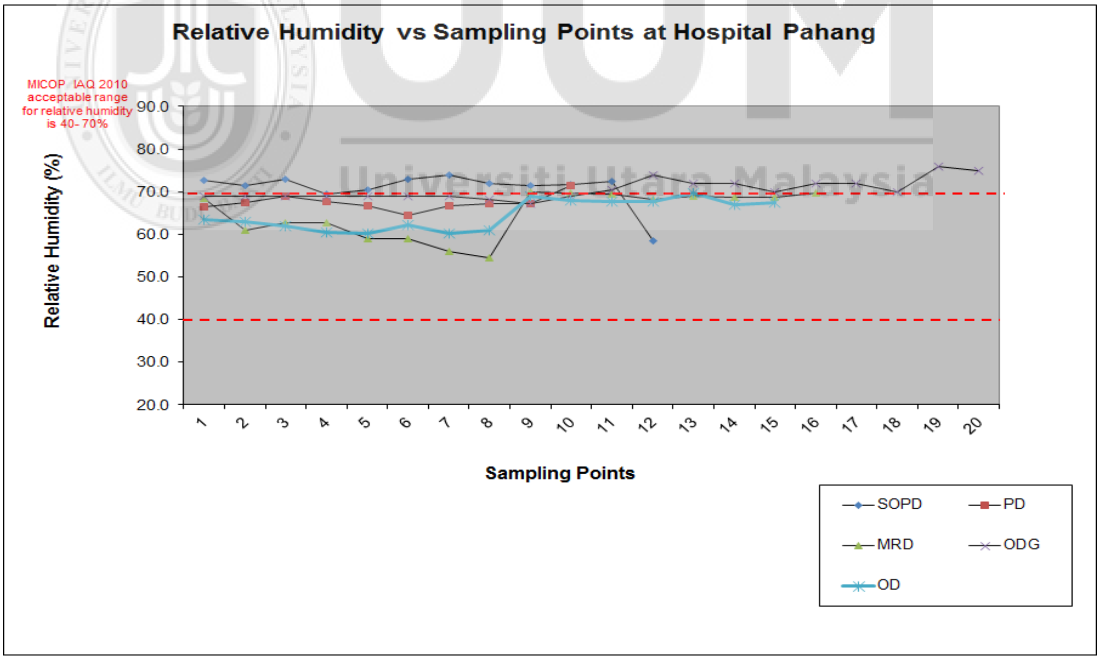

Figure 4.15. Relative Humidity Vs. Sampling Points at Hospital Pahang

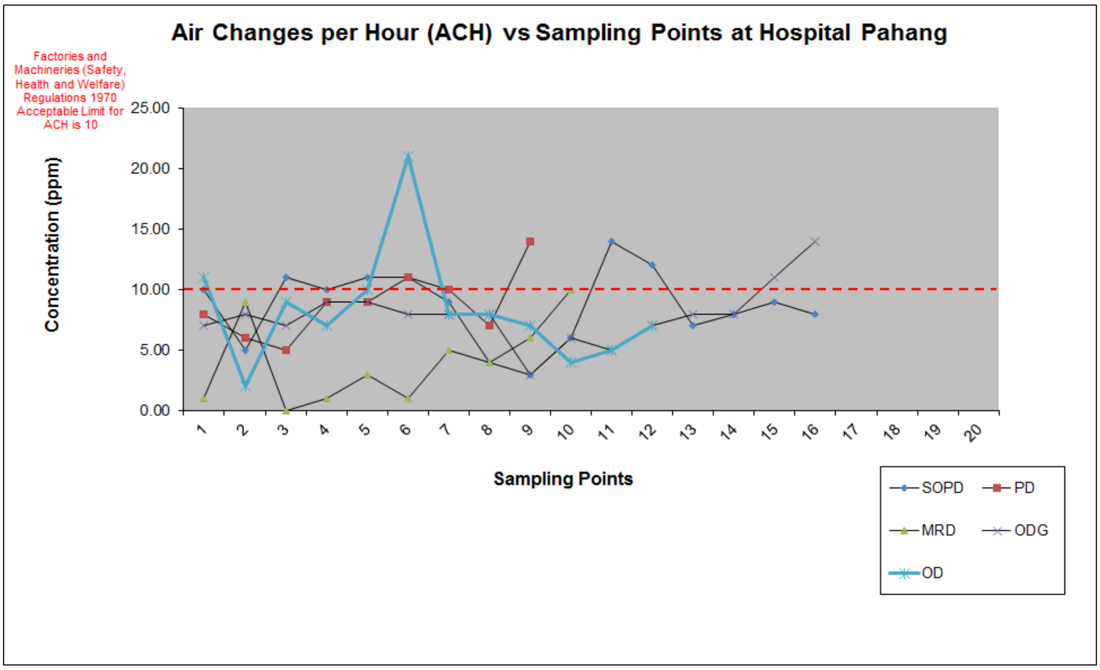

Figure 4.16. ACH Vs. Sampling Points at Hospital Pahang

4.2.2.3 Summary of IAQ in Hospital Selangor and Hospital Pahang

As a summary, Table 4.15 and 4.16 showed the average results, mean and standard deviation that have been obtained for all departments at Hospital Selangor and Hospital Pahang.

Table 4.15

Summary of results at SOPD, PD, MRD, OGD and OD in Hospital Selangor

Variables	Department					Limit or range	Mean	SD
	SOPD	PD	MRD	OGD	OD			
Temp. (ºC)	21.9	20.9	20.7	21.4	22.9	23- 26	21.6	0.88
Relative Humidity (RH%)	68.5	73.3	63.1	72.1	70.3	40- 70	69.5	4.0
Air Changes per Hour (ACH)	7	8	7	11	3	<10	7	3

Table 4.15 (Continued)

Variables	Department					Limit or range	Mean	SD
	SOPD	PD	MRD	OGD	OD			
Carbon dioxide (CO_2)	653	744	948	641	1227	1000	843	248
Carbon Monoxide (CO)	0.66	1.60	0.52	0.82	1.72	10	1.06	0.56
Total volatile organic compounds (TVOC)	1.02	0.31	0.41	0.93	0.55	3	0.64	0.55
Formal. (HCHO)	0.04	0.06	0.04	0.04	0.13	0.1	0.06	0.04
Respirable particulates (RP)	0.021	0.038	0.017	0.041	0.023	0.15	0.028	0.011

The above summary for Hospital Selangor shows temperature for all departments are lower than acceptable range of 23 - 26°C. RH for PD, OGD and OD were above the acceptable range of 40 - 70%. In addition, ACHs for all departments except OGD are lower than minimum limit of 10. Among all departments, OD had the highest level of CO_2 and HCHO which have exceeded the acceptable limit of 1000 ppm (CO_2) and 0.1 ppm (HCHO). Other results for all departments are well below the acceptable limits or range as specified under MICOP IAQ 2010 or FMA(SHW) 1970.

Table 4.16

Summary of results at SOPD, PD, MRD, OGD and OD in Hospital Pahang

Variables	Department					Limit or range	Mean	SD
	SOPD	PD	MRD	OGD	OD			
Temp. (ºC)	22.3	24.3	25.1	22.1	22.1	23- 26	23.2	1.42

Table 4.16 (Continued)

Variables	Department					Limit or range	Mean	SD
	SOPD	PD	MRD	OGD	OD			
Temp. (ºC)	22.3	24.3	25.1	22.1	22.1	23- 26	23.2	1.42
Relative Humidity (RH%)	70.8	67.4	64.8	70.5	64.6	40- 70	67.6	3.0
Air Changes per Hour (ACH)	9	9	4	8	8	<10	8	2
Carbon dioxide (CO_2)	882	684	679	738	708	1000	738	84
Carbon Monoxide (CO)	0.08	1.45	1.61	0.70	1.21	10	1.01	0.62
Total volatile organic compounds (TVOC)	0.00	1.79	0.59	0.13	0.72	3	0.65	0.71
Formal. (HCHO)	0.08	0.00	0.02	0.05	0.03	0.1	0.04	0.03
Respirable particulates (RP)	0.005	0.022	0.033	0.008	0.021	0.15	0.018	0.011

Meanwhile, the above summary for Hospital Pahang shows temperature for SOPD, OGD and OD are lower than acceptable range of 23 - 26°C. RH for SOPD and OGD were slightly above the acceptable range of 40 - 70%. Furthermore, ACHs for all departments are lower than minimum limit of 10. Other results for all departments are well below the acceptable limits or range as specified under MICOP IAQ 2010 or FMA(SHW) 1970.

The summary of IAQ parameters and locations that have exceeded the stipulated limits are given in Table 4.17.

Table 4.17

IAQ Parameters and Locations where the Results have exceeded the Acceptable Limits

Hospital	Variables	Department					Limit or range
		SOPD	PD	MRD	OGD	OD	
Selangor	Temp. (ºC)	21.9	20.9	20.7	21.4	22.9	23- 26
	Relative Humidity (RH%)	-	73.3	-	72.1	70.3	40- 70
	Air Changes per Hour (ACH)	7	8	7	-	3	<10
	Carbon dioxide (CO_2)	-	-	-	-	1227	1000
	Formal. (HCHO)	-	-	-	-	0.13	0.1
Pahang	Temp. (ºC)	22.3	-	-	22.1	22.1	23- 26
	Relative Humidity (RH%)	70.8	-	-	70.5	-	40- 70
	Air Changes per Hour (ACH)	9	9	4	8	8	<10

4.3 The Adequacy of the MVAC System in Maintaining Good IAQ

4.3.1 Walkthrough Survey Results

A walkthrough survey was conducted with the following objectives:

a) To identify the potential contaminant sources and their pathways

b) To review immediate and nearby surroundings to examine if any of the exterior factors may contribute to the IAQ problem

c) To review the building envelope, MVAC system, appliances, furnishings, drains, water supply, etc., to judge their impact on IAQ

d) To gain insights into the occupant practices that may have an impact on IAQ

The workplace inspection was carried out by referring to the given checklist to collect an overview of IAQ performance in the selected departments. A short discussion was also held with the maintenance team and the workers to obtain the general feedback related to IAQ issues at both hospitals. The basic information of both hospitals is described in Table 4.18.

Table 4.18

Basic Information of Hospital Selangor and Hospital Pahang

No.	Item	Hospital Selangor	Hospital Pahang
1	Years of operation	10 years	22 years
2	Type of air conditioning system	MVAC	MVAC
3	Average of time workers spend in the workplace	<40 hours per week	<40 hours per week
4	Type of Workstation	Offices • Counters • Staff's room • Workbenches Doctor's Room • Procedure rooms • Consultation rooms Laboratory • Preparation room • Closed area for specific task Patients area • Bedded • Open space • Isolated rooms	Offices • Counters • Staff's room • Workbenches Doctor's Room • Procedure rooms • Consultation rooms Laboratory • Preparation room • Closed area for specific task Patients area • Bedded • Open space • Isolated rooms

In the MICOP IAQ 2010, the "Prescribed Activities" means any activity that could pose health hazard to the occupants, including but not limited to:

a) applying or removing floor coverings including carpeting, floor tiles and other surfaces
b) applying wall coverings
c) painting or the application of similar coatings;
d) cleaning carpets
e) applying floor finishing and stripping products
f) applying pest control products
g) applying caulking, sealing, or glazing compounds

Based on the walkthrough survey and interviews with the available personnel of maintenance team, there was no “Prescribed Activities” that had taken place in both hospitals during the study. Thus, potential sources of indoor air contaminants due to these prescribed activities are not expected. In general, the pollutants that may potentially affect IAQ at both hospitals are as follows:

a) Total volatile organic compounds (TVOC) and formaldehyde (HCHO)- Most of the sources are coming from laboratory chemicals, cleaning agents, disinfectants, solvents, fuels, adhesives and emissions from furnishings
b) Particles and Aerosols- Derived from housekeeping activities, printing, photocopying, smoking, combustion and dust that is brought in together from the workers’, visitors’ and patients’ work clothes and shoes. However, the spaces are likely to be seen very clean since the cleaning activities performed routinely as schedule basis in a day. The workers mopping and wipe all the surfaces with high tendency of dust suspended
c) Carbon dioxide (CO_2)- The occupants (workers, visitors and patients) themselves who exhaled carbon dioxide gas is the primary source of CO_2

d) Carbon monoxide (CO)- Incomplete combustion of carbon- containing fuels, such as gasoline, oil and natural gas from machine, equipment and kitchen. Also, vehicles may also one of the source of CO. CO may enter the building as fresh air intakes were located near to vehicles parking area.

4.3.2 Adequacy of the Existing MVAC System

The centralized air conditioning systems are installed and used at all the assessed areas. Theoretically, fresh air is drawn into the Air Handling Units (AHUs) room where both fresh and return air from the spaces are mixed, filtered and then supplied to spaces by ceiling mounted supply air diffusers connected to AHU via ducts. Return ventilation is also provided by the AHU, which draws air through ceiling mounted exhaust diffusers via ducts. However, it was observed that most of the fresh air dampers in the AHU room were closed. This may reduce the amount of fresh air inside the working space which may subsequently reduce the ability of the air to dilute the indoor air pollutants. Table 4.19 shows the types of air-conditioning system used and their identification number at the selected areas.

Table 4.19

The types of Air- conditioning System

No	**Location/ Area**	**Type of air-conditioning system**	
		Hospital Selangor	**Hospital Pahang**
1	SOPD	MVAC 1	MVAC 1
2	PD	MVAC 6	MVAC 6
3	MRD	MVAC 2	MVAC 2
4	OGD	MVAC 4	MVAC 3
5	OD	MVAC 5	MVAC 4

The record of servicing and maintenance of the air handling unit were reviewed and maintenance personnel were interviewed. The maintenance and servicing of the MVAC system were carried out periodically. The adequacy of ventilation system within the served area was measured in order to obtain Air Changes per Hour (ACH). Air change can be defined as how many times the air enters and exits a room from the MVAC system in one hour or how many times a room would be filled up with the air from the supply registers in sixty minutes. The ACH is calculated using the following equation:

$$\textbf{ACH} = \frac{\textbf{Total Flow Rate (ft}^{2}\textbf{/min)}}{\textbf{Volume of Room (ft}^{3}\textbf{)}} \textbf{ X 60 (min/ hour)}$$

According to Malaysian Factories and Machinery (Safety, Health and Welfare) Regulations 1970, Regulation 25, the number of ACH for processes which generate little or no heat, smoke or fume shall not be less than 10. Thus, all results were compared to its standard limit of 10. Besides ACH, CO_2 concentration is also used as an indicator for human comfort and adequate ventilation. Results for both ACH and CO_2 have been discussed in section 4.2. In general, at most of the areas in Hospital Selangor and Hospital Pahang, the average results for ACH failed to achieve the minimum limit of 10 as required by FMA (SHW) 1970. Meanwhile, most of the average results for CO_2 were well below the acceptable limit of 1000 ppm. As a summary, Table 4.20 shows all average results for ACH and CO_2 at both hospitals. Hospital Selangor's OGD was found to have a good result of ACH where the average result is 11, above the minimum limit of 10. The poor average result for CO_2 was observed at OD, Hospital Selangor where the result is 1227, exceeded the acceptable limit of 1000 ppm.

Table 4.20

Summary Results of ACH and CO_2 at Hospital Selangor and Hospital Pahang

Hospital	Variables	Department					Limit or range	Mean	SD
		SOPD	PD	MRD	OGD	OD			
Hospital Selangor	ACH	7	8	7	11	3	<10	7	3
	CO_2	653	744	948	641	1227	1000	843	248
Hospital Pahang	ACH	9	9	4	8	8	<10	8	2
	CO_2	882	684	679	738	708	1000	738	84

4.4 Common Symptoms of SBS in Hospitals

4.4.1 Demographic Profiles of the Workers

A questionnaire was distributed to the selected workers of five departments from both Hospital Selangor and Hospital Pahang to obtain their general health feedback as well as signs and symptoms related to IAQ problem. The distribution of the questionnaire for each hospital shows that 72% (Hospital Selangor) and 80% (Hospital Pahang) of workers completed the questionnaire. The workers who responded to the questionnaire are mostly with medical background such as physicians, medical assistants and nurses. The questionnaire was distributed to the workers who were working for eight hours during normal working hours (8.00 am until 5.00 pm) and their workplace includes an open area shared with others and a closed office.

According to Table 4.21, 76 out of 100 workers or 76% have responded to the questionnaire where gender-based distribution was not balanced as the respondents are 22.4% male and 77.6% female. Table 4.21 shows three main personal characteristics of respondents in Hospital Selangor and Hospital Pahang. Majority of respondents are female (77.6%), age between 25 - 39 (55.3%) and non-smoker (88.2%).

Table 4.21

Personal Characteristics of Respondents in Hospital Selangor and Hospital Pahang

Variables	**Respondents of both hospitals**				
	Hospital Selangor (n = 36)	**Hospital Pahang (n = 40)**	**%**	**χ 2**	**p**
Gender					
Male	7	10	22.4	0.34	0.56
Female	29	30	77.6		
Age (Year)					
Under 25	5	7	15.8	0.69	0.88
25- 39	19	23	55.3		
40- 55	12	10	28.9		
Above 55	0	0	0		
Smoking					
Yes	3	6	11.8	0.81	0.37
No	33	34	88.2		

* Significant at p <0.05

4.4.2 Workers with SBS Symptoms

The SBS was assigned to workers according to the positive response where the workers must have at least one symptom of SBS symptoms in a week (Nordstrom et al., 1995; Syazwan et al., 2009). Analysis of questionnaire revealed that 38.9% of the workers at Hospital Selangor were having SBS, compared to 7.5% of the workers at Hospital Pahang. The total number of respondents having SBS (at least one symptom of SBS symptoms that appear at least once in a week) from each department is tabulated in Table 4.22.

Table 4.22

Number of Respondents having SBS at five departments in Hospital Selangor and Hospital Pahang

Department	Hospital Selangor SBS (n = 36)		Hospital Pahang SBS (n = 40)	
	Yes (%) n = 14	No (%) n = 22	Yes (%) n = 3	No (%) n = 37
SOPD	4 (11.1)	4 (11.1)	0 (0)	16 (40.0)
PD	6 (16.6)	1 (2.8)	0 (0)	3 (7.5)
MRD	0 (0)	7 (19.4)	2 (5.0)	10 (25.0)
OGD	2 (5.6)	8 (22.2)	1 (2.5)	4 (10.0)
OD	2 (5.6)	2 (5.6)	0 (0)	4 (10.0)

From the above Table 4.22, 14 out of 36 (38.9%) respondents in Hospital Selangor were identified as having SBS. However, only 3 out of 40 (7.5%) respondents were identified as having SBS in Hospital Pahang. As shown in Figure 4.17 and 4.18, most of the respondent’s complaints have been raised at Hospital Selangor compared to Hospital Pahang with identification of symptom for all except scaling/itching scalp or ears. Only four symptoms were reported at Hospital Pahang by the respondents. These symptoms are nausea/ dizziness, difficulties to concentrate, dry or flushed facial skin and hand dry, itching and redskin.

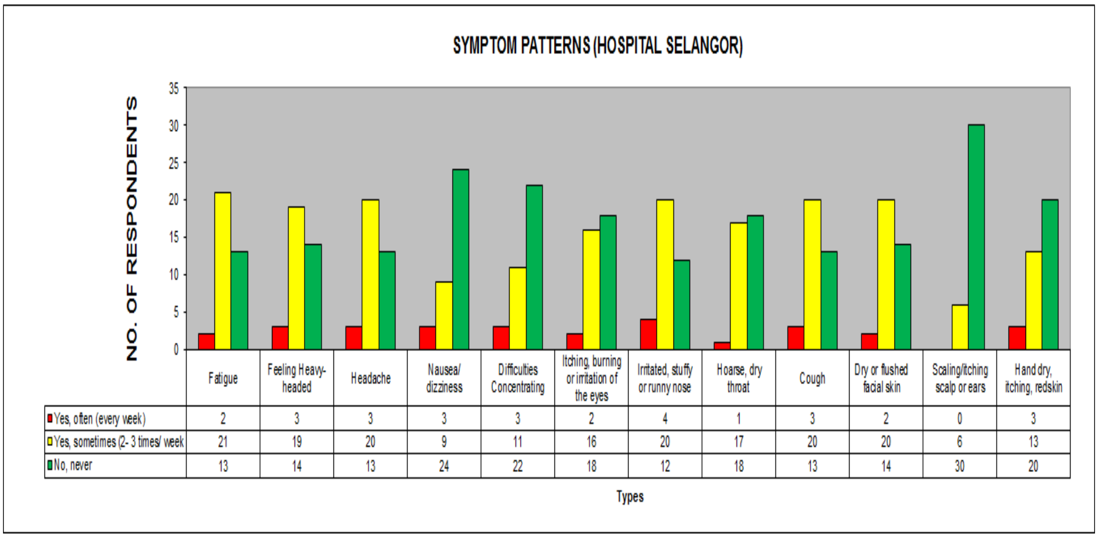

Figure 4.17. Symptom Patterns Vs. Number of Respondents at Hospital Selangor

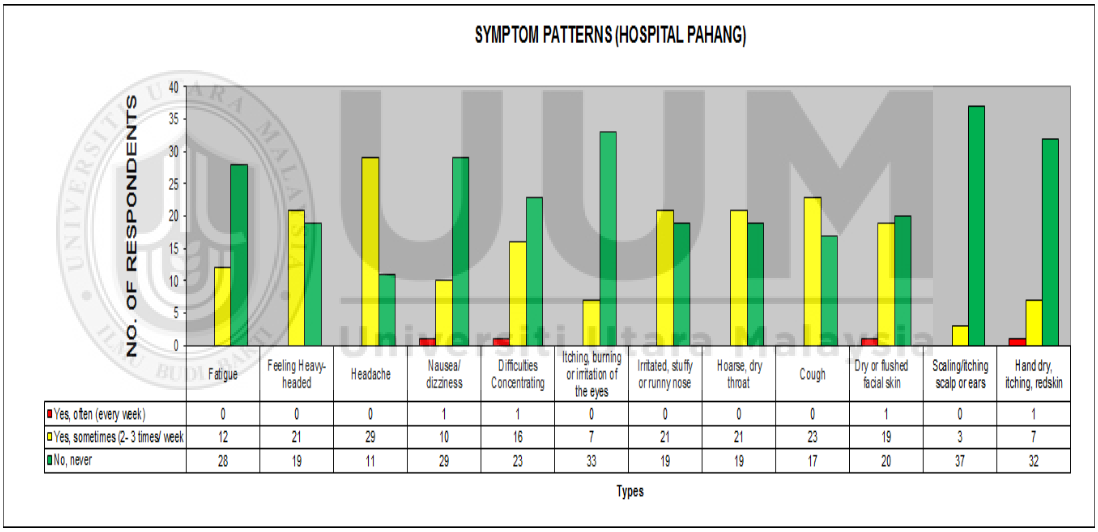

Figure 4.18. Symptom Patterns Vs. Number of Respondents at Hospital Pahang

Figure 4.19 showed that most of the respondents at Hospital Selangor thought that the symptoms are due to their work environment. Meanwhile, Figure 4.20 showed that most of the respondents at Hospital Pahang were uncertain whether the symptoms are due to their work environment.

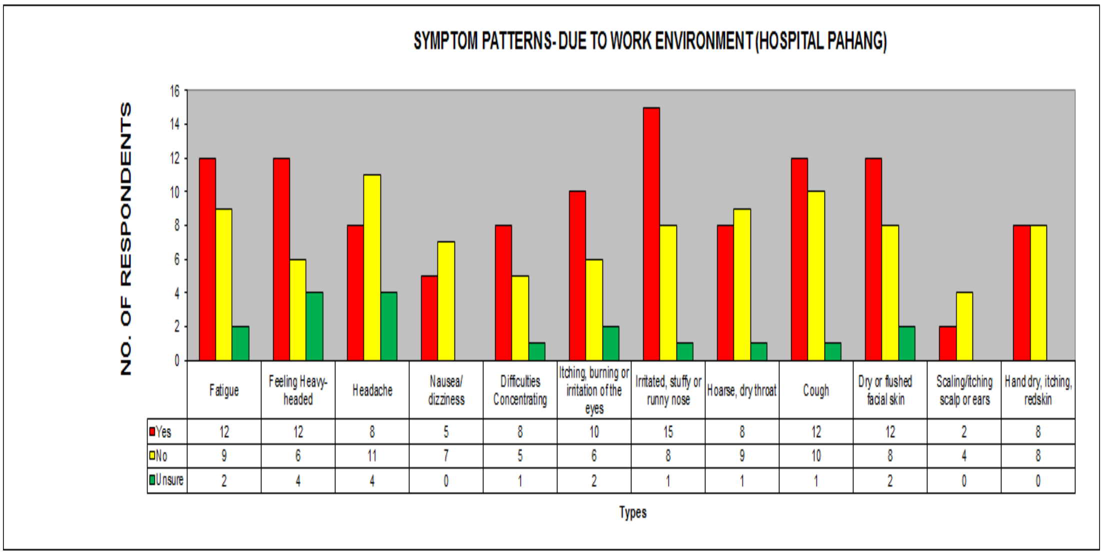

Figure 4.19. Symptom Patterns Vs. Work Environment at Hospital Selangor

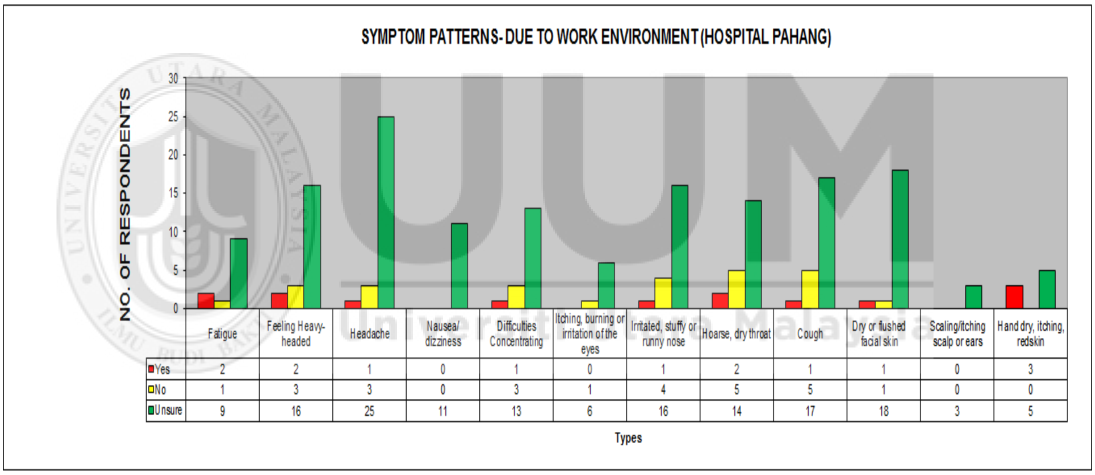

Figure 4.20. Symptom Patterns Vs. Work Environment at Hospital Pahang

4.5 Comparison of Reported SBS Symptoms in Hospitals

To clearly compare, Table 4.23 presents the difference of reported SBS of respondents at both hospitals. Chi-Square test (χ 2) was performed for all symptoms of SBS and the results showed that there was only statistically significant difference for irritated, stuffy or runny nose (χ 2 = 4.69, p = 0.03). For other symptoms, there was no significant difference between Hospital Selangor and Hospital Pahang. The highest SBS at Hospital Selangor was irritated, stuffy or runny nose (11.1%) followed by feeling heavy-headed, headache, nausea/ dizziness, difficulties to concentrate, cough and hand dry, itching, redskin (8.3% for each symptom). While at Hospital Pahang, only nausea/ dizziness, difficulties to concentrate, dry or flushed facial skin and hand dry, itching, redskin were reported with 2.5% for each symptom. Scaling/itching scalp or ears was not reported in both hospitals.

Table 4.23

The difference of reported SBS symptoms among workers in Hospital Selangor and Hospital Pahang

Symptoms	**Hospital Selangor (n = 36)**	**Hospital Pahang (n = 40)**	**χ 2**	**p- value**
	Yes (%)	**Yes (%)**		
Fatigue	2 (5.6)	0 (0)	2.28	0.13
Feeling Heavy- headed	3 (8.3)	0 (0)	3.47	0.06
Headache	3 (8.3)	0 (0)	3.47	0.06
Nausea/ dizziness	3 (8.3)	1 (2.5)	1.29	0.26
Difficulties Concentrating	3 (8.3)	1 (2.5)	1.29	0.26
Itching, burning or irritation of the eyes	2 (5.6)	0 (0)	2.28	0.13
Irritated, stuffy or runny nose	4 (11.1)	0 (0)	4.69	0.03
Hoarse, dry throat	1 (2.8)	0 (0)	1.13	0.29
Cough	3 (8.3)	0 (0)	3.47	0.06
Dry or flushed facial skin	2 (5.6)	1 (2.5)	0.47	0.49
Scaling/itching scalp or ears	0 (0)	0 (0)	0	1
Hand dry, itching, redskin	3 (8.3)	1 (2.5)	1.29	0.26

*significance at p<0.05

4.6 Comparison of the Prevalence of SBS in Hospitals

According to the study's operational definition of SBS, an individual worker was diagnosed as having SBS if they had at least one symptom of SBS symptoms which appear at least once in a week. Thus, the prevalence of SBS among workers and the difference of the prevalence between both hospitals are presented in Table 4.24. This table shows that the prevalence of SBS was significantly higher at Hospital Selangor (38.9%) compared to Hospital Pahang (7.5%) ($\chi 2$ = 10.8, p = 0.001).

Table 4.24

The difference of the prevalence of SBS among workers in Hospital Selangor and Hospital Pahang

Variables	Prevalence of SBS N = 76		χ 2	p- value
	Yes (%)	No (%)		
Hospital Selangor (n = 36)	14 (38.9)	22 (61.1)	10.8	0.001
Hospital Pahang (n = 40)	3 (7.5)	37 (92.5)		

***significance at p<0.05**

4.7 Relationship between IAQ and SBS

4.7.1 Summary of Results

The number of respondents with or without SBS at Hospital Selangor and Hospital Pahang was available in Table 4.25.

Table 4.25

Number of Respondents having SBS at five departments in Hospital Selangor and Hospital Pahang

Department	Hospital Selangor SBS (n = 36)		Hospital Pahang SBS (n = 40)	
	Yes n = 14	**No n = 22**	**Yes n = 3**	**No n = 37**
SOPD	4	4	0	16
PD	6	1	0	3
MRD	0	7	2	10
OGD	2	8	1	4
OD	2	2	0	4

Table 4.26 and 4.27 summarized the level of IAQ parameters at Hospital Selangor and Hospital Pahang respectively. All IAQ parameters were categorized into high concentrations (High) and low concentrations (Low) depending on the mean value of all departments involved, either higher or lower than acceptable limits or range of the MICOP IAQ 2010 and FMA(SHW) 1970.

Table 4.26

The level of IAQ at five departments in Hospital Selangor

Variables	Department (Mean)					Mean	Standard Deviation
	SOPD	**PD**	**MRD**	**OGD**	**OD**		
Temperature (ºC) High- Lower than *23°C or above 26°C* *Low- Within 23-26°C*	High (21.9)	High (20.9)	High (20.7)	High (21.4)	High (22.9)	21.6	0.88

Table 4.26 (Continued)

Variables	Department (Mean)					Mean	Standard Deviation
	SOPD	PD	MRD	OGD	OD		
Relative Humidity (RH%) *High- Lower than 40% or above 70%* *Low- Within 40-70%*	Low (68.5)	High (73.3)	Low (63.1)	High (72.1)	Low (70.3)	69.5	4.0
Air Changes per Hour (ACH) *High- Above 10* *Low- Lower than 10*	High (7)	High (8)	High (7)	Low (11)	High (3)	7	3
Carbon dioxide (CO_2) *High- Above 1000 ppm* *Low- Lower than 1000 ppm*	Low (653)	Low (744)	Low (948)	Low (641)	High (1227)	843	248
Carbon Monoxide (CO) *High- Above 10 ppm* *Low- Lower than 10 ppm*	Low (0.66)	Low (1.60)	Low (0.52)	Low (0.82)	Low (1.72)	1.06	0.56
Total volatile organic compounds (TVOC) *High- Above 3 ppm* *Low- Lower than 3 ppm*	Low (1.02)	Low (0.31)	Low (0.41)	Low (0.93)	Low (0.55)	0.64	0.55
Formaldehyde (HCHO) *High- Above than 0.1 ppm* *Low- Lower than 0.1 ppm*	Low (0.04)	Low (0.06)	Low (0.04)	Low (0.04)	High (0.13)	0.06	0.04
Respirable particulates (RP) *High- Above than 0.15 mg/m^3* *Low- Lower than 0.15 mg/m^3*	Low (0.021)	Low (0.038)	Low (0.017)	Low (0.041)	Low (0.023)	0.028	0.011

Table 4.27

The level of IAQ at five departments in Hospital Pahang

Variables	Department (Mean)					Mean	Standard Deviation
	SOPD	PD	MRD	OGD	OD		
Temperature (ºC) High- Lower than *23°C or above 26°C* *Low- Within 23-26°C*	High (22.3)	Low (24.3)	Low (25.1)	High (22.1)	High (22.1)	23.2	1.42
Relative Humidity (RH%) *High- Lower than 40% or above 70%* *Low- Within 40-70%*	High (70.8)	Low (67.4)	Low (64.8)	High (70.5)	Low (64.6)	67.6	3.0
Air Changes per Hour (ACH) *High- Above 10* *Low- Lower than 10*	High (9)	High (9)	High (4)	High (8)	High (8)	8	2
Carbon dioxide (CO_2) *High- Above 1000 ppm* *Low- Lower than 1000 ppm*	Low (882)	Low (684)	Low (679)	Low (738)	Low (708)	738	84
Carbon Monoxide (CO) *High- Above 10 ppm* *Low- Lower than 10 ppm*	Low (0.08)	Low (1.45)	Low (1.61)	Low (0.70)	Low (1.21)	1.01	0.62
Total volatile organic compounds (TVOC) *High- Above 3 ppm* *Low- Lower than 3 ppm*	Low (0.00)	Low (1.79)	Low (0.59)	Low (0.13)	Low (0.72)	0.65	0.71
Formaldehyde (HCHO) *High- Above than 0.1 ppm* *Low- Lower than 0.1 ppm*	Low (0.08)	Low (0.00)	Low (0.02)	Low (0.05)	Low (0.03)	0.04	0.03

Table 4.27 (Continued)

Variables	**Department (Mean)**					**Mean**	**Standard Deviation**
	SOPD	**PD**	**MRD**	**OGD**	**OD**		
Respirable particulates (RP) *High- Above than 0.15 mg/m^3* *Low- Lower than 0.15 mg/m^3*	Low (0.005)	Low (0.022)	Low (0.033)	Low (0.008)	Low (0.021)	0.018	0.011

Table 4.26 and 4.27 showed that all results were categorized as high if they have failed to meet the acceptable limits or range as stipulated in the MICOP IAQ 2010 and FMA(SHW) 1970.

4.7.2 Association between IAQ and SBS

The association between SBS with the level of IAQ in Hospital Selangor and Hospital Pahang were described in Table 4.28 and 4.29 respectively. Chi-Square test (χ 2) was performed to find a significant association between them.

In Hospital Selangor, 14 workers were having SBS and 22 workers were not having SBS. These workers were further categorized as either high or low in Table 4.27 based on the information retrieved from Table 4.25 and Table 4.26. If mean value from Table 4.26 showed it was high or low, the number of respondents with or without SBS will be chosen from Table 4.25.

p- value for all variables were more than 0.05, thus there were no significant difference between SBS and the level of IAQ by means of the environmental measurements in Hospital Selangor.

Table 4.28

Association between SBS with the level of IAQ in Hospital Selangor (n = 36)

Variables	SBS (n = 36)		$\chi 2$	p- value
	Yes (%) n = 14	No (%) n = 22		
Temperature (ºC)				
High	14	22	0	1
Low	0	0		
Relative Humidity (RH%)				
High	8	9	0.905	0.34
Low	6	13		
Air Changes per Hour (ACH)				
High	12	14	2.079	0.15
Low	2	8		
Carbon dioxide (CO_2)				
High	2	2	0.234	0.63
Low	12	20		
Carbon Monoxide (CO)				
High	0	0	0	1
Low	14	22		
Total volatile organic compounds (TVOC)				
High	0	0	0	1
Low	14	22		
Formaldehyde (HCHO)				
High	2	8	2.079	0.15
Low	12	14		
Respirable particulates (RP)				
High	0	0	0	1
Low	14	22		

* Significant at $p < 0.05$

In Hospital Pahang, 3 workers were having SBS and 37 workers were not having SBS. These workers were further categorized as either high or low in Table 4.29 based on the information retrieved from Table 4.25 and Table 4.27. If mean value from Table 4.27 showed it was high or low, the number of respondents with or without SBS will be chosen from Table 4.25.

p- value for all variables were more than 0.05, thus there were no significant difference between SBS and the level of IAQ by means of the environmental measurements in Hospital Pahang.

Table 4.29

Association between SBS with the level of IAQ in Hospital Pahang (n = 40)

Variables	**SBS (n = 40)**		**χ 2**	**p- value**
	Yes (%) n = 3	**No (%) n = 37**		
Temperature (ºC)				
High	1	24	1.18	0.28
Low	2	13		
Relative Humidity (RH%)				
High	1	20	0.48	0.49
Low	2	17		
Air Changes per Hour (ACH)				
High	3	37	0	1
Low	0	0		
Carbon dioxide (CO_2)				
High	0	0	0	1
Low	3	37		
Carbon Monoxide (CO)				
High	0	0	0	1
Low	3	37		
Total volatile organic compounds (TVOC)				
High	0	0	0	1
Low	3	37		
Formaldehyde (HCHO)				
High	0	0	0	1
Low	3	37		
Respirable particulates (RP)				
High	0	0	0	1
Low	3	37		

* Significant at p <0.05

4.8 Discussion

4.8.1 Social Demographic of the Workers

Analysis of data showed that majority of workers who responded to the questionnaire are female (77.6%), age between 25-39 (55.3%) and non-smoker (88.2%). From the simple interview with workers during phase 1 and phase 2 of the study, it was found that most of the workers are aware on the relationship between IAQ and SBS. This is probably due to the fact that most of them are educated workers with medical background such as physicians, medical assistants and nurses.

The workers involved in this study were both female and male but it was recorded that more female work in both hospitals than male. A trend mentioned in the literature pertaining to study a relationship between IAQ and SBS is that female usually reported SBS symptoms more often than male (Lu Aye et al., 2005). This finding was not conclusive due to imbalance number between female and male.

Study by Nordstrom et al. (1995) found that the smoking status could be a major contributor to the prevalence of SBS among workers. However, data from this study showed there were a less number of smokers in both hospitals. Thus, the smoking status of the workers may not significantly contribute to the prevalence of SBS.

Last but not least, SBS also may become worse when the age of the worker increases, especially for those around 40-56 years old (Nur Fadilah et al., 2012). Since the majority of workers in hospitals were between 25- 39 years old, the age is considered as not the main contributing factor to the prevalence of SBS.

4.8.2 IAQ Parameters

Literature suggests that the level of IAQ parameters in buildings is one of the good indicators to determine the prevalence of SBS symptoms. The most frequent causes of SBS which can be connected to the level of IAQ parameters are indoor air pollutants, inadequate ventilation and lack of fresh air and humidity control inside the building (Armstrong Laboratory, 1992; U.S EPA, 2016).

In this study, both hospitals had similar findings in terms of environmental measurements as they both recorded lower level of IAQ parameters. In general, most of the results for IAQ parameters were below the acceptable limits or range of the MICOP IAQ 2010 except for temperature, RH and ACH. This suggested that the distribution of cooled fresh air over the occupied space was poor at certain areas and the ventilation rate is insufficient. Thus, the adequacy of the existing MVAC system in both hospitals was inadequate as the amount of cooled fresh air added to or removed from an occupied area was not enough to meet the specified requirement.

Nevertheless, ACH results have been found to contradict the CO_2 results as most of the areas tested for CO_2 have met the requirement of 1000 ppm. Since both ACH and CO_2 were used as a ventilation performance indicator, this suggested that the level of indoor air pollutants accumulated in both hospitals were actually low during the measurement day. This was supported by previous finding by Norhidayah et al. (2013) who suggested that the important predictor of SBS is both ventilation and accumulation of possible pollutants within the indoor environment.

Based on the years of operation and the age of building, Hospital Pahang is significantly older compared to Hospital Selangor. However, the level of IAQ parameters in Hospital Pahang (22 years of operation) is found to be better compared to Hospital Selangor (10 years of operation). None of the indoor air pollutants in Hospital Pahang were exceeded the acceptable limits but CO_2 and HCHO were observed to exceed the acceptable limits in Hospital Selangor (OD). From the questionnaire, it was also noticed that the old building (Hospital Pahang) had a less number of complaints compared to the new building (Hospital Selangor). Thus, it was not conclusive from this study that the years of operation and the age of building were a major factor that contributed to the good or poor level of IAQ parameters. This finding contrasts to what was found by Syazwan et al. (2009) who suggested that the poor level of IAQ in the old building was higher compared to the new building.

CO_2 and HCHO at OD, Hospital Selangor exceeded the acceptable limits. This may suggested there was a good connection between high level of CO_2 and high level of HCHO as CO_2 is nearly correlated with other indoor air pollutants that may cause SBS symptoms (Micheal et al., 2000; Sulaiman et al., 2011).

4.8.3 The Prevalence of SBS Symptoms

The symptoms of SBS are generic and varied (Godish, 1995; Michael et al., 2000; Raw, 1992). In this study, SBS symptoms reported at Hospital Selangor were irritated, stuffy or runny nose, feeling heavy-headed, headache, nausea/ dizziness, difficulties concentrating, cough and hand dry, itching and redskin. Similar symptoms found in Hospital Pahang were nausea/ dizziness, difficulties concentrating and hand dry, itching and redskin. The highest SBS symptom reported was irritated, stuffy or runny nose and this symptom was also found as one of the major SBS symptoms in study by Zuliza et al. (2016). There was no significant difference between reported SBS symptoms in both hospitals except for irritated, stuffy or runny nose. This finding is similar to finding from Nur Fadilah et al. (2012) that identified stuffy or runny nose was the only symptom showing significant different between buildings.

Findings from this study indicate that only Hospital Selangor can be concluded as having SBS since 38.9% of workers experienced SBS. Buildings can be concluded as having SBS if 20% of the occupants show symptoms of SBS (Burroughs & Hansen, 1991). Hospital Selangor is considered as a new building compared to Hospital Pahang, thus the prevalence of SBS in the old building was not significantly higher compared to the new building. In contrast with finding from Syazwan et al. (2009), the age of the building was not one of the major factors that contributed to SBS. However, both studies agree that there was actually no significant difference of the prevalence of SBS between the two buildings.

4.8.4 Association between SBS and IAQ

In this study, only SBS symptoms relating to the environmental measurements of IAQ were used to make relationship between the IAQ and the prevalence of symptoms. Based on the reported SBS symptoms and measurement results of IAQ parameters at both hospitals, basically there was no significant association between all individual IAQ parameters and SBS symptoms experienced by workers ($p > 0.05$). This relationship shown between IAQ parameters and SBS symptoms is not in accordance with the findings reported in literature, which state that CO_2, temperature, RH, TVOC (Sulaiman et al., 2011), RP, CO (Mohd Ezman et al., 2013) and HCHO (Norback et al., 1995) are related to the prevalence of SBS symptoms.

High level of CO_2 at OD, Hospital Selangor showed a good connection with high level of HCHO and low level of ACH but there was no significant association between CO_2 and SBS for all areas (p, Selangor = 0.63 and p, Pahang = 1). Thus, the measurement results of CO_2 were found to support Michael et al. (2000) that stated there was no direct causal link between exposure to CO_2 and SBS symptoms. There was a trend where the workers have symptoms such as irritated, stuffy or runny nose associated with the high level of the HCHO. According to Apter et al. (1994), headache, eye, nose and throat irritation, lethargy and fatigue symptoms have been attributed to indoor air pollutants. However, there was no significant association between exposure to other indoor air pollutants such HCHO, CO, TVOC and RP and SBS symptoms.

Although some researchers (e.g. Arya & Rajput, 2011) believe that lower level (below the applicable limits) of physical environmental factors were significantly associated with SBS symptoms, this study concluded that the SBS were not influenced solely by their level.

The conclusion observed in this study is similar to study conducted by Ooi et al. (1998) and Norhidayah et al. (2013) that found the measurements of IAQ or ventilation were not significantly associated with SBS symptoms. Most of the IAQ parameters monitored by them in the area with health complaints remained within acceptable limits.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this study, chapter 5 is the final chapter concludes the research. Several important issues that are discussed in this chapter include the implications, limitations and the contribution of the study. Possible future research areas are also discussed.

5.2 Overall Findings

The study was conducted at Hospital Selangor and Hospital Pahang and respondents were workers who work at the five selected departments namely as SOPD, PD, MRD, OGD and OD. As stated in previous chapters, the introduction, problem statement and research questions led to the following research objectives:

1. To study the current status of IAQ in hospitals
    - To measure the IAQ parameters (indoor air pollutants and physical environment factors) of carbon dioxide (CO_2), carbon monoxide (CO), total volatile organic compounds (TVOC), formaldehyde (HCHO), respirable particulates (RP), air temperature and air humidity
    - To compare the results with acceptable limits or range as stipulated in the MICOP IAQ 2010
2. To determine the adequacy of the existing MVAC system in maintaining good IAQ

- To measure air changes per hour, ACH (how many times the air enters and exits a space from the MVAC in one hour) and compare the results with acceptable limit as stipulated in the Factories and Machineries (Safety, Health and Welfare) Regulations 1970 (FMA(SHW) 1970)
- To measure CO_2 and compare the results with acceptable limit as stipulated in the MICOP IAQ 2010

3. To identify the common symptoms of SBS among workers in hospitals
4. To make a comparison of reported SBS symptoms by workers in different hospitals
5. To make a comparison of the prevalence of SBS among workers in different hospitals
6. To find a relation between IAQ and symptoms of SBS experienced by workers

The research findings were firstly organized according to the sections of the questionnaire comprising personal factors, indoor air complaints, symptoms included in the SBS and the psychosocial climate at the workplace. However, only questions on symptoms included in the SBS were assessed due to the main objective of this study is to find a relationship between IAQ (by means of the technical measurements, not by human perceptions) and symptoms of SBS experienced by workers. Then, findings from walkthrough survey and measurement of IAQ parameters were captured and analyzed. All measurement results are compared to the acceptable limits or range from the established standards in Malaysia, namely as MICOP IAQ 2010 and FMA(SHW) 1970.

Based on the research objectives, the major findings deriving from this study are as follows:

1. The results for indoor air pollutants were found to be satisfactory as most of them are well below the acceptable limits of MICOP IAQ 2010 except for CO_2 and HCHO measured at OD of Hospital Selangor. This suggested there was a good connection between high level of CO_2 and high level of HCHO. Micheal et al. (2000) and Sulaiman et al. (2011) suggested that CO_2 is correlated with other indoor air pollutants that may cause SBS symptoms. Nonetheless, most of the areas had low levels of CO_2 which indicate that a sufficient fresh air is being delivered to the occupied areas to keep the pollutants to an acceptable level.
2. At most of the areas in Hospital Selangor and Hospital Pahang, the results for physical environmental factors (air temperature, relative humidity and ACH) have failed to achieve the acceptable limits or range as specified in the MICOP IAQ 2010 and FMA(SHW) 1970. This finding strongly suggested that the distribution of cooled fresh air over the occupied space was poor at certain areas and the ventilation rate is insufficient. Thus, the adequacy of the existing MVAC system in both hospitals was inadequate as the amount of cooled fresh air added to or removed from an occupied area was not enough to meet the specified requirement. In this study, results for ACH and CO_2 were used as a ventilation performance indicator. ACH results contradicted the CO_2 results as most of the areas tested for CO_2 have met the requirement of 1000 ppm.
3. The highest SBS symptoms at Hospital Selangor was irritated, stuffy or runny nose (11.1%) followed by feeling heavy- headed, headache, nausea/

dizziness, difficulties concentrating, cough and hand dry, itching, redskin (8.3% for each symptom). While at Hospital Pahang, only nausea/ dizziness, difficulties concentrating, dry or flushed facial skin and hand dry, itching, redskin were reported with distribution of 2.5% for each symptom. Scaling/itching scalp or ears was not reported by workers at both hospitals.

4. There was no significant difference between reported SBS symptoms at Hospital Selangor and Hospital Pahang ($p > 0.05$) except for irritated, stuffy or runny nose ($\chi 2 = 4.69$, $p = 0.03$). This is the highest reported symptom in Hospital Selangor.
5. The potential of workers towards SBS was observed in both hospitals whereby SBS symptoms were recorded significantly higher at Hospital Selangor (38.9%) compared to Hospital Pahang (7.5%). Based on the years of operation, Hospital Pahang (22 years) is much older compared to Hospital Selangor (10 years).
6. Based on the reported SBS symptoms and measurement results of IAQ parameters at both hospitals, basically there was no significant association between all individual IAQ parameters and SBS symptoms experienced by workers ($p > 0.05$).

Based on these overall findings, there is no significant relationship between the prevalence of symptoms of SBS and IAQ.

5.3 Research Implications

Theoretically, the IAQ inside buildings can be represented by concentrations of indoor air pollutants, temperature, humidity and air movement (MICOP IAQ 2010). Poor IAQ may affect the health, comfort and performance of occupants (Ossama, Gamal & Amal, 2006). According to the U.S EPA (2016), poor IAQ can be associated with Sick Building Syndrome (SBS) and the causal factors of SBS can be understood in several categories such as inadequate ventilation, indoor air pollutants either from indoor or outdoor sources and biological pollutants. However, there are many other causal factors such as psychosocial factors (e.g. stress, work-load), noise, vibration, improper lighting and ergonomics.

Since SBS has variety of causes, a multifactorial approach should be applied in the prevention of SBS. Therefore, more studies with bigger scope should be planned and conducted in the future especially at healthcare facilities due to the following reasons:

1) most of the hospitals are aging with an out-dated ventilation system that need improvement, maintenance and repair
2) the occupant density of people in hospitals is relatively high
3) hospitals house many people with heightened susceptibility to problems associated with air contaminants

The research methods used in this study were not novel as they were adapted from the MICOP IAQ 2010, an established guideline developed by local authority in Malaysia. This guideline is fruitful to be used in investigating concerns about IAQ when complaints are received. The study process is similar to the investigation process which involves three phases; worker's questionnaire, walkthrough survey and environmental measurements. The findings from the environmental measurements were easily compared to the acceptable limits or range and the prevalence of SBS symptoms were easily gathered through questionnaire. Thus, the relationship between IAQ and SBS can be achieved. Anyhow, the difficulty to link SBS to IAQ parameters are understandable due to the following reasons as explained in many previous studies:

1) Worker's health complaints affected by several variables such as personal and psychosocial factors (e.g. stress, work-load, perception) and other environmental factors (e.g. noise, vibration, improper lighting and ergonomics) which can produce symptoms that are almost similar to those associated with poor IAQ
2) The combined effects of multiple indoor air pollutants at low concentrations
3) A small percentage of the workers may be sensitive to several chemicals

Results obtained from this study is useful to be used as a baseline data for IAQ level in hospitals and, they can be used as a reference to improve IAQ level in hospitals by improving control measures to ensure that all workers are not continuously affected by the poor IAQ or experienced any SBS in the future. Two main approaches to improve IAQ are source control and removal of indoor air pollutants. Source control is the most effective approach to improve IAQ by eliminating individual indoor air pollutants or reducing their emissions. Removal of contaminants is applied by increasing the fresh air ventilation rate or using air cleaning devices.

SBS problems must be resolved immediately as it may lead to increased absenteeism, reduced work efficiency and worsening employee morale (Ossama et al., 2006; WHO, 1995). While there is no evidence that good IAQ leads to maximum productivity, there is no doubt that an improved IAQ decreases worker complaints (Ossama et al., 2006). More research in this area is thus needed that could help to collect more scientific data and raise awareness about SBS and IAQ.

5.4 Research Limitations

Basically, the results were based on environmental measurement and input obtained from respondents that are randomly selected. The generalizability of the research results is possibly limited due to the several limitations. These limitations which might impact negatively on the generalizability of the research results are as follows:

i. The study focused on environmental measurements and involved only five selected departments and workers who were working in SOPD, PD, MRD, OGD and OD during normal working hours for each hospital. Thus, results from other areas and workers were not included during the data collection phase of this research.

ii. Non-probability sampling (convenience sampling) and a small sample size instead of larger sample was used. Also, the distribution based on gender was not balance as the respondents are 22.4% male and 77.6% female. The data gathered might not fully represent the population as a whole and it might be biased by participants' genders

iii. Participants for the study were limited as permission from the supervisors or voluntary participation was declined due to busy schedules of those in the targeted departments. Thus, the likelihood that the sample failed to include workers who experienced SBS symptoms is higher.

iv. Little interest by participants and the data from the questionnaires is significantly influenced by the reliability of the respondent. Honesty of participants and dealing with participants who are not cooperative to respond to questionnaires might not resemble real situation.

5.5 Suggestion for Future Research

This research focuses on to find a relationship between IAQ by means of the environmental measurements and symptoms of SBS experienced by workers without other variables such as personal and psychosocial factors (e.g. stress, work-load, perception) and other environmental factors (e.g. noise, vibration, improper lighting and ergonomics). Despite the limitations that were previously discussed, the following recommendations are suggested to assist future intended research:

i. Future research is needed to generate more information in the area especially for healthcare facilities with different setting such as bigger scope and sample from a larger population to gain more diversity and perspective.

ii. Future research is needed to measure other variables such as noise, vibration, improper lighting and ergonomics, not just environmental measurements in order to obtain more accurate picture of the influence of IAQ on the SBS

iii. There is a need to conduct further investigation about human perceptions (e.g. job satisfaction, work-load, stress) which can produce symptoms that are similar to those associated with poor IAQ

iv. Future research is needed to determine personal variables such as gender differences, age differences and educational level differences in order to find association between personal factors and SBS symptoms experienced by workers.

v. Non-probability sampling (convenience sampling) was used in selecting the sample. Thus, other sampling methods such as probability or random sampling is recommended.

vi. This study did not test the relationship amongst the independent variables (e.g. CO_2 and HCHO). It is recommended for future study to examine the relationship amongst independent variables that were found to correlate.

5.6 Conclusion

Findings from this study indicate that only Hospital Selangor can be categorised as having SBS since more than 20% of the occupants show its symptoms. The difference between Hospital Selangor and Hospital Pahang for irritated, stuffy or runny nose was found to be significant.

The results for indoor air pollutants were found to be satisfactory except for CO_2 and HCHO measured at OD of Hospital Selangor. In addition, the results for air temperature, relative humidity and ACH have failed to achieve the acceptable limits or range. Thus, the adequacy of the existing MVAC system in both hospitals was found to be inadequate. Although many researchers believe that lower level of IAQ parameters were significantly associated with SBS symptoms, this study concluded differently. The SBS were not influencing solely by the levels of IAQ parameters as there was no significant relationship between the prevalence of symptoms of SBS and IAQ. The conclusion observed in this study is similar to study conducted by Ooi et al. (1998) and Norhidayah et al. (2013) who found that the measurements of IAQ or ventilation were not significantly associated with SBS symptoms.

Findings from this study is hoped to improve the working environment and ensure that the health, comfort and well-being of all workers are not to be affected or continuously affected by the IAQ problems. Source control is the most effective way to improve IAQ by eliminating individual indoor air pollutants or reducing their emissions. Further study is needed to explore other causal factors of SBS such as personal, psychosocial factors, stress level and other environmental factors such as lighting, noise and ergonomics.

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APPENDIX A- QUESTIONNAIRE

INDOOR AIR QUALITY

QUESTIONAIRE FOR BUILDING OCCUPANTS

This short questionnaire has been given to you to facilitate the identification of potential sources of indoor air quality (IAQ) pollutants and to identify adverse health effects that may be associated with exposure to these pollutants. Your answers will remain confidential. Please complete the form as accurately as possible before returning to us.

Completed by : ______________________________
Disediakan oleh
Date/ Tarikh : ______________________________

General Information/ Maklumat Am

1. Building/Company name : ______________________________
2. Department/Division : ______________________________
3. Has your Company carried out any assessment related to IAQ?
   Adakah syarikat anda pernah menjalankan apa-apa ujian kualiti udara dalaman?
   ☐ Yes ☐ No ☐ In Progress ☐ Not Sure

Background factor/ Latar Belakang

4. Sex : ☐ Male ☐ Female
5. Age : ☐ <25 yrs ☐ 40- 55 yrs ☐ 25- 39 yrs ☐ >55 yrs
6. Do you smoke? ☐ Yes ☐ No

Nature of Occupation

7. Occupation/ Position : ______________________________
8. How long you have been at your present place of work? ________ yr(s) ________ mth(s)
9. No. of hours spent per day at your main workstation : ________ hr(s)
10. Brief description of your work/ *Ringkasan tugas-tugas anda di tempat kerja* :

____

____

Environmental Conditions/ Keadaan Persekitaran

11. Type of workstation : ☐ Enclosed Room ☐ Open Concept
12. How is your area air-conditioned? ☐ Central Unit ☐ Local Unit (split unit)
13. Please indicate if you work with or near the following equipment:

	Everyday	2-3 times weekly	Never
a) Typewriter	☐	☐	☐
b) Video display unit (VDU)/ computer	☐	☐	☐
c) Photocopier	☐	☐	☐
d) Fax machine	☐	☐	☐

14. Have you been bothered during the last three (3) months by any of the following factors at your workstation/ workplace?/ Adakah anda rasa terganggu sejak 3 bulan lepas dengan mana-mana faktor yang berikut di tempat kerja?

	Yes, often (every week)	Yes, sometimes	No, never
a) Draught/ *Aliran udara dalam bilik*	☐	☐	☐
b) Room temperature too high/ *Suhu bilik yang terlalu tinggi*	☐	☐	☐
c) Varying room temperature/ *Suhu bilik yang tidak menentu*	☐	☐	☐
d) Room temperature too low/ *Suhu bilik yang terlalu rendah*	☐	☐	☐
e) Stuffy "bad" air/ *Udara yang menyesakkan pernafasan*	☐	☐	☐
f) Dry air/ Udara yang kering	☐	☐	☐
g) Unpleasant odour/ *Bau yang kurang menyenangkan*	☐	☐	☐
h) Passive smoking/ *Merokok pasif*	☐	☐	☐
i) Dust and dirt/ *Habuk dan kotoran*	☐	☐	☐

APPENDIX A- (CONTINUED)

INDOOR AIR QUALITY

QUESTIONAIRE FOR BUILDING OCCUPANTS

This short questionnaire has been given to you to facilitate the identification of potential sources of indoor air quality (IAQ) pollutants and to identify adverse health effects that may be associated with exposure to these pollutants. Your answers will remain confidential. Please complete the form as accurately as possible before returning to us.

Past/Present Diseases/Symptoms/ *Penyakit/ Simptom Dulu/ Sekarang* :

	Yes	No
15. Have you ever had asthmatic problems/ *respiratory- related diseases* ?	☐	☐
If yes, during last year?	☐	☐
16. Have you ever suffered from sinusitis/ *nose-related diseases* ?	☐	☐
If yes, during last year?	☐	☐
17. Have you ever suffered from eczema/ *skin diseases* ?	☐	☐
If yes, during last year?	☐	☐

Present Symptoms/ *Simptom Sekarang*

18. During the last three (3) months, have you had any of the following symptoms at work (Answer every question even if you have not had any symptoms)?/ *Sejak 3 bulan lepas, adakah anda mengalami mana-mana simptom yang berikut di tempat kerja?*

	Yes, often (every week)	Yes, sometimes	No, never	If Yes, do you believe that is due to your work environment		
				Yes	No	Unsure
a) Fatigue/ *Letih*	☐	☐	☐	☐	☐	☐
b) Feeling heavy-headed/ *Lembab*	☐	☐	☐	☐	☐	☐
c) Headache/ *Sakit Kepala*	☐	☐	☐	☐	☐	☐
d) Nausea/dizziness/ *Mual/ Pening*	☐	☐	☐	☐	☐	☐
e) Difficulties concentrating/ *Sukar menumpukan perhatian*	☐	☐	☐	☐	☐	☐
f) Itching, burning or irritation of the eyes/ *Gatal, pedih atau merengsa pada mata*	☐	☐	☐	☐	☐	☐
g) Irritated, stuffy or runny nose/ *Merengsa, tersumbat atau hidung berair*	☐	☐	☐	☐	☐	☐
h) Hoarse, dry throat/ Serak, *kering Tekak*	☐	☐	☐	☐	☐	☐
i) Cough/ *Batuk*	☐	☐	☐	☐	☐	☐
j) Dry or flushed facial skin *Kulit muka kering atau kemerahan*	☐	☐	☐	☐	☐	☐
k) Scaling/itching scalp or ears/ *Pengelupasan/ Kegatalan kulit kepala atau telinga*	☐	☐	☐	☐	☐	☐
l) Hand dry, itching, redskin *Tangan kekeringan, gatal, kemerahan*	☐	☐	☐	☐	☐	☐

19. When do these symptoms occur? ☐ Mornings

Bila simptom-simptom selalu terjadi? ☐ Afternoons

☐ No noticeable trend

20. When do you experience relief from these symptoms? ☐ Mornings

Bila anda akan berasa lega daripada simptom-simptom yang dinyatakan? ☐ Afternoons

☐ No noticeable trend

APPENDIX B- WORKPLACE INSPECTION CHECKLIST

Checklist for Walkthrough Inspection

Date of Inspection: ____

Inspected by: ____

Location: ______________________________ **Time:** ____________

1.0 GENERAL CONSIDERATIONS

	Yes	No	N/A
1.1 Ensured that temperature and humidity are maintained within ..	☐	☐	☐
acceptable ranges	☐	☐	☐
1.2 Ensured that no obstructions exist in supply and exhaust vents	☐	☐	☐
1.3 Checked for odors	☐	☐	☐
1.4 Checked for signs of mold and mildew growth	☐	☐	☐
1.5 Checked for signs of water damage..	☐	☐	☐
1.6 Checked for evidence of pests and obvious food sources.............	☐	☐	☐
1.7 Checked for presence of hazardous substances	☐	☐	☐
1.8 Dirty or unsanitary conditions	☐	☐	☐
1.9 Inadequate ventilation (e.g stuffy, stale air)...................................	☐	☐	☐
1.10 Poor conditions (e.g drain pans, cooling towers, filters, air cleaners)	☐	☐	☐
1.11 Overcrowding	☐	☐	☐

2.0 GROUND LEVEL

	Yes	No	N/A
2.1 How many occupants in the work area?	☐	☐	☐
2.2 How long are they in the work area?...	☐	☐	☐
2.3 Is the indoor temperature regulated by thermostats?	☐	☐	☐
2.4 Is there discomfort from heat radiation from visual display units?	☐	☐	☐
2.5 Is there discomfort due to radiant heat from warm window surfaces?	☐	☐	☐
2.6 Are temperature, relative humidity and air flow rates checked .. regularly during working hours?	☐	☐	☐
2.7 Does air reach all parts of the office or there are no dead spaces?	☐	☐	☐
2.8 Is the building is still being used for the purpose it was intended?	☐	☐	☐
2.9 Have partitions/ walls been added or removed?	☐	☐	☐
2.10 Have occupancy levels changed?...	☐	☐	☐

APPENDIX B- (CONTINUED)

3.0 Potential Sources of Contaminants

	Yes	No	N/A
3.1 Are they any occupants smoking?	☐	☐	☐
If yes, indicate where and if no, is there any designated area?	______		
3.2 Are they furniture, carpets etc that emit noticeable odours?.......	☐	☐	☐
3.3 Have detergents, pesticides or other chemicals been used in the Building?	☐	☐	☐
3.4 Has there been any recent renovation or maintenance in any part of the building?	☐	☐	☐
3.4.1 Done during working hours?	☐	☐	☐
3.4.2 That can be a source of contaminants (e.g painting, carpet Installation/ cleaning, pesticide application etc)?	☐	☐	☐
3.4.3 That can alter air flow patterns such as installation of .... Partitions or relocation of air intake or exhaust?	☐	☐	☐
3.5 Is there a kitchen or pantry where cooking is done?	☐	☐	☐
If yes, is exhaust ventilation provided?	☐	☐	☐
3.6 Is the building adequately clean?...	☐	☐	☐
3.7 Is regular dusting of office furniture, ledges, shelves etc. carried out to help keep dust to a minimum?	☐	☐	☐
3.8 Are the carpets vacuum- cleaned regularly?............................	☐	☐	☐
3.9 Are they any office equipment giving off gases or fumes such as photocopying machines, blueprint machines and other office machines	☐	☐	☐

4.0 Ventilation and air-conditioning

	Yes	No	N/A
4.1 Is there at least one supply air and exhaust air vents in every area?	☐	☐	☐
If yes, how many vents provided in each area?	______		
4.2 Are supply air or exhaust air vents blocked in any way by partitions, files or other structures that obstruct air flow			
4.3 Has dust collected around the air vents?	☐	☐	☐
4.4 Is the air-conditioning system turned off..	☐	☐	☐
4.4.1 any time during the day?	☐	☐	☐
4.4.2 after office hours?	☐	☐	☐
4.4.3 are there still occupants in the building after office hours?	☐	☐	☐
4.5 Where is the outdoor air intake duct located?	☐	☐	☐
4.5.1 near the cooling tower in the building?	☐	☐	☐
4.5.2 near adjacent buildings?	☐	☐	☐

APPENDIX B- (CONTINUED)

4.5.3 at street level?	☐	☐	☐
4.5.4 near a car park?...	☐	☐	☐
4.5.5 is it obstructed?...	☐	☐	☐
4.5.6 others, please specify?	____	____	____
4.6 Are heavy industries located nearby?	☐	☐	☐
4.7 Are there any construction work going on nearby?	☐	☐	☐
4.8 Is outdoor air actually getting into the building?	☐	☐	☐
4.9 Is there regular schedule for cleaning and maintenance of the ..... air- conditioning system in the building?	☐	☐	☐
4.10 Are all the components of the air- conditioning system regularly... Inspected for leaks, breaches etc.?	☐	☐	☐

APPENDIX C- PHOTOS OF SITE ASSESSMENT

Photo 1
Fresh air intakes were located near to vehicles parking area

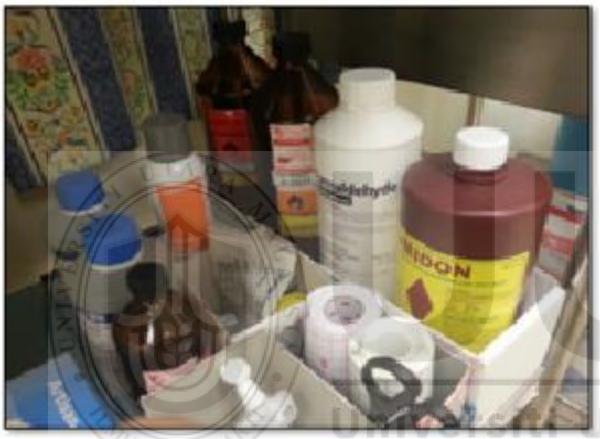

Photo 2
TVOC sources in indoors

Photo 3
MVAC and the log book for maintenance activities

APPENDIX C- (CONTINUED)

Photo 4
Fresh air dampers in the AHU room were closed

Photo 5
Example of IAQ equipment and its sampling location