INDOOR AIR QUALITY ASSESSMENT IN KLANG VALLEY PUBLIC HOSPITALS : A PROPOSAL TO IMPROVE MALAYSIAN HOSPITAL IAQ STANDARD.

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FACULTY OF ENGINEERING
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RESEARCH PROJECT SUBMITTED TO THE FACULTY OF ENGINEERING UNIVERSITY OF MALAYA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF ENGINEERING (SAFETY, HEALTH AND ENVIRONMENT)

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ABSTRACT

Air quality and clean air are important requirements that always been given higher priority in public health issue. It is become more important when it involves sensitive working environment such as hospitals which exposes high risk to staff, patients and visitors. Therefore, it is crucial for the hospital to put indoor air quality into concerns in particular. This study aims to investigate the distribution and pattern of Indoor Air Quality (IAQ) within selected Klang Valley hospitals. Besides that, this study also aims to evaluate the potential risk of the hospitals' IAQ to the exposed healthcare workers. Three selected hospitals in Klang Valley were chosen for this cross sectional study. The study comprises of three phases. The first phase is walkthrough inspection where it was conducted prior the site assessment to check the room conditions and environment based on observation. The second phase is an experimental and quantitative phase where a structured IAQ assessments has been conducted at the selected hospitals which cover physical, chemical and biological parameters. The parameters reading were collected and compared to our national IAQ standard. The third phase is a qualitative phase where IAQ questionnaire responses were collected from the healthcare providers based on convenient sampling, aims to collect information on any IAQ related diseases signs and symptoms encountered. The data collected was analyzed using various association tests by using Statistical Package for Social Sciences (SPSS). It was found that during walkthrough inspection, poor housekeeping and maintenance issues at the Air Handling Unit rooms were one of the major issues identified. Generally, the main IAQ issues found were high relative humidity, low temperature and low air movement in all sampling areas. TVOC is below the recommended standard (<3) with reading of <0.01ppm at all locations. There is a concern on carbon dioxide (792ppm – 955ppm) and carbon monoxide (0.5ppm – 1.5ppm) concentration where it was detected in dental laboratory in all three hospitals. The IAQ assessment has recorded that majority of the hospitals has low temperature (19.8°C - 30.2°C), below the Indoor Air Quality Codes of Practice (ICOP), 2010 standard (23°C - 26°C). It was also found that the majority of the area sampled has exceed the relative humidity recommended by the standard (40% - 70%) ranging from 60% to 83.5%. Lastly, low air movement (m/s) was also found where the reading were below the recommended standard between 0.15m/s to 0.50m/s. The demographic of the respondents are 65.6% were female, 77.9% were in the age of 26 to 39 years old, 90.2% were not smoking, 67.5% were working less than 5 years and 84.7% were working in enclosed room type workstation. It was found that majority of the staff with 86% responses claim that the workstation is too cold and agreed that sometimes they experienced drowsiness (78%), fatigue (75%) and headache (74%). A comprehensive action plan covering immediate and preventive action plan is needed where it focuses on improving housekeeping practices and continuous indoor air quality monitoring are needed.

Keywords : Indoor Air Quality, Air Pollution, Public Health, Exposure Risk, Air Handling Unit.

ABSTRAK

Kualiti udara dan udara bersih adalah keperluan penting dan perlu diberi keutamaan dalam isu kesihatan awam. Ia menjadi lebih penting apabila ia melibatkan persekitaran kerja yang sensitif seperti hospital yang memperlihatkan risiko tinggi kepada kakitangan, pesakit dan pelawat. Oleh itu, adalah penting bagi hospital untuk meletakkan kualiti udara dalaman menjadi isu yang penting untuk diberikan perhatian. Kajian ini bertujuan untuk menyiasat taburan dan corak Kualiti Udara Dalaman (IAQ) di hospital-hospital terpilih, sekitar Lembah Klang. Selain itu, kajian ini juga bertujuan untuk menilai potensi risiko pendedahan IAQ hospital kepada perkerja sektor kesihatan yang terdedah. Tiga hospital di sekitar Lembah Klang telah dipilih untuk kajian ini. Kajian ini terdiri daripada tiga fasa. Fasa pertama adalah pemeriksaan di mana ia dijalankan sebelum penilaian IAQ dijalankan, bertujuan untuk memeriksa keadaan bilik dan persekitaran berdasarkan pemerhatian. Fasa kedua adalah fasa eskperimen dan kuantitatif, di mana penilaian IAQ berstruktur telah dijalankan di hospital terpilih yang meliputi parameter fizikal, kimia dan biologi. Pembacaan parameter dikumpulkan dan dibandingkan dengan standard IAQ kebangsaan. Fasa ketiga adalah fasa kualitatif di mana respons soal selidik IAQ dikumpulkan dari penyedia penjagaan kesihatan berdasarkan persampelan yang mudah, bertujuan mengumpulkan maklumat mengenai sebarang tanda-tanda dan gejala-gejala penyakit berkait dengan IAQ. Data yang dikumpul dianalisis dengan menggunakan pelbagai ujian menggunakan Paket Statistik untuk Sains Sosial (SPSS). Telah didapati bahawa semasa pemeriksaan, masalah pengemasan dan penyelenggaraan telah isu utama dikenalpasti di bilik Unit Pengendalian Udara. Umumnya, isu utama IAQ yang terdapat adalah kelembapan relatif tinggi, suhu rendah dan pergerakan udara rendah di semua kawasan. Terdapat kebimbangan terhadap kepekatan karbon dioksida (792ppm - 955ppm) dan kepekatan karbon monoksida (0.5ppm - 1.5ppm) di mana ia dikesan di makmal pergigian di ketiga-tiga hospital. Penilaian IAQ telah mencatatkan bahawa kebanyakan hospital mempunyai suhu rendah (19.8^{o}C - 30.2^{o}C), di bawah Kod Amalan Kualiti Udara Dalaman (ICOP), 2010 standard (23^{o}C - 26^{o}C). Keadaan ini menimbulkan persekitaran yang tidak baik dan ketidakselesaan di kalangan penghuni bangunan. Ia juga didapati bahawa majoriti kawasan sampel telah melebihi kelembapan relatif yang disyorkan oleh standard (40% - 70%) dari 60% hingga 83.5%. Keadaan kelembapan yang tinggi ini boleh meningkatkan pertumbuhan kulat dan bakteria di alam sekitar. Akhir sekali, pergerakan udara rendah (m / s) juga didapati di mana bacaan di bawah standard yang disyorkan antara 0.15m / s hingga 0.50m / s. Ini boleh membawa kepada udara dalaman yang kaku dan menyebabkan ketidakselesaan penghuni. Demografi responden adalah 65.6% adalah wanita, 77.9% adalah pada usia 26 hingga 39 tahun, 90.2% tidak merokok, 67.5% bekerja kurang daripada 5 tahun dan 84.7% bekerja di stesen kerja bilik jenis tertutup. Ia didapati bahawa majoriti kakitangan dengan 86% menjawab bahawa stesen kerja terlalu sejuk dan bersetuju bahawa kadang-kadang mereka mengalami rasa mengantuk (78%), keletihan (75%) dan sakit kepala (74%). Menjelang akhir kajian ini, satu set cadangan mengenai langkah-langkah kawalan dan mekanisme kawalan yang sesuai untuk peningkatan kualiti udara dalam bangunan dicadangkan. Pelan tindakan yang komprehensif yang merangkumi pelan tindakan segera dan pencegahan diperlukan di mana ia memberi tumpuan untuk meningkatkan amalan pengemasan dan pemantauan kualiti udara dalaman yang berterusan adalah diperlukan.

Katakunci : Kualiti Udara Bangunan, Kesihatan Awam, Risiko Pendedahan, Bilik Kawalan Udara.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASHRAE	: American Society of Heating, Refrigerating and Air Conditioning Engineers
BRI	: Building Related Illness
CH_2O	: Formaldehyde
CO	: Carbon monoxide
CO_2	: Carbon dioxide
CFU	: Colony Forming Unit
DOE	: Department of Environment
DOSH	: Department of Occupational, Safety and Health
EPA	: Environmental Protection Agency
ETS	: Environmental Tobacco Smoke
HVAC	: Heating, Ventilation and Air Conditioning (HVAC)
IAQ	: Indoor Air Quality
ICOP	: Industry Codes of Practice
MS	: Mainstream Smoke
MAE	: Malt Extract Agar
MOH	: Ministry of Health
MPN	: Most Probable Number
NO_2	: Nitrogen dioxide
OSHA	: Occupational Safety and Health Act
PM	: Particulate Matter
PAH	: Polycyclic Aromatic Hydrocarbon
RH	: Relative Humidity
SBS	: Sick Building Syndrome
SM	: Sidestream Smoke
SO_2	: Sulphur dioxide
TSA	: Trypticase Soy Agar
TVOC	: Total Volatile Organic Compound
VOC	: Volatile Organic Compound
WHO	: World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Background of Study

The relationship between indoor air pollution and the health effects is getting more attention amongst community. Indoor Air Quality (IAQ) plays a crucial role in human health as majorities of people spend more time in indoor environment (M. Ramaswamy, October, 2010). IAQ is the quality of the indoor air in a building which exposed to the occupant where it may lead to discomfort and adverse health effect upon exposure (Deloach, 2004).

In average, 88% of human time is spent inside buildings, not including 7% time spent while commuting in vehicle. It shows that only 5% of time was spent in outside environment (Robinson, 2005). As such, it shows relatively that the exposure of indoor air contaminants is higher to human compare to outdoor air contaminants exposure, yet the severity of the effects is varies based on many attributes. The level of exposure is significantly depending on the pattern of human behavior and activities (Harrison et.al, 2013).

Hospital has a challenging environment where it exposed to many air contaminants such as chemical from cleaning and medical process, radioactive from imaging and scanning equipment, and other biological contaminants from patients such as bloods, mucus and etc. At the same time, hospital also requires to strive for a hygienic condition which indirectly affect the process and procedure in their daily job. Therefore, it is very crucial for hospital to reduce the indoor air contaminants exposure and maintain a good IAQ standard in place.

1.2 Problem Statement

Indoor air quality plays important roles in human total exposure to air contaminants (World Health Organization (WHO) R. O., 2010). Poor IAQ may invites short-term and long-term health issues such as allergic reactions, breathing difficulties, conjunctivitis, sinusitis and bronchitis (Ministry of Health Malaysia, 2015). Therefore, an IAQ assessment shall be conducted to ensure a good and healthy indoor environment where it is a method to characterize the air quality standard environmental risks associated with exposure to pollution.

There is studies conducted to find the significant relationship between IAQ and its impact to the health standard in a population. For example, WHO has found that there is a significant relationship between the daily ambient suspended particulate levels and the mortality rate in an environment (World Health Organization (WHO), 1997). As such, with considering hospital as one of a challenging and complex environment where it requires a particular focus in ensuring the compliance of health and wellness standard where IAQ is one of the crucial component to be account for (Michael Leung, 2006), a comprehensive study on the Indoor Air Quality trend and pattern in hospital shall be studied.

Hospitals is an important platform in healthcare system where most resources including the building facilities and the healthcare providers are assigned and expected to effectively and efficiently functioning, with aims to promote and ensure the health to public. Hospital is a place where the public seeks diagnosis and treatment of a sickness, a place to get the health awareness from education, training and research, and many other activities takes place in the facility. As it serves as a place with many healthcare activities, it is very important for the hospital to put indoor air quality into concerns in particular.

M Rawaswamy (2010) state that there are four components where hospital indoor air is different from other building indoor air. The hospital indoor air shall has the characteristic to restrict air exchange between departments in the hospital. Besides that, the hospital shall also have the mechanism to dilute, filter and / or remove the indoor air contaminants which might come in the form of odor, microorganism, chemical and radioactive substances. The hospital also need to have a control in various areas where each areas might have a different temperature and humidity requirement to serve the areas purpose. In total, the indoor air system in the hospital should be design to allow the control to ensure an accurate standard environmental conditions are complied. Therefore, this study will help to identify whether the components are met.

Besides that, air quality in Malaysian hospitals need to be studied as Malaysia has hot and humid weather throughout the year as it is located in tropical region. This vulnerable environment has invites many IAQ concerns especially in hospital (Khew S.L., 2010). Ministry of Health has developed the IAQ framework to be implemented in all public healthcare facilities in Malaysia where it shall define a target set to IAQ services in providing and strengthening a complete connotation between good indoor air environments and building management (Ministry of Health Malaysia, 2015). However, the indoor air contaminants and its sources in hospital was not well discussed (Khew S.L., 2010). Therefore, this study also aims to provide an overview on what are the air contaminants that might contribute to the indoor air problem in the selected hospitals.

Hospital has many air contaminants sources that affect the indoor air quality in the environment. This includes susceptible patients that are easily prone to diseases, possible biological contaminant (i.e. bioaerosol, fungi and molds, etc) and chemical contaminants (i.e. formaldehyde, laboratory reagents, cleaning products, etc), hygiene process and procedure (i.e. laboratory, surgery theatre, operation room, pharmacy etc) (Ramawasmy, 2010).

Therefore, hospitals need to have special requirement and standard for air quality during design, operation and maintenance to prevent infections and contamination parameters from spreading. There was a study showed that 5% of patients has acquired nonsocomial infections as they are exposed to hospital environment while attending for medical treatment (O'Neal, 24 September 2000). It shows that, IAQ is very important in hospital as it will safeguard patients, visitors and healthcare providers against nosocomial infections and occupational diseases. As such, there is a need to have further understanding on the IAQ patterns in hospitals especially in our environment setting.

Many IAQ studies has been conducted in Malaysia (Norhidayah et al, 2013) but none of them are focusing the indoor air quality in hospitals. In general, there are few studies conducted on IAQ were conducted in hospitals such as studies from Ramawasmy, setting but none of the studies are conducted in Malaysia. A study conducted by Khew in 2010 that study the sources of indoor air quality problem in a new hospital but the sample areas only cover the general workstation such as library and open area in each levels. As such, it is important to study the distribution and pattern of the IAQ in the Malaysian hospitals as this data will serve as a baseline study.

This research studies the pattern of IAQ contaminants in identified hospitals, assess the indoor air quality diseases amongst healthcare providers, and recommend appropriate actions measures for continual improvement of IAQ standard in hospitals.

1.3 Objectives

The research study aims to assess the Indoor Air Quality in Klang Valley hospitals. The assessment findings is compared to the following Malaysian Indoor Air Quality Guidelines :

1. Guideline on Indoor Air Quality for Hospital Support Services (MOH 2015)
2. Industry Code of Practice on Indoor Air Quality 2010 (ICOP on IAQ 2010)

Based on the IAQ results and findings, hospitals management will be able to rectify and improve the IAQ standard with the consideration of the proposal herewith.

1.3.1 Specific Objectives

1. To study the pattern of indoor air quality within Klang Valley hospitals.
2. To evaluate the potential exposure and health risk to healthcare providers.
3. To recommend appropriate actions measures and / or control mechanism for continual improvements in IAQ in the hospitals.

1.4 Scope of the study

This research study was conducted in three public hospital facilities in Klang Valley area. The study compares the IAQ standards between the facilities and conclude the pattern of IAQ findings accordingly.

The methodology of the IAQ assessment for this research is adapted from the the Industry Code of Practice on Indoor Air Quality 2010, (DOSH, 2010). The IAQ assessment includes walkthrough inspection, building occupant’s questionnaire and IAQ assessment.

1.5 Significance of Study

The distribution and pattern of possible air contaminants in Malaysian hospitals is identified and discussed. With this data, the significance relationship between the air contaminants exposure and its impact to healthcare personnel is also discussed.

This research explains the possible air contaminants in Malaysian hospitals, serving as a foundation / benchmarking IAQ statement for healthcare facilities in the tropical area. The general distribution and pattern of air contaminants in the hospitals are identified, helping the management on mitigating the highlighted issues. The proposal for improvement will help for continual improvement of air quality standard in healthcare facilities. This study will help to provide data, and platform for improving the standard and guideline in designing and maintaining the indoor air quality effectively.

1.6 Outline of the study

This research report consists of 5 main chapters which are, Introduction, Literature Review, Methodology, Results and Discussions and Conclusion and Recommendations. In the Introduction, it will discuss the study background, problem statement and the study objectives. Followed by the Literature Review, it compiles the previous study findings on indoor air quality conducted in various settings. The methodology chapter will discuss the preparation plan on conducting this research. As for Results and Discussion, this part will share the findings from the indoor air assessments, walkthrough inspection and responses collected from the respondents. Lastly, there will be a conclusion on the overall study and a recommendation to the hospital management on how to improve and / or maintain the indoor air quality in the hospital environment.

This research report contains six main chapters. A brief introduction of each chapter that will be discussed is as shown in Figure 1 below:

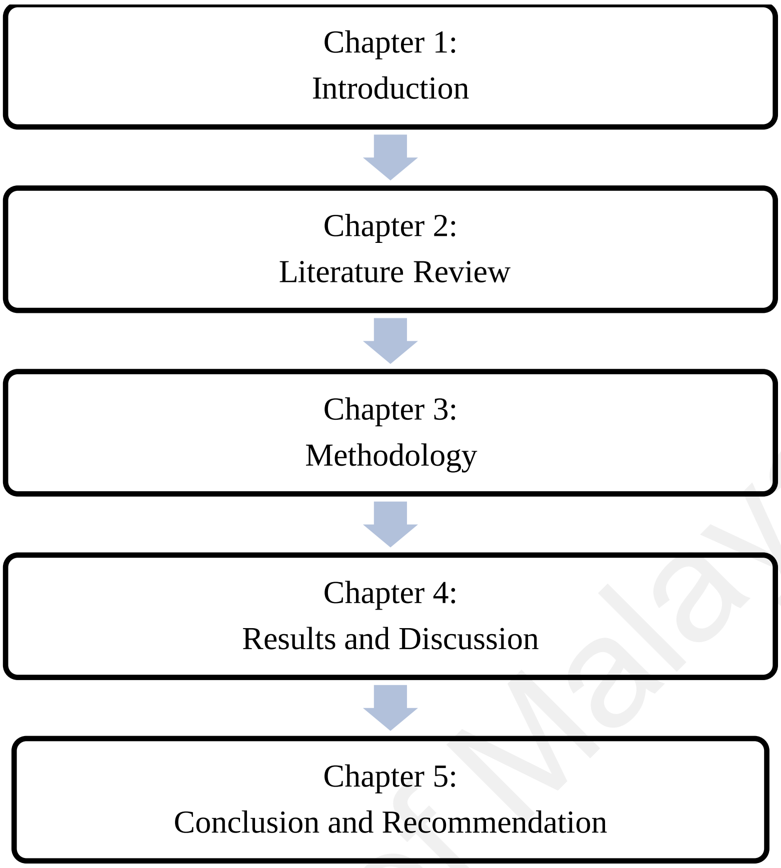

Figure 1 : Research Outlines

CHAPTER 2: LITERATURE REVIEW

2.1 Background of Indoor Air Quality

IAQ is the quality of the indoor air in a building which exposed to the occupant where it may lead to discomfort and adverse health effect upon exposure (Deloach, 2004). IAQ is a basis determinant on determining the healthy environment and the people states of being comfort, and productive (Norhidayah et.al, 2013). Poor IAQ in a building is associated with Sick Building Syndrome (SBS) which define as a situation where the respective building occupants experience acute health or / and comfort related effects where showing the significance relationship linked to time spent in the building (Joshi, 2008). The airborne building contaminants created Building Related Illness (BRI) which defines as any discomforts and acute illnesses acquired due to poor indoor air quality exposure (Bourbeau et.al, 2007).

2.2 Sources of Indoor Air Contaminants

The indoor air pollutant concentration is affected by the air volume in the enclosed area, production and emission rate of the pollutant from the source, circulation and removal of pollutant via mechanism available, rate of air exchange between indoor and outdoor environment and the outdoor pollutant concentration (Maroni et al., 2015). The major sources of indoor air contaminants may derive from occupants, furnishing and equipment (WHO, 2010). Besides that, outdoor sources also may contribute to indoor air quality which depends on the ventilation types in used (either natural or mechanical ventilation), the ventilation rate per hour and the contaminants in nature (Wanner, 2014).

The air we breathe may be degraded into various types of contaminants that might potentially jeopardize the health. The contaminants can be classified into 2 categories;

non-biological pollutant sources and biological pollutant sources which generally summarized in Table 1.

Table 1 : Major Indoor Pollutants and Emission Sources

Pollutant	Major Emission Sources
Allergens	House dust, domestic animals, insects
Asbestos	Fire retardant materials, insulation
Carbon dioxide	Metabolic activity, combustion activities, motor vehicles in garages
Carbon monoxide	Fuel burning, boilers, stoves, gas or kerosene heaters, tobacco smoke
Formaldehyde	Particleboard, insulation, furnishings
Micro-organisms	People, animals, plants, air conditioning systems
Nitrogen dioxide	Outdoor air, fuel burning, motor vehicles in garages
Organic substances	Adhesives, solvents, building materials, volatilization, combustion, paints, tobacco smoke
Ozone	Photochemical reactions
Particles	Re-suspension, tobacco smoke, combustion products
Polycyclic aromatic hydrocarbons	Fuel combustion, tobacco smoke
Pollens	Outdoor air, trees, grass, weeds, plants
Radon	Soil, building construction materials (concrete, stone)
Fungal spores	Soil, plants, foodstuffs, internal surfaces
Sulphur dioxide	Outdoor air, fuel combustion

Source : Spengler et.al, (2013)

Studies shows that reactive gasses are easily to be produced at lower concentrations in indoor setting compare to outdoor as the gasses component will actively contact and react with indoor surfaces (Wallace, 2016). Therefore, the concentration of reactive gasses is usually higher in indoor setting compare to outdoor environment, which shows that the exposure to human is significantly higher.

IAQ parameters also includes the level of temperature and humidity of the enclosed area. Indoor temperature is influenced by many factors for example the air-conditioning temperature

The human activity indoors also affecting the concentration of indoor air pollutant. Heating and cooking activities are very crucial and typical in our daily lives however the activities produce emission i.e. smokes and gases that indirectly affect the air quality in a building. The challenges become harder in colder climate as heat from combustion is needed to warm the building but it also produces air pollutant emission from the combustion by-product (Burr, 2015). High dependence on wood and coal for source of combustion to produce heat leads to increase of indoor air pollutant emission (Wallace, 2016). It was found that bad conditions of equipment used for the activities such as improper vented appliances, vent malfunction or improper installations can lead to a worse indoor air quality which increase the health severity of the people exposed (Nagda, 2006). Smoking indoor would also deteriorate the IAQ status in a building. Besides that, there are lots of chemical compounds appears as indoor air pollutant which emit from indoor finishes such as paints, varnishes and solvents (Wanner, 2014).

2.2.1 Non-Biological Pollution Sources

Non-Biological pollution sources is any substances that includes chemicals, radioactive substances and dusts that will affect the indoor air quality due to their presence in the environment (Wanner, 2014)

Asbestos is a type of high temperature fibrous hydrated silicate minerals that has various types of filaments which includes chrysotile, crocidolite and amosite (Maroni et al., 2015). Usually the general health symptoms are related to exposure and inhalation of fibers longer than 5 microns and shorter than 3 microns' diameters size which generally leads to asbestos related disease such as asbestosis, bronchial carcinoma, mesothelioma and pleural conditions problems (Lin et.al, 2005). Some asbestos are presence in old hospital's ceiling and building construction. However, in 1999, many asbestos based materials in the government building such as schools, clinics and hospitals has been replaced (Khew S.L., 2010).

Carbon dioxide (CO_2) is colorless and odorless gas which majorly formed by combustion process (Wanner, 2014). The amount of $CO_2$is increases in operations that involve with combustion from gas, kerosene, wood and coal fueled appliances (Moriske et.all, 2010). CO_2 is an asphyxiant agent that also potentially cause shortness of breath, stuffiness, discomfort, dizziness, nausea and act as respiratory irritant (Schwarzberg, 2013), (Yang et.al, 2007) which affect the cells activity within visual cortex. On the other hand, carbon monoxide (CO) is an odorless gas which produced by incomplete combustion process especially fossil fuels (IEH, 2006). The contribution in IAQ usually from fossil fuel powered appliances, tobacco smoke and vehicle exhaust smoke where parked nearby a building (Houck & Hampson, 2007). CO has higher affinity compare to oxygen to bound to hemoglobin and myoglobin, forming carboxyhemoglobin and lowering the oxygen diffusion in blood circulation system (US EPA, 2008). This may lead to series of myocardial ischemia, whereas exposure more than 50% can lead to unconsciousness, seizures, coma and death (Burr, 2015).

Formaldehyde is a type of volatile organic compound which has colorless and pungent characteristic at normal room temperatures. Primary sources come from building materials i.e. particle board, fibreboard, plywood, solvents, adhesives and carpeting (Hines et.al, 2013). Formaldehyde may be introduced into the body system by inhalation and / or direct skin contact. Formaldehyde has the carcinogen attribute which has significance relationship to nasopharyngeal cancer (Wong, 2013), (Morgan, 2007).

Nitrogen dioxide (NO_2) is a reddish to brownish water soluble gas with pungent acrid odor which formed between nitrogen and oxygen in high combustions temperatures (Maroni et al., 2015), associated with activities such as gas appliances operations, kerosene heaters, and smoking of cigarettes. NO_2 is an oxidizing agent that can combine with water vapor inhaled to form nitrous acid which irritate the pleural cavity and lung mucous membrane (Spengler.et.al, 2013). Exposure to NO_2 is associated to trigger asthma, increase the allergic reaction susceptibility and reduce immunity to lung infections (Jones, 2007).

Sulphur dioxide (SO_2) is a water soluble, colorless gas with strong pungent smell which produced by the oxidation of sulphur impurities during combustion of sulphur contains substances i.e. coal and fossil fuels (Maroni et al., 2015). It has shown few indications of short-term health impacts as the particle irritates nose, throat and airways which causing coughing, wheezing, shortness of breath and chest tightness (Lyman, 2007). In extreme SO_2 exposure, it may associate to increase chronic respiratory complaints and impaired lung function with other typed of respiratory symptoms (Qin et.al, 2013) (Jin et.al, 2013). Hospital may be exposed to SO_2 exposure due to their location. Many hospital that are located in the middle of the city are affected by the SO_2 exposure that comes from the vehicles' smokes especially during high traffic (Warren, 2014).

Radon is an inert radioactive gas that arises from decay process of radium-226 that presence in various minerals (Lyman, 2007). Radon is formed in rocks and soils and it released into the surrounding air. Radon is not dangerous because it is inert and easily exhaled during breathing. However, the progeny Po-218 and Po-214 are electrically charged and have high tendency to stick in lungs and increase the cancer potential (Polpong, 2008). It has been linked to lung carcinogen, where research by Pershagen shows that a significant relationship between radon exposure and lung cancer mortality (Pershagen.et.al, 2014).

Respirable particle is a type of aerosols that has small diameter of 6-7µm or smaller that can enter and remain in the lungs (Martonen.et.al, 2012). Respirable particle may comprises wide varieties of organic and inorganic substances mixture such as aromatic hydrocarbon compound, trace metals, nitrates, sulphate and etc (Maroni et al., 2015). The irritant effects depend on the volume inhaled and usually will results in airway constriction. Respiratory problem such as asthmatic problem is prone to the hereditary acquired asthma and youngster whereas the reduction in lung function symptoms will prominently show amongst smokers. Point source identification in an indoor environment is very important in order to implement appropriate air quality control strategies (Zhang, 2005) (Massey.et.al, 2012).

Polycyclic aromatic hydrocarbon (PAHs) is a fat soluble compound that are formed due to incomplete combustion of an organic matter and has at least two benzene rings. PAHs is easily absorbed onto particle in air which easily inhaled into the lungs. PAH is a carcinogenic compound that shown a significance impact of lung cancer death rates (Mumford.et, 2015).

Tobacco smoke is one of the major pollutant agent affecting IAQ in homes and offices. The tobacco smoke exposure can be divided into two types; Mainstream smoke (MS) is the smoke exhaled by the smoker whereas Sidestream smoke (SS) is the smoke from exhalation breath between puffs (Maroni et al., 2015). The tobacco smoke released to the environment is called Environment Tobacco Smoke (ETS). In hospital, the tobacco smoke might be introduced into the indoor air from the air intake from the outside. Non-smokers are exposed to the same substances and toxins inhaled by the smokers and as well as some additional substances where they may inhale 10 times the amount of carbonyl compound compare to the active smoker (Guerin.et.al. 2012). Acute health exposure to ETS are irritation at eyes, nose and throat. Other than that, ETS also associated with exacerbation of asthmatic symptoms and the chances is higher among susceptible people such as youngster, elderly, pregnant lady and individual with existing conditions. Higher exposure of ETS evidence to carcinogenic effects such as lung cancer (Janerich.et.al, 2010). In other research, there was high rates of bronchitis, pneumonia and bronchiolitis amongst infants due to ETS exposure (Harlap & Davies, 2012).

Volatile Organic Compound (VOC) is a compound that has one carbon and hydrogen atom in its molecular structure where commonly available in many household appliances and substances. The sources may come from consumer and commercial product, paints related products, adhesives products, building materials, combustion appliances and also available in potable water (Hodgson, 2001). The concentrations are higher in newly constructed buildings and after renovation process where the substances release significant proportion of their volume in a short period of time (Balaras C.A, 2007). A number of studies show that VOC has a significant relationship between mucous membrane irritation and central nervous system symptoms such as impaired neurobehavioral function. At low concentration, individual may experience headache, drowsiness, fatigue and confusion, Increase of exposure will lead to lethargy, dizziness, confusion and may lead to coma, seizures and fatality.

2.2.2 Biological Pollution Sources

Biological allergens may derive from a wide range of source such as dust-mite, cat, dog, rodent, cockroach, and fungi. Mites can be found in any fabric based equipment and soft furnishing such as sofas, carpets, sheets, duvets, pillow and mattresses. Dust mite feces is considered one of primary indoor antigens where it consists of intestinal enzymes protein that has a strong allergen characteristic. There are studies shows that occupant that are staying in high infested mites and cockroaches building are likely to report nocturnal breathlessness, wheezing and other asthma related symptoms (Peat.et.al, 2008).

Presence of fungi and bacteria are everywhere including indoor building which affecting the IAQ standard in a building. Presence of organic matter increase the rate of fungi and bacteria available in an enclosed building. The rate of fungi and bacteria growth is higher in high humidity area where homes that has damp conditions due to structural problems (Montanaro, 2007).

Exposure to airborne microorganism leads to a number of diseases with less defined sign and symptoms as it depends on the microorganism infection (Peat.et.al, 2008). High CFU m-3 reading associated with increase of medical conditions amongst youngster with wheezing and asthma attack whereas high blood pressure and breathlessness in adult especially elderly.

Table 2 : Diseases and syndromes associated with exposure to bacteria and fungi

Disease / Syndrome	**Example of causative agents**
Rhinitis	*Alternaria, Cladosporium, Epicoccum*
Asthma	*Various aspergilli and penicillia, Alternaria, Cladosporium, Mucor, Stachybotrys, Serpula (dry rot)*
Humidifier fever	Gram-negative bacteria and their lipopolysaccharide endotoxins, Actinomycetes and fungi
Extrinsic allergic alveolitis	*Cladosporium, Sporobolomyces, Aureobasidium, Acremonium, Rhodotorula, Trichosporon, Serpula, Penicillium, Bacillus*
Atopic dermatitis	*Alternaria, Aspergillus, Cladosporium*

Source : IEH, 2006

2.3 IAQ Limits

In order to monitor the level of contaminants available in an enclosed building, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has developed a standard. For local setting, Malaysia has developed Industry Code of Practice on Indoor Air Quality 2010 which comprises of establishment of IAQ standard as highlighted in Table 3. The standard is based on Malaysian setting and yet it is still aligned to the ASHRAE standard.

Table 3 : List of Indoor Air Contaminants and the Acceptable Limits

Indooor Air Contaminants		Acceptable Limits			
		ppm	mg/m^3	cfu/m^3	Others
Chemical Contaminants					
i.	Carbon monoxide	10	-	-	-
ii.	Formaldehyde	0.1	-	-	-
iii.	Ozone	0.05	-	-	-
iv.	Respirable particulates	-	0.15	-	-
v.	Total volatile organic compounds	3	-	-	-
Biological Contaminants					
i.	Total bacterial counts	-	-	500	-
ii.	Total fungal counts	-	-	1000	-
Ventilation Performance Indicator					
i.	Carbon dioxide	C1000	-	-	-
Physical Parameters					
i.	Air temperature	-	-	-	23-26^{o}C
ii.	Relative humidity	-	-	-	40-70%
iii.	Air movement	-	-	-	0.15-0.50 m/s

Source : DOSH, 2010

2.4 Building Related Illness

Indoor air quality plays important roles in human total exposure to air contaminants (WHO, 2010). Indoor air contaminants exposed to human may lead to many adverse health outcomes (Bascom et al., 2005). Poor IAQ may invites short-term and long-term health issues such as allergic reactions, breathing difficulties, conjunctivitis, sinusitis, bronchitis and etc (Ministry of Health Malaysia, 2015). The indoor air pollutant also proven to cause other health adverse impact which lead to morbidity, disability, diseases and fatality (Berglund et al., 2000).

The susceptibility of the illness to engage to the exposed person is varies depends on few factors such as the person's sensitivity towards the contaminant, the contaminant concentration which influence by the duration and frequency of exposure, and the individual's physical and psychological health status (Kamaruzzaman et.al, 2011).

Sick Building Syndrome (SBS) is a situation where the wide number of people affected by the bad IAQ status in a building have shown sign and symptoms that often subjective health complaints (Horvath, 2017). It is supported by another finding where SBS is a term where people in a building or an area are displaying several clinically familiar signs and symptoms without a clear cause (Israeli & Pardo, 2011). The signs and symptoms usually resolve once occupant left the building (US EPA, 2008), (Norhidayah et.al, 2013). Many SBS related outbreak and cases recorded in early 1970s in developed country which involve offices, schools, hospitals, senior welfare home, and apartment. However, the SBS symptoms reported were minor and nonspecific (common in general population but the cases are increase in poor IAQ buildings (Lan et.al, 2009).

SBS symptoms are shown to have a significant impact on public health and economic growth as it affects the productivity and increase the absenteeism rate (Wallace, 2017). The trend of SBS phenomenon has changed by time where previously SBS usually occurs in older, naturally ventilated buildings. Nowadays, the phenomenon becomes more common in modern building that has energy-efficient and airtight characteristic, especially for building that use mechanical HVAC system (Redlich, 2007).

Therefore, many concludes that SBS are more common and easily associated under this buildings conditions. Besides that, the symptoms do impact the individual performance where affected staff will be on sick leave which indirectly impact the productivity growth. In general, the common symptoms of sick building syndrome are depicted as per Table 4.

Table 4 : Common symptoms of sick building syndrome

- Headache and nausea
- Nasal congestion (runny/stuffy nose, sinus congestion, sneezing)
- Chest congestion (wheezing, shortness of breath, chest tightness)
- Eye problems (dry, itching, tearing, or sore eyes, blurry vision, burning eyes, problems with contact lenses)
- Throat problems (sore throat, hoarseness, dry throat)
- Fatigue (unusual tiredness, sleepiness, or drowsiness)
- Chills and fever
- Muscle pain (aching muscles or joints, pain or stiffness in upper back, pain or stiffness in lower back, pain or numbness in shoulder/neck, pain or numbness in hands or wrists
- Neurological symptoms (difficulty remembering or concentrating, feeling depressed, tension, or nervousness)
- Dizziness
- Dry skin

Source : Wallace (2016)

The exposure to VOCs is claimed to be one of the major contribution cause to SBS. The view point based on the findings where majorities of small scale projects show that there is a significance relationship between VOCs presence and the SBS symptoms shown amongst occupant exposed. However, throughout the year, a more comprehensive study shows that a negative relationship where not all cases of SBS is due to VOCs exposure (Sundell.et.al, 2004). The focus has changed to building ventilation systems where it also plays an important role in maintaining IAQ standard and reducing the likelihood of SBS incidents. The possible socio-psychological factors responsible for the emergence of sick building syndrome are rises in the number of workers in non-industrial indoor environments, increased awareness of chemical hazards un the workplace, extensive media coverage of outbreaks of SBS and changes in office world leading to loss of control and stress amongst workers (Letz, 2010).

2.5 Malaysian Indoor Air Quality Setting

In Malaysian context, many studies were carried out in assessing the IAQ and how its impact and affect the occupant in a building. A comparison of IAQ study between new and old buildings indicates the CO2 concentration on certain level shows a positive SBS signs and symptoms which increase number of complaints among the occupants (Aizat.et.al, 2009). A study in determining the association between IAQ parameters and SBS symptoms in three selected buildings in Malaysian found that the ventilation plays a crucial role in controlling the IAQ status where it reduce the possible contaminants accumulation which also reducing the number of SBS complaints (Norhidayah et.al, 2013).

On different research in investigating the association between SBS and air pollutants through questionnaire adopted from Malaysia Industry of Practice on Indoor Air Quality 2010 (MCPIAQ) also support the finding from previous research (Aizat.et.al) where CO2 concentration has strong correlation with other indoor air contaminants that lead to SBS issues. It was also indicate that other important indoor air factors i.e. temperature, TVOC, humidity, and bacteria are also have the significance in affecting the SBS prevalence (Sulaiman & Mohamed, 2011). This research finding was also supported by another research where it shows that the ventilation is important to be well maintained to ensure it capacity and ability to remove all the IAQ contaminants effectively (Fadilah & Juliana, 2012).

Majority research were focused on the temperature, relative humidity, air velocity, particulate matter and carbon dioxide which has the relationship with SBS. Poor IAQ that leads to SBS can be reduced by increase the ventilation rate and managing any point source detected which is more effective and cost efficient (Aizat.et.al, 2009). In another research conducted in several Malaysian hospitals shows that there is some defect in roof structure which has caused the rain water to enter the building. The leakage enters the building porous materials such as ceiling board and partition wall. This high moisture condition promotes the microbe growth.

Malaysian has come out with number of legislations in regards to safeguard the safety and health and also to maintain the welfare of the occupants and / or workers which can relates to IAQ. In 1967, Malaysian government has introduced Factories and Machinery Act 1967. Under The Factories and Machinery (Safety, Health and Welfare) Regulations 1970, it focuses on ensuring the healthy work environment such as proper ventilation, air cleanliness and measures for controlling heat exposure which is very much relatable in maintaining the IAQ in a building.

The IAQ parameters are varies in pattern and distribution depending in varieties of factors such as climatic conditions, lifestyle, building construction style based on different demographical setting. However, the symptoms portray on the sign and symptoms of bad IAQ management are similar. IAQ is an outcome from many influences as the air in the environment interact with other agents such as outdoor air, microbiological, toxicological and other physical systems i.e. mechanical ventilation, HVAC and etc (O'Neal, 2000). The fluidity and interdependence of the IAQ with other factors and makes the study to find the correlation between the parameters and the outcome is a bit challenging.

As many research were carried out in other countries, it can serve as guideline and principle for our internal study. It is because, the physical parameters and the climate are different between countries and regions where these characteristic does play important roles in the IAQ in a building. As Malaysia is hot and humid weather is more favorable for the growth of microorganism such as bacteria, fungi and mold, the IAQ is also indirectly affected (Norhidayah.et.al, 2013). Besides that, Malaysian types of building is also different based on the legal requirement and location setting. Malaysian initiative to ban the usage of asbestos in building equipment has starts in 1990th has also improved the IAQ in our local building (M. Ramaswamy, 2010). In addition, the type, materials and design styles used in the construction of the building is also different compare to western countries. The design plays an important role where it affects the movement and ventilation of air. Between Malaysian states, the building construction styles and materials is also different from one to another, which slightly affect the IAQ in building nationwide. Apart from that, the indoor activity in a building also play important roles in affecting the building IAQ.

In order to maintain the IAQ status in a building, mechanical ventilation system is usually installed in a building especially in the urban setting building. However, the improper management of mechanical ventilation such as low maintenance of the equipment also contributes to poor IAQ in a building. This may lead to a problem such as high level or air contaminants due to insufficient of airflow which promotes to SBS. As such, the important key area to maintain a good IAQ is a good housekeeping where applies to both technical i.e. mechanical ventilation related system and non-technical aspect i.e. sweeping and vacuuming to reduce dust accumulation.

2.5 Malaysian Hospital Indoor Air Quality

Good air quality is an important requirement that always been given higher priority in public health issue. Air pollutants can cause respiratory diseases (influenza, asthma, and cardiovascular disease), cancers and poisonings. Often, the sources of air pollutant are originated from outdoor burning activities, industrial emission (gas, oil, coal, wood), automobile emissions and etc. Traditionally, air quality has not been a point of concern at a regional level in Malaysia, although local concerns have been raised periodically. Today, Ministry of Health (MOH) has taken their initiative step to produce the new Guideline on

Indoor Air Quality for Hospital Support Service on October 2015. This guideline has been drawn up to ensure that healthcare employees and patients are protected from potential Indoor Air Quality contaminants that could affect their health, wellbeing and reduce their daily work operation. As per section 15 and section 17 of Occupational Safety and Health Act 1994 (OSHA), it is general duties of employers to provide "so far as is practicable, the safety, health and welfare at work of all his employee".

A study conducted by Khew in 2010 that study the sources of indoor air quality problem in a new hospital but the sample areas only cover the general workstation such as library and open area in each levels. As such, it is important to study the distribution and pattern of the IAQ in the Malaysian hospitals as this data will serve as a baseline study.

CHAPTER 3: METHODOLOGY

The methodology of the IAQ assessment for this research is adapted from the Industry Code of Practice on Indoor Air Quality 2010, (DOSH, 2010). The IAQ assessment includes walkthrough inspection, building occupants questionnaire and IAQ assessment. The selected hospitals are assessed and monitored from February to July 2018.

3.1 Study Design

A cross sectional comparative study is conducted between 3 selected hospitals in Klang Valley area. This research methodology is divided into three parts, starting with walkthrough inspection, followed by questionnaire amongst health providers and IAQ assessment in selected sites in the hospital vicinity areas.

This type of study uses hospitals in three different locations but shares the same working setting and environment, with aims to check the indoor air quality standard at each of the location. Besides that, this study also uses different groups of people who based in different hospitals but share the same characteristic by working as healthcare providers where their responses on the indoor air quality problems and issues are collected and analyzed.

3.2 Study Area

The study compares the IAQ standards between the facilities and conclude the pattern of IAQ findings accordingly. Three hospitals were identified for this study where the assessments involved the indoor air quality assessment, walkthrough inspection and questionnaire on indoor air quality to the healthcare providers working in the facilities.

3.3 Walkthrough Inspection

Walkthrough inspection is conducted prior to the IAQ sampling. As the five sampling locations in each hospital has been identified in this study, which were Reprocessing Room, Dental Laboratory, General Workstation, Autopsy Room, and lastly the Outdoor area for control variables.

This walkthrough inspection were conducted to identify any potential source of IAQ problems as well as to document the condition of proposed area at the time of this assessment. Example of issues to check during the walkthrough inspection may include any sightings of source of moisture problems or microbiological contamination, presence of unusual odor, inadequate ventilation or air movement, excessive settled dust, and other indoor air quality issues that might be spotted.

A walkthrough inspection was also conducted at several Air Handling Unit (AHU) Room to see on the general and overview of the AHU Room conditions and to check any possible contamination sources that presence in the room that might affect the air distributed throughout the hospitals' areas. The findings of the overall walkthrough inspection was discussed as presented in Chapter 4 : Results and Discussion.

3.4 IAQ Questionnaire

Questionnaire for building occupants health risk is conducted to facilitate the identification of potential sources of indoor air quality pollutants and to identify adverse health effects that may. Therefore, a questionnaire is derived from the ICOP IAQ, 2010 which has been validated by the DOSH in 2010. The example of the questionnaire are enclosed in the Appendix 1.

The design of this questionnaire study is simple random sampling. This is where the questionnaire were shared to the focus group and their responses are collected and collated for data analysis.

The questionnaire are sampled from the focus group based on the convenient sampling. The focus group is health providers i.e. nurse, doctors, lab technician, pharmacist, etc where exposed to possible indoor air contaminant while working in the facilities. On the other note, the exclusive group is visitors, patients and other public that were temporarily exposed for possible contaminant.

The questionnaire defines as the data collection tools from the respondents. This study used a questionnaire that has six parts. The first three parts comprises of demographical based questions which includes the respondents' general information, background factor such as gender, age group, and smoking habits, and the nature of the respondents' occupation.

The fourth section asks questions on the environmental conditions. This section poses questions such as the respondents' workstation types, equipment usage and any issues encountered in regards of indoor air quality such as draught, room temperature if too high or too low, varying room temperature, stuffy air, unpleasant odor, passive smoking and any dust and dirt presence in the workplace.

The last two sections poses questions on past / present diseases or symptoms experienced by the staff in regards to indoor air quality. The present symptoms were further assessed by identifying the frequency of the symptoms experienced by the staff for the past 3 months. Lastly, all the data was collected and compiled for further statistical analysis.

3.5 Experimental Analysis on Indoor Air Quality Assessment

3.5.1 Indoor Air Physical Contaminants Analysis

Intermittent measurement strategy based on the average of half-hour measurements conducted at four time-slots is adopted in the IAQ assessment. The four time-slots is evenly distributed over the operation hours for the sampling locations. Real-time monitors are used for detection of contaminant sources and provided information on the variation of contaminants level throughout the day.

The Indoor Air Quality (IAQ) assessment is carried out in strict conformance to internationally accepted methods of sampling and analysis. The analytical techniques as well as equipment used in measuring the physical contaminants are stated in the Table 5 :

Table 5 : Instruments for Physical Contaminants Assessment

Bil	Instrument	Test Parameters
1	Fluke Air Meter 975	1. Temperature (°C) 2. Relative Humidity (RH) 3. Carbon Dioxide (CO_2) 4. Carbon Monoxide (CO)
2	TSI Air Flow	1. Air Movement

Physical contaminants analysis used two instrument which is Fluke Air Meter 975 and TSI Air Flow instrument. Fluke air meter 975 was used to check the indoor air quality temperature, relative humidity, carbon dioxide and carbon monoxide. Whereas, TSI Air Flow instrument was used to check the air movement in the indoor environment.

3.5.2 Indoor Air Chemical Contaminants Analysis

Chemical contaminants were also sampled and assessed by using the intermittent measurement strategy based on the average of half-hour measurements conducted at four time-slots is adopted in the IAQ assessment. The four time-slots is evenly distributed over the operation hours for the sampling locations. Real-time monitors are used for detection of contaminant sources and provided information on the variation of contaminants level throughout the day. The analytical techniques as well as equipment used in measuring the physical contaminants are stated in the Table 6 :

Table 6 : Instruments for Chemical Contaminants Assessment

Bil	Instrument	Test Parameters
1	Gray Wolf Advanced Sense Monitoring Kit IQ-610	1. Total volatile Organic Compound (TVOCs) 2. Ozone (O3)
2	Environmental Sensor ZDL-300 Formaldehyde Monitor	1. Formaldehyde (CH_2O)
3	Lighthouse Hand Held 3016 Q	1. Respirable Particulate (PM_{10})

Chemical contaminants assessment used three different instruments. Gray Wolf Advance Sense Monitoring Kit 1Q-610 was used to check two chemicals contaminants in the indoor air which is total volatile organic compound and ozone. Environmental Sensor ZDL-300 Formaldehyde Monitor was used to check the presence of formaldehyde in the indoor air quality environment. Lastly, Lighthouse Hand Held 3016 Q instrument was used to check the Respirable Particulate (PM10) presence in the environment.

3.5.3 Indoor Air Microbiological Contaminants Analysis

A portable microbiological air sampler is used in determining microbial contamination. Trypticase Soy Agar (TSA) is used as a sampling medium for bacteria with 2 minutes sampling period and with a fixed volume of air (100 Litres per minute) pulling into the sampler. The sampler is a combination of Buck Bio-Culture Pump B30120 and the SAS Super IAQ instruments. The sampled air is passed through the medium agar before it further incubated and processed.

The plate is incubated for 48 hours at 35 ^{o}C prior to microbial counts. Malt Extract Agar (MEA) is used for the cultivation of fungi. The sampler operated for 2 minutes sampling period and with a fixed volume of air (100 Litres per minute) pulling into the sampler and then is incubated for 5 days at 25 ^{o}C. The reference method as well as equipment used in determining the presence of biological contaminants is stated in Table 7 :

Table 7 : Biological Contaminants and Instruments

Bil	**Instrument**	**Test Parameters**
1	Buck Bio-Culture Pump B30120	Total Bacterial Counts and Total Fungal Counts
	SAS Super IAQ	

In order to correlate the colony forming unit (cfu) present on the agar plate to the most probable number (MPN) of microorganisms per cubic meter of air sampled, the following formula is used :

$$\mathbf{Pr = N[1/N + 1(N\text{-}1) + 1/(N\text{-}2) + \ldots + 1/(N_{-r}+1)]}$$

(*Equation 1*)

Pr = Most probable number of microorganism in the volume of air sampled
N = Number of holes on micro-flow sampling head
R = Number of cfu on the agar plates after incubation

Results are reported as colony forming unit (cfu) per plate. Hence, the results is converted to give cfu/m3. The calculation as below :

$$\frac{\text{Total Plate Count/Total Bacteria Count/Total Yeast \& Mould Count (cfu/plate)}}{\text{Sampling Period (minutes) x Fixed volume of air (L/min)}}$$

= x cfu/L

(*Equation 2*)

Where, 1000 L = 1m^3,
Hence, x cfu/L x 1000L = y cfu/m^3

3.4 Data Analysis

The data collected from respondents circulated responds and environmental sampling are analyzed by using Statistical Package for Social Science (SPSS 17.0) for statistical processing purposes. Multiple regressions are used to analyses the correlation between variables.

The parameters tested in all three hospitals are compiled and tested for the significance value by using multiple regressions. The parameter tested includes the carbon dioxide, carbon monoxide, ozone, total volatile organic compound, formaldehyde, particulate matter, temperature, relative humidity and air movements. The parameters are tested against the test locations which is based on the hospitals locations.

The data from the questionnaire is collected and collated for statistical analysis. P-value was calculated to check the evidence to support the association between parameters and variables tested. On the other hand, Pearson R value were also calculated to understand the positive and negative association between the two variables tested.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter is divided into four main parts which aims to answer the research objectives. Firstly, the result is focused on the pattern and distribution of contaminants and stressors found during assessment at the selected hospital. This section starts by discussing the all three hospital general features during walkthrough inspection at the identified sampling points. Secondly, the IAQ parameters are compared to the standard guideline constructed by the Department of Safety and Health (DOSH); Industrial Code of Practice, 2010 (ICOP, 2010). The third part is more fixated to the survey result which aim to evaluate the awareness level and its potential exposure and health risk may pose to the health providers. Lastly, the fourth part is a proposal to recommend appropriate actions measures and control mechanism for IAQ continual improvements in the hospitals. The proposal is divided into several parts where it based on the severity and weightage on the IAQ related issues based on the contribution factors founds from the hospitals during the assessment.

4.1 Walkthrough Inspection

In this section, it discusses the general reading and photograph taken during walkthrough inspection at some of the identified sampling locations (i.e. Reprocessing Room, Dental Laboratory, General Workstation and Autopsy Room) at all three hospitals. This gives an overview how the sampling location looks like in general for all three hospitals. Besides that, the walkthrough inspection also discuss some Air Handling Unit (AHU) rooms to provide a general overview on the sample of issues detected during the inspection.

4.1.1 Reprocessing Room (Endoscopy)

All three rooms were found to be clean and satisfactory condition. The rooms were tidy and clean even though Hospital A and Hospital C rooms were found congested with machines and other equipment.

Figure 2 : Hospital A Endoscopy Room Condition

Figure 3 : Hospital C Endoscopy Room Condition

With reference to the Figure 2 and Figure 3, it shows that the Hospital A and Hospital C endoscopy room was congested with sterilization equipment. Hospital A endoscopy room was warm and humid with 30.2°C and 73.3% relative humidity reading. However, Hospital B endoscopy room and Hospital C endoscopy room were chill and dry with 21.7 °C and 20.1 °C respectively.

Figure 4 : Hospital A Endoscopy Room with malfunction air conditioning split unit.

Hospital C and Hospital B were equipped with centralized air conditioning system. However, with reference to Figure 4, Hospital A room was equipped with one split air conditioning unit. The unit was not functioning since September 2016.

Figure 5 : Hospital A Endoscopy Room equipped with standing fan for ventilation

Therefore, with reference to Figure 5, the room was equipped with a standing fan to ventilate the entire room. From our finding, the fan was not able to ventilate the whole room due to the big size of the room.

Figure 6 : Endoscopy Room with removed ceiling panel.

During the walkthrough inspection, we also found that there are some areas in all rooms had open ceiling where the ceiling panel was removed and left open as shown in Figure 6. This conditions made the room exposed to the dust from the ceiling area. Besides that, the area without ceiling also has higher temperature compare to other regions in the room.

Figure 7 : Hospital A Endoscopy Room with opened window glass panel.

As the high temperature was recorded in Hospital A room, two heat radiation source were identified during the walkthrough inspection. Hospital A room has window glass panel where it was opened to allow for natural ventilation and to vent out chemical odor produced from the endoscopy cleaning and sterilization process as shown in Figure 7. Besides that, the heat radiation also comes from the sterilization machines as it produces heat when operates.

Figure 8 : Example of chemical used for sterilization purposes at Hospital A & Hospital B.

All three rooms used the same type of chemical used for sterilization purposes. It were Aniosyme Synergy 5 (enzyme detergent with non-VOC formulation) and Chlor HEX 4% (alcoholic based detergent) as shown in Figure 8. The SDS were available at all locations.

Figure 9 : Hospital C Endoscopy Room with malfunctioning fume hood.

From our observation, the fume hood above the sink at Hospital C room was not functioning as pictured in Figure 9. As such, the room become congested during the cleaning process as there is lack of air dilution mechanism were in place.

4.1.2 Dental Laboratory

All three room was found to be clean, neat and satisfactory. Good housekeeping at all places were noted. All rooms were ventilated by centralized air conditioning system with ducted supply diffusers and return air grilles.

Figure 10 : General Hospital A Dental Laboratory.

As shown in Figure 10, the general conditions of Hospital A Dental Laboratory shows as clean and tidy environment. However, the room is packed and congested with dental laboratory equipment on top of the processing table.

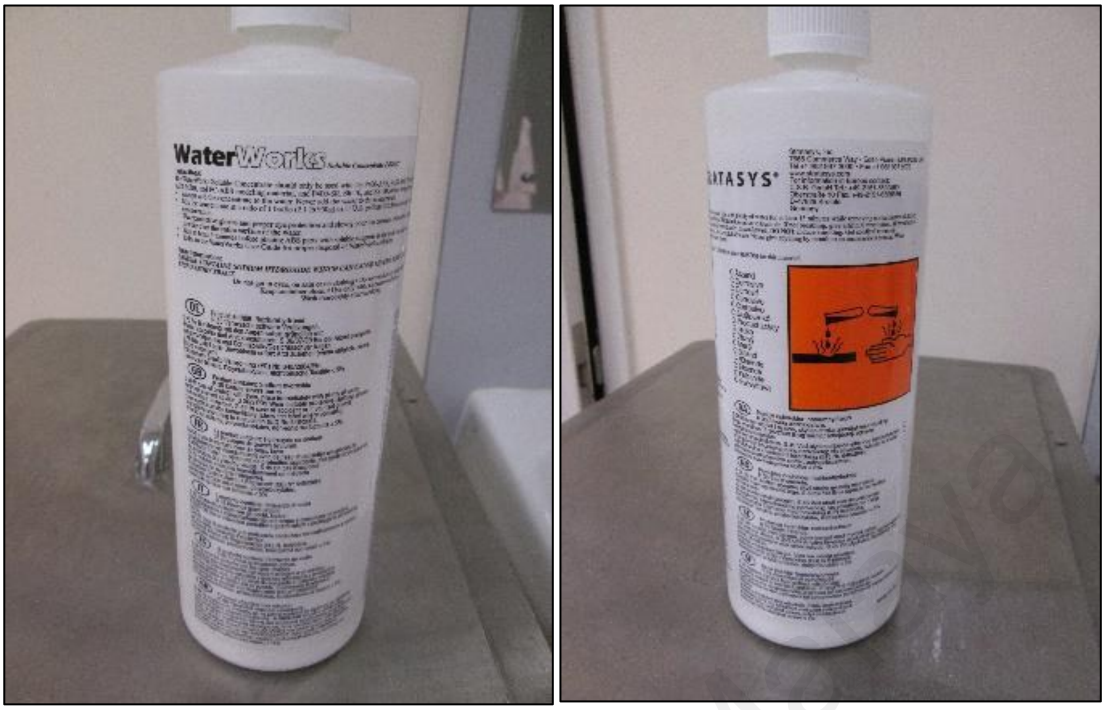

Figure 11 : Stratasys P4000SC chemical used in Hospital A Dental Laboratory.

There were chemicals are used during dentures and cleaning process as shown in Figure 11. However, only Hospital A room does not has any fume hood being provided to reduce the chemical exposure to the staffs as depicted in Figure 10. As such, a strong chemical odor i.e. Stratasys P4000SC (contains sodium hydroxide which is non-volatile but highly corrosive) was presence in the environment. The chemical is used for dentures cleaning process. During informal interview with the staff, some complaints were captured where the staff are frequently engage with sore throat and eye irritation symptoms.

Figure 12 : Malfunctioned Fume Hood in Hospital B.

On the other hand, the fume hood in Hospital B was found malfunctioned as shown in Figure 12 and a formal complaint from the staff has been lodged with aim to rectify the issue. However, there was no significant chemical odor during our walkthrough inspection.

Figure 13 : Dental Trimming activity that use silmagum.

In general, all locations involved with trimming activity during all site inspections. The example of the process as shown in Figure 13. During this activity, the staff used silagum and during the trimming sessions, it produces puffy soft dust at the workstation. With reference to Figure 13, staff were equipped with surgical face mask. However, as the silagum dust size were not being studied, it might poses some potential risk and more complete and comprehensive set of PPE should be proposed for staff to use.

4.1.3 General Workstation

The area in all three hospitals were found in a good condition with satisfactory cleanliness and tidiness.

Figure 14 : Hospital A General Workstation.

Figure 15 : Hospital B General Workstation.

However, high human traffic were observed at the location as depicted in Figure 14 and Figure 15. The rooms were also congested with medical equipment and machines. As many activities are carried out here, indirectly it affects the indoor air quality in the room.

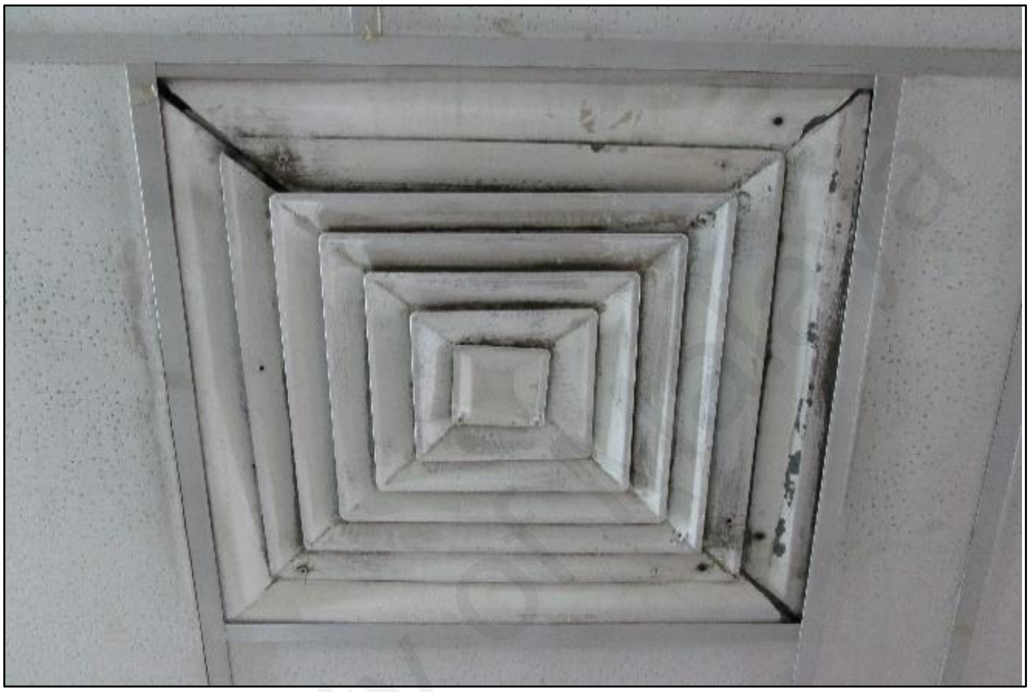

Figure 16 : Example of dusty supply diffusers.

All the areas were served by ducted centralized air conditioning system and wall mounted split air conditioning units. All locations have the same issues where the supply diffusers were found to be dusty as shown in Figure 16.

4.1.4 Autopsy Room

All three rooms' cleanliness were found medium and satisfactory. All the rooms are served by centralized air conditioning system with supply diffusers and return air grilles.

Figure 17 : Hospital A General Autopsy Room.

Figure 18 : Hospital C General Autopsy Room.

The picture of general autopsy area can be observed in Figure 17 and Figure 18. All three rooms are operating at a lower temperature below the standard and acceptable range as per ICOP on IAQ 2010. However, it was noted that the chiller temperature is maintained in order to get a relative cold temperature that aims to reduce the odor in the area.

Figure 19 : Severe mold growth at Hospital A Autopsy Room (a)

Figure 20 : Severe mold growth at Hospital A Autopsy Room (b)

Mold stains were noted on the wall and ceiling due to surface condensation as the rooms are maintain relatively colder but with high humidity, which creates the mold growth. Severe mold contamination was noted at the entrance area of the Hospital A room, shown in Figure 19 and Figure 20. The wall, ceiling was growth with mold and damp smell was noted.

Figure 21 : Mold growth and water stains at Hospital B Autopsy Room.

In a different room at Hospital B room, there were some water and mold stains on the wall and ceiling were noticed as shown in Figure 21. These conditions were suspected due to the same reason where the room were kept in relatively low temperature and in a humid condition.

4.1.5 General AHU Inspection

There are several AHU that serve a specific locations in a hospital. As such, a random inspections were carried out at numbers of AHU that serves the hospitals areas in order to give a scope and overview on IAQ issues.

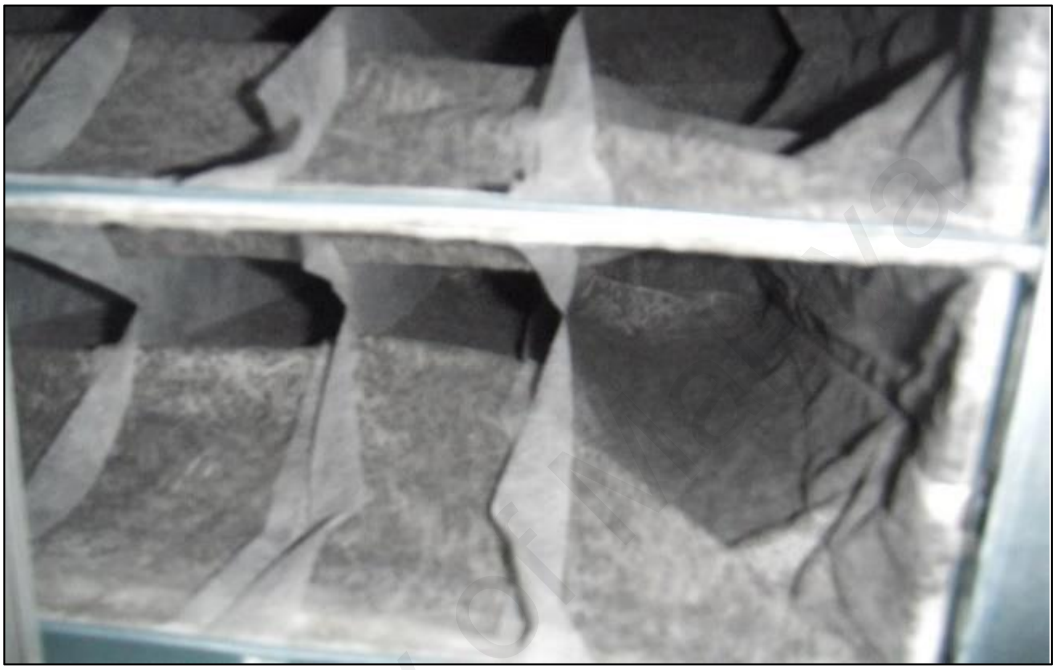

Figure 22 : Dusty secondary filters in one of Hospital A AHU.

Some issues were spotted in some AHU in Hospital A walkthrough inspection, mainly three issues were noticed. During the inspection, the secondary filters were found to be dusty and loaded with dust particulates as shown in Figure 22.

Figure 23 : Water ponding and leakage in one of Hospital A AHU.

Besides that, there was also some water ponding on the drainage area, which the water might be leaks from the cooling liquid from the chiller as shown in Figure 23. This condition will create a damp situation and it will become favorable for the microbial growth, which might affect the air that distributes to the hospital networks.

Figure 24 : Dusty fresh air intake grilles in one of Hospital A AHU.

Figure 25 : Fresh air intake that facing outside motorcycle parking lot at Hospital A.

Other than that, the fresh air intake grilles was found to be dirty and accumulated with dust as shown in Figure 24. Besides that, with reference to Figure 25, the fresh air intake is facing outdoor motorcycle parking lots where this might invites some increase of Carbon Monoxide concentrations in the hospital.

Figure 26 : One of AHU room condition in Hospital C.

During the walkthrough inspection at some Hospital C AHU rooms, some issues were also identified. Some of the AHU room was found to be congested, dusty and unhygienic as shown in Figure 26. This condition suggests that the room has low maintenance and low housekeeping were performed.

Figure 27 : Congested and dirty pre-filters in one of Hospital C AHU.

Besides that, all the pre-filters in one of the AHU room were found to be heavily loaded with dust particulates as shown in Figure 27. This will affect the air intake into the hospital building.

Figure 28 : Unused items and consumable parts left unattended (a).

Figure 29 : Unused items and consumable parts left unattended (b).

Figure 30 : Unused items and consumable parts left unattended (c).

Other than that, several unused items and consumable parts were found in the AHU room as shown in Figure 28, Figure 29 and Figure 30. The items were heavily accumulated with dust and might affect the air intake into the hospital.

Figure 31 : Slime formation at cooling coils fin area (c).

The cooling coils were also found to be dirty with slime at the fin area as shown in Figure 31. This suggest a low maintenance and housekeeping were performed.

Figure 32 : Dirty pre-filters with accumulated dust.

Walkthrough inspection at some Hospital B AHU rooms were conducted and some issues were identified. Some of the pre-filters were found to be dirty and accumulated with dust as shown in Figure 32.

Figure 33 : Stagnant water and rusty drain pan in one of Hospital B AHU.

Besides that, there were also presence of dirty cooling coils, stagnant waters, and rusty drain pan was observed as depicted in Figure 33. The cooling coils were extremely dirty accumulated with grime and biofilm. Some brownish stain were observed at the drain pan area.

Figure 34 : Mold stains in one of Hospital B AHU wall and ceiling.

Figure 35 : Water stains with suspected water leakage at one of Hospital B AHU ceiling.

Figure 36 : Dusty blower fans.

There were also some AHU room with mold stain on the room ceiling and wall as shown in Figure 34. During the inspection, musty and stuffy smell was noted. The problem was suspected due to leakages on the ceiling as there were water stains observed as in Figure 35. Lastly, with reference to the shown Figure 36, some blower fans in AHU rooms was found to be heavily accumulated with dust particulates.

4.2 Indoor Air Quality Dataset

The following table is the data representation of IAQ parameters from the selected hospitals. As the hospital areas are very broad and wide, the locations are focused on only four general working environments with one controlled environment. The locations are selected based on the risk of working environment (i.e. involve with chemicals) and also depends on convenient sampling basis. The locations include reprocessing room (endoscopy), autopsy room, dental laboratory, general workstation (outside general ward) and outdoor area as control.

Table 8 and Table 9 shows the reading for all parameters tested during the indoor air quality assessment. The data was compared with the Industry Code of Practice for Indoor Air Quality Standard (DOSH, 2010), in order to detects any reading has exceed or below the standard stated by DOSH. Table 8 shows the physical and chemical parameters dataset whereas the Table 9 shows the dataset for biological parameter. The data that does not meet with the standard were highlighted in red as shown in Table 8 and Table 9.

Table 8 : Indoor Air Quality Dataset (Physical Parameters)

Hospital	Test Location	CO^2 (ppm)	CO (ppm)	O_3 (ppm)	TVOC (ppm)	CH_2O (ppm)	PM_{10} (mg/m^3)	Temperature (°C)	RH (%)	Air Movement (m/s)
ICOP Standard, 2010		C1000	10	0.05	3	0.1	0.15	23-26	40-70	0.15-0.50
Hospital A	Reprocessing Room	599	<0.1	<0.01	<0.01	<0.01	0.063	30.2	73.3	0.20
	Autopsy Room	445	<0.1	<0.01	<0.01	<0.01	0.024	24.4	74.2	0.10
	Dental Laboratory	792	0.5	<0.01	<0.01	<0.01	0.021	21.2	82.5	0.09
	General Workstation	529	<0.1	<0.01	<0.01	<0.01	0.073	29.4	83.5	0.01
	Outdoor (Control)	671	<0.1	<0.01	<0.01	<0.01	0.043	28.1	72.6	-
Hospital B	Reprocessing Room	482	<0.1	<0.01	<0.01	<0.01	0.017	21.7	63.6	0.10
	Autopsy Room	500	<0.1	<0.01	<0.01	<0.01	0.03	22.1	72.6	0.10
	Dental Laboratory	955	1.5	<0.01	<0.01	<0.01	0.022	19.8	65.8	0.45
	General Workstation	574	<0.1	<0.01	<0.01	<0.01	0.093	22.3	75.6	0.30
	Outdoor (Control)	425	<0.1	<0.01	<0.01	<0.01	0.035	29.4	74	-
Hospital C	Reprocessing Room	500	<0.1	<0.01	<0.01	<0.01	0.013	20.1	66.9	0.20
	Autopsy Room	482	<0.1	<0.01	<0.01	<0.01	0.035	19.8	77.3	0.22
	Dental Laboratory	829	0.6	<0.01	<0.01	<0.01	0.019	23.2	70.8	0.12
	General Workstation	540	<0.1	<0.01	<0.01	<0.01	0.087	21.6	76.3	0.20
	Outdoor (Control)	439	<0.1	<0.01	<0.01	<0.01	0.062	30.4	69	-

Table 9 : Indoor Air Quality Dataset (Biological Parameters)

Hospital	Test Location	Total Bacteria Count (cfu/m^3)	Total Fungal Count (cfu/m^3)
ICOP Standard, 2010		500	1000
Hospital A	Reprocessing Room (Endoscopy)	115	91
	Autopsy Room	79	29
	Dental Laboratory	95	20
	General Workstation (Outside General Ward)	540	23
	Outdoor (Control)	163	134
Hospital B	Reprocessing Room (Endoscopy)	108	25
	Autopsy Room	76	22
	Dental Laboratory	89	34
	General Workstation (Outside General Ward)	430	24
	Outdoor (Control)	175	124
Hospital C	Reprocessing Room (Endoscopy)	123	98
	Autopsy Room	98	63
	Dental Laboratory	87	14
	General Workstation (Outside General Ward)	304	34
	Outdoor (Control)	154	98

Table 8 and Table 9 tabulate the IAQ parameters based on the hospital and selected locations. The reading recorded in red shows that the reading has been exceeded the standard guideline by ICOP 2010. In general, all hospitals are having three main parameters concern which are the Temperature, Relative Humidity and Air Movement where the reading were above the standard by ICOP 2010. The discussion of each of the IAQ parameters concentration reading are as follow.

Figure 37 shows that the concentration of CO_2 in all selected location in the hospitals. In comparison to the ICOP on IAQ, 2010 Standard, all locations did not exceed the comfort threshold of 1000 ppm. However, the highest concentration recorded in all location was in dental laboratory. The possible buildup of CO_2 might be due to exhale gas from patients and staff in the room. During normal working hour, dental laboratory has quite number of patients which may contribute to the increase buildup of CO_2 in an environment.

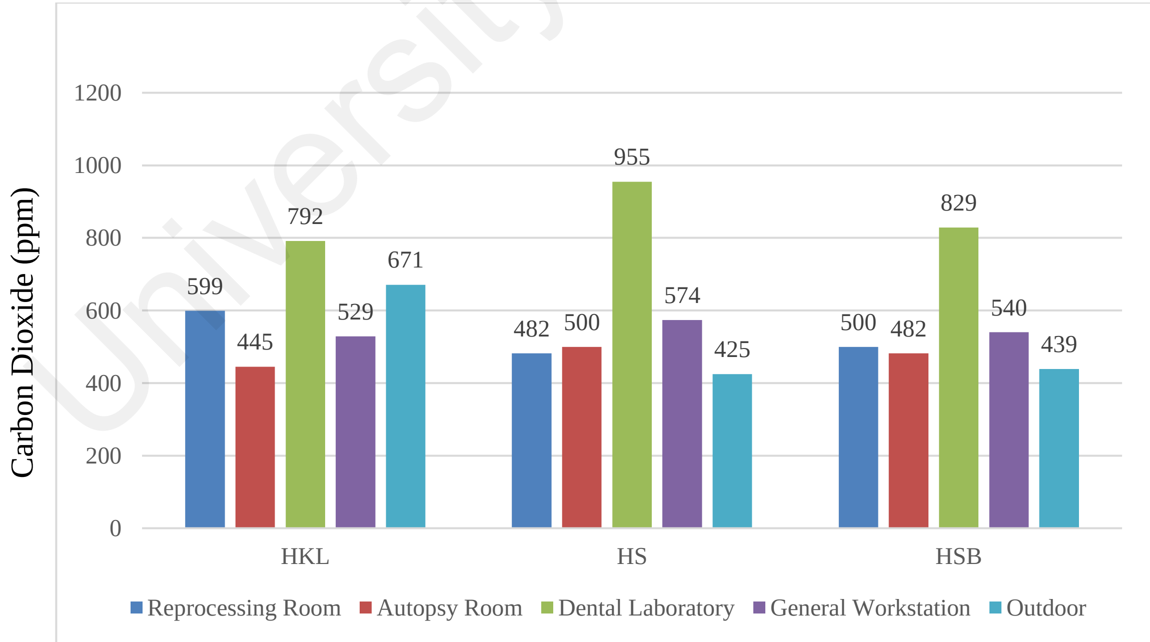

Figure 37 : Carbon Dioxide (CO_2) Parameter with ICOP on IAQ, 2010 Standard

Higher concentration level of carbon dioxide may indicate the area was lack of fresh air intake. For higher carbon dioxide level, the occupants will experience the feeling of 'stuffiness', potential drowsiness, lower productivity and/or loss concentration, sleepiness, fatigue and headaches. The CO_2 buildup in the indoor environment might lead to mild drowsiness and can escalate to headaches, sleepiness, slight nausea (ASHRAE, 1989). As such, proper inspection and maintenance to ensure efficient mechanical ventilation and air-conditioning (MVAC) system should be carried out. With efficient mechanical ventilation, it brings stream of fresh air to ensure optimal air quality supply to the room occupant. It helps to remove stale air and replace them with adequate supply of fresh air. In particularly, internally generated pollutants can build up collectively when carbon dioxide is at higher concentration due to the lacking of fresh air in diluting the pollutants to acceptable level.

Figure 38 shows that the concentration of CO in all selected location in the hospitals. In comparison to the ICOP on IAQ, 2010 Standard, all locations did not exceed the threshold of 10 ppm.

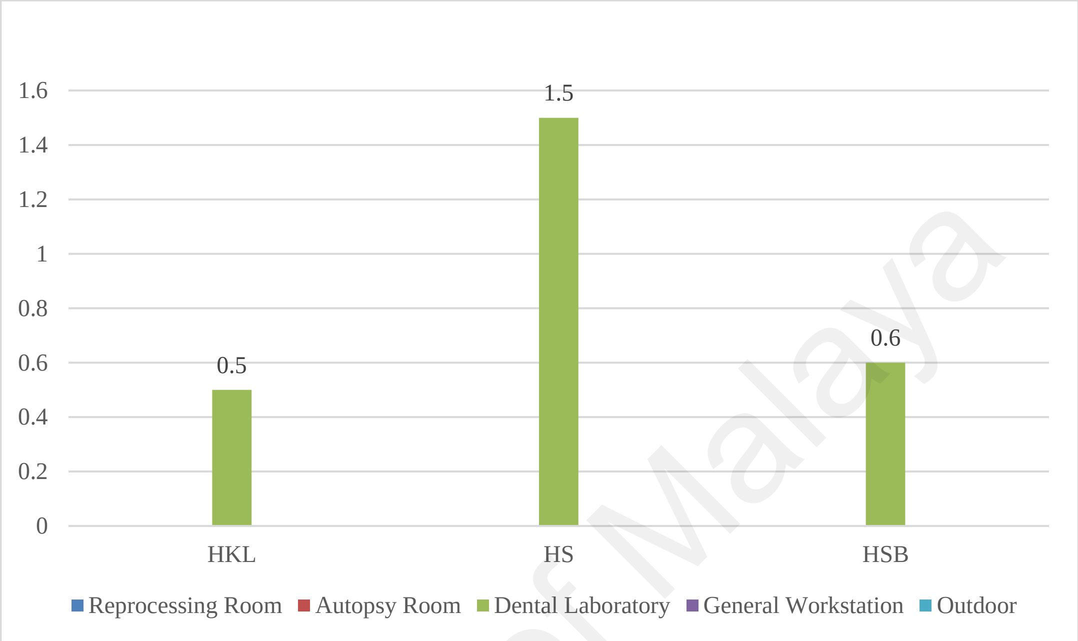

Figure 38 : Carbon Monoxide (CO) Parameter with ICOP on IAQ, 2010 Standard

However, the highest concentration recorded in all location was in dental laboratory. Same pattern was found with the CO_2 buildup as per Figure 37. There might be due to the breakdown of CO_2 buildup in the environment. There also might be some possibility that the contribution of the gaseous buildup comes from the dental laboratory activities and equipment. However, there were no relevant studies shows that to support the findings. The increase of CO may induce fatigue and chest pain (ASHRAE, 1989).

It was found that during the walkthrough inspection in Hospital B, one of the AHU room supply air intake from the motorcycle parking spot. As such, this conditions might contribute to the high CO in the Dental Laboratory at Hospital B.

Figure 39 shows the pattern of PM_{10} concentration in all the accessed areas in the selected hospitals. The highest pattern comes from the general workstation areas where the locations are located outside of a general ward. However, all readings did not exceed the standard of <0.150 mg/m^3 based on the ICOP on IAQ, 2010 Standard.

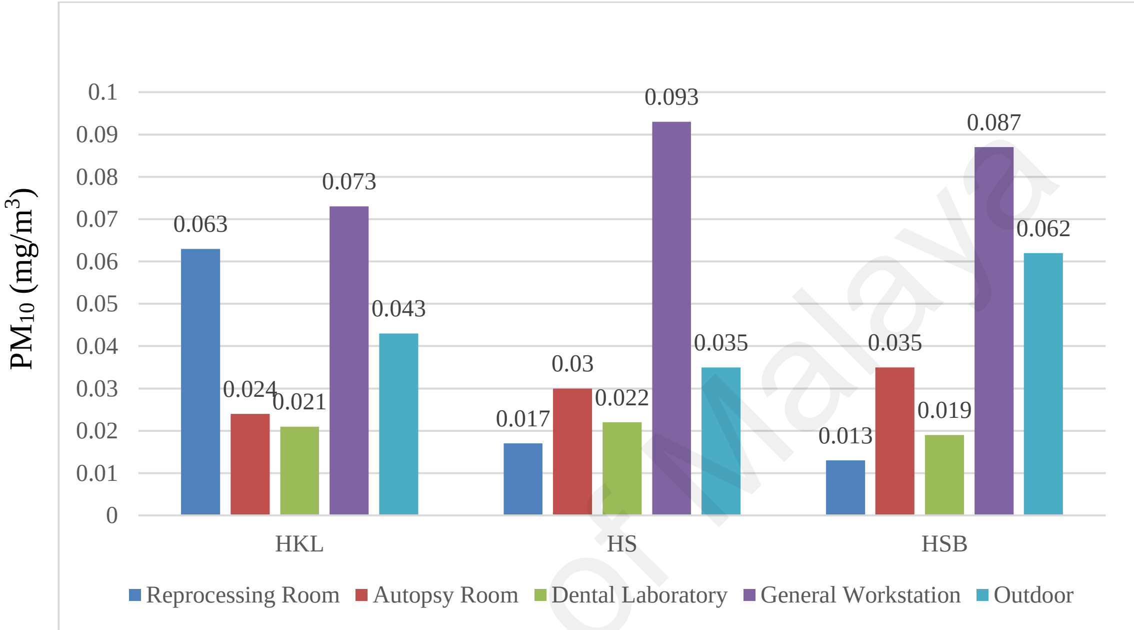

Figure 39 : Particulate Matter (PM_{10}) Parameter with ICOP on IAQ, 2010 Standard

There are some reasons on the high PM_{10} readings from the areas. From the observation, there are high numbers of passerby in the isle in front of the general workstation especially visitors during visiting hour. Visitor may bring other particulate matter that settles on their body from the outside environment i.e. sands, dusts, pollen, etc. This invites the increase buildup of the PM_{10} in the environment as the location is highly accessible and used for public and all staff although the location has a scheduled cleaning sessions which includes sweeping and mopping.

The coarse particle with 2.5-10 µm will be deposited in the upper respiratory tract and large airways when a person inhaled such air in the environment (Kim et al., 2015). Those susceptible people with lower body weigh that exposed to the environment will affect the function and development of the lung where it leads to less lung surface area

(Beatty, 2012). As such, the exposure to PM_{10} will have greater health adverse effect towards children, person with breathing problems and elderly.

Figure 40 represents the temperature reading according to the sampling locations. It shows that majority of the locations did not meet with the ICOP on IAQ, 2010 Standard where the temperature shall be in the range of 23-26 ºC.

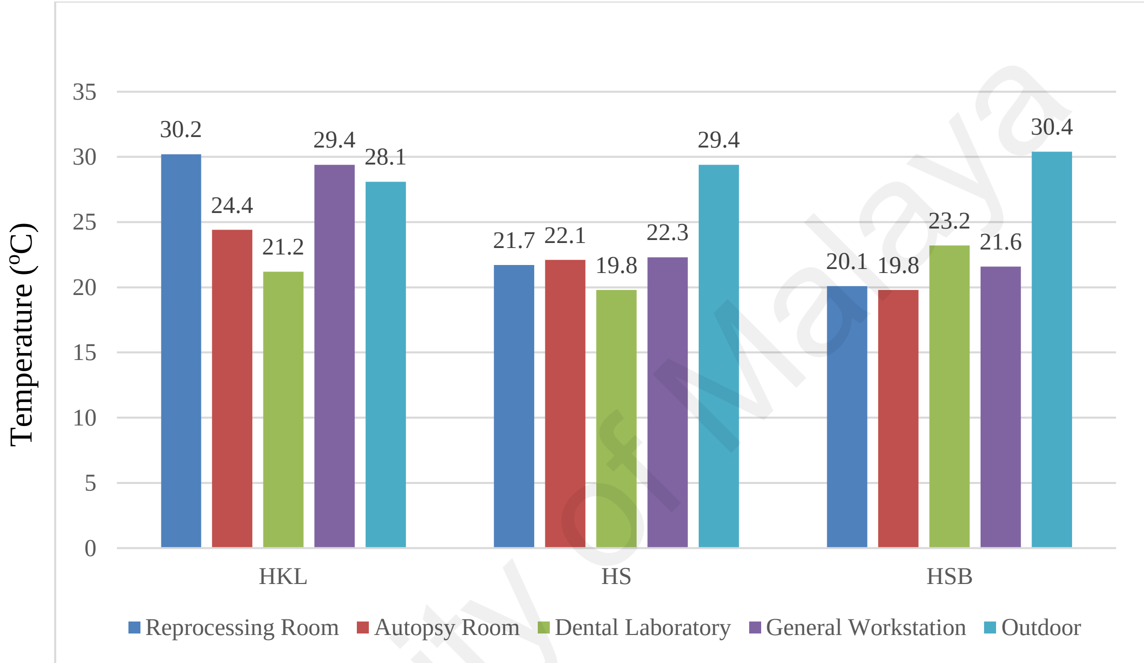

Figure 40 : Temperature Parameter with ICOP on IAQ, 2010 Standard Temperature (ºC)

In the event of temperature either below or above of the recommended standard, it will affect the comfort level of the occupant. If the temperature exceeds the recommended temperature, it will lead to occupant discomfort, draught and dehydration especially among children. The extreme temperature may cause either hypothermia or hyperthermia.

Uniformity of temperature is important to comfort. Excessive high or low temperature in an area can lead to minor health effects to the building occupants. High temperature is associated with fatigue, irritability, headache and a decrease in performance and alertness. Likewise, if the location is too cold, persons may experience shivering, fatigue and decrease in performance and alertness.

The data shows that the majority of the temperature readings is not following the standard. As such, recalibration on the building thermostat and air conditioning unit balancing shall be carried out in order to ensure optimum temperature in the areas.

However, from the reading taken, it also shows that rooms are also has different temperature value. During the walkthrough inspection, some split unit were found malfunction for example in the Endoscopy Room in Hospital A. Other than that, majority of the area were too cold below the recommended standard. The reason being, the chill environment were applied to reduce the odor formation and to suit the medical processes and activities takes place. Nevertheless, the indoor temperature either too low or too high does affect the building occupant such as health care providers, patients and visitors.

Figure 41 presents the data of the average relative humidity reading based on the sampling locations. With reference to the IAQ standard for Relative Humidity (%), the preferred relative humidity is in between 40-70%.

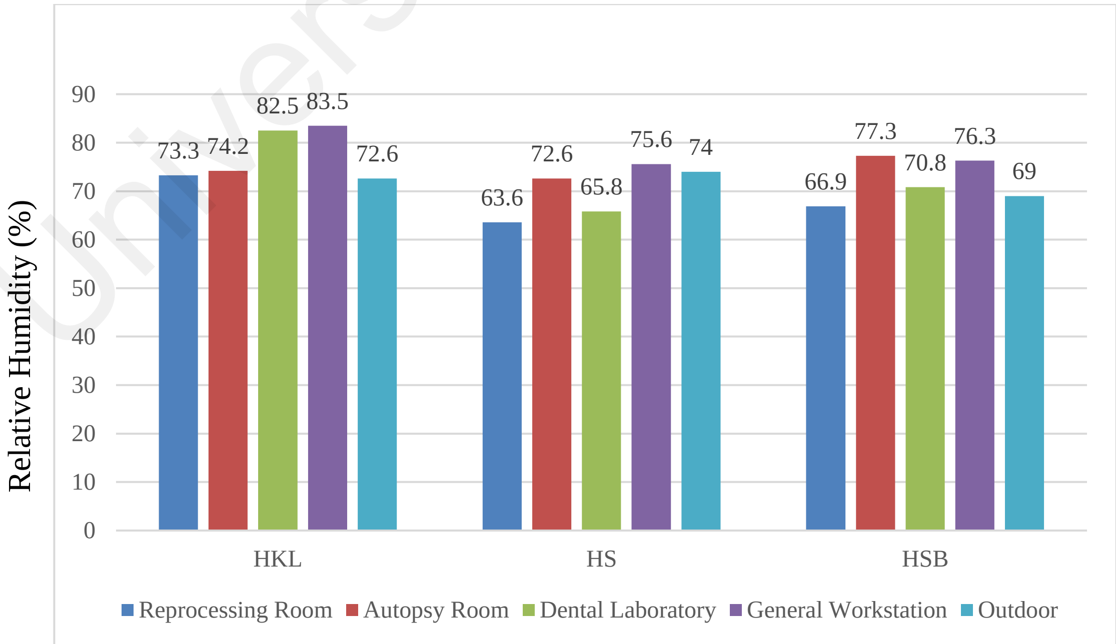

Figure 41 : Relative Humidity Parameter with ICOP on IAQ, 2010 Standard

As such, all locations tested in Hospital A were above the recommended standard ranges from (72.6-83.5), and other majority areas sampled in other selected hospital also depicts a high relative humidity in the indoor areas.

Relative humidity refers to the amount of water vapor in the air (ICOP, 2013). It is crucial to maintain the relative humidity level in the recommended standard as it will help to reduce the influence of bacteria and fungi growth in the environment. Increasing relative humidity value causes the increase of dew point temperatures, may elevate the likelihood of surface condensation and subsequent potential microbial growth. Referring to the reading, majority of the location has exceeded the preferred relative humidity.

This condition may be resulting due to low maintenance of the AHU rooms. This affect the mixing between the cooling water in the system which has impacted the relative humidity of the indoor air quality in the hospitals.

This condition where the air is very moist above the recommended standard will make the occupant to experience chill in cold weather and hot and sticky in warm weather. Whereas, in a location with low relative humidity will make the air feels dry and affect occupant comfort by feeling dry to skin and may induce skin itchiness and allergies.

Besides that, it also invites a favorable environment to fungi, bacteria and dust mite which can create respiratory problems and / or induce allergic reactions to the occupant. Low relative humidity will increase the condensation rate when the surface is colder than the air temperature, resulting water moist that potentially affect the building equipment and material integrity.

Figure 42 presents the data of the average relative humidity reading based on the sampling locations. With reference to the IAQ standard for Air Movement (m/s), the preferred relative humidity is in between 0.15-0.50 m/s.

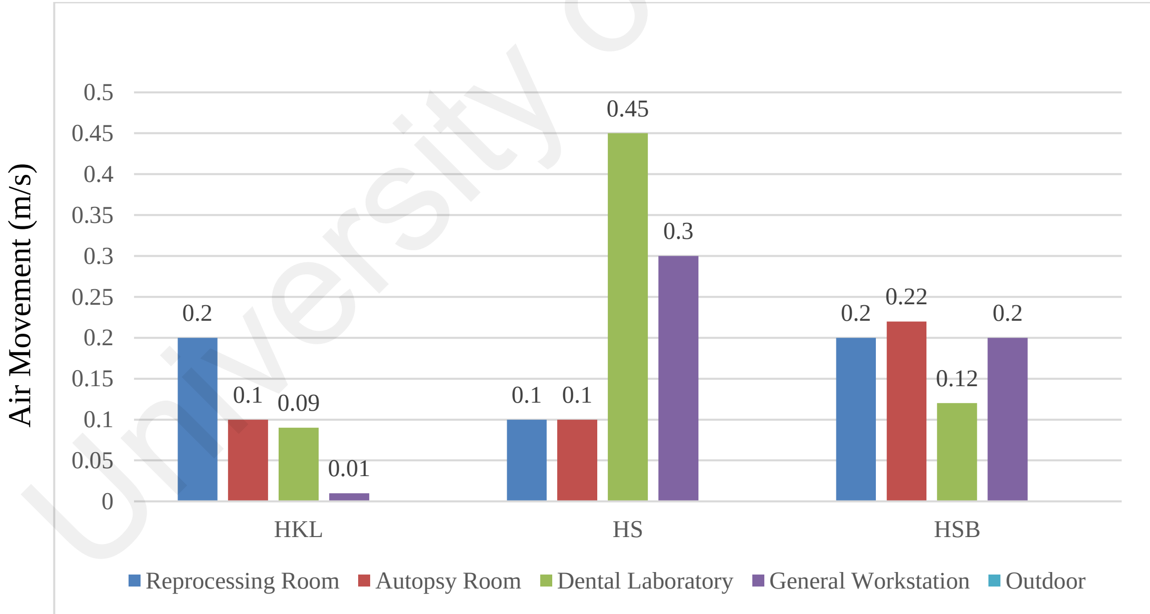

Figure 42 : Air Movement Parameter with ICOP on IAQ, 2010 Standard

Majority of the areas have low air movement where this can lead to stale indoor air quality where the air didn't mix up well which creates stuffy environment. This can be the result from improper air conditioning balancing. It was found that some blower duct has been tampered by putting tape as the areas that claimed by the occupant to be colder. This creates imbalance in the air conditioning distribution, which create too high and too low blower power at some of the air conditioning ducts. As such, air conditioning balancing exercise is needed to ensure enough supply of air to the indoor area and rectify this issues.

Figure 43 shows the daily average of bacteria colony forming unit (CFU/m-3) based on sampling locations. With reference to the IAQ standard for Total Bacteria Count (CFU/m^{-3}), the preferred relative humidity is below 500 (CFU/m^{-3}).

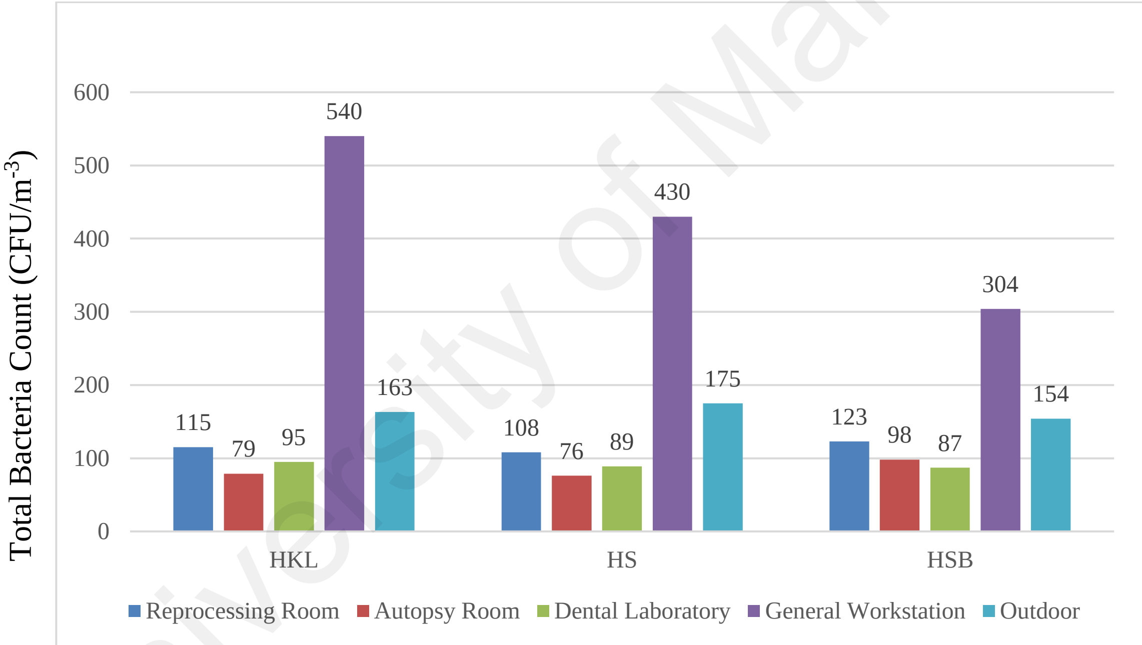

Figure 43 : Total Bacteria Count (CFU/m^{-3}) with ICOP on IAQ, 2010 Standard

Only one sampling point exceed the ICOP guideline of maximum 500 cfu/m^3. It also shows a pattern where the general workstation is the highest bacteria count compare to other locations. One of the contributing factor is the high occupancy and number of people that are using the area. Besides that, the areas are also near to the general ward which might indirectly affect the bacteria colony forming unit as the air in the general ward might transverse to the general workstation area.

From the figure, the highest contamination is from the general workstation area. This is because the area is nearby with ward patients, and has many medical activities conducted in the area such as cleaning wounds and revisiting patients for follow up. Besides that, the area is very congested with activities and equipment, which make it hard for the cleaner to perform a proper housekeeping i.e. sanitizing the work environment, etc. As such, the area is easily contaminated with bacteria that comes from patients.

The condition is also influenced by the high temperature and humidity level recorded. It is proven where the desired indoor air temperature, humidity and air movement must be maintained in the favored range in order to prevent any microbial growth (Mui et al., 2017).

Moreover, higher humidity environment can make the pathogenic bacteria to attach into the water droplets and easily transmit to host and cause possible infections and diseases i.e. respiratory problems (Wang et al., 2005).

Figure 44 shows the daily average of fungi colony forming unit (CFU/m^{-3}) based on sampling locations. By comparing to the ICOP 2010 standard, all locations have low fungi count, as per recommended by the standard where count to be below 1000 CFU/m^{-3}.

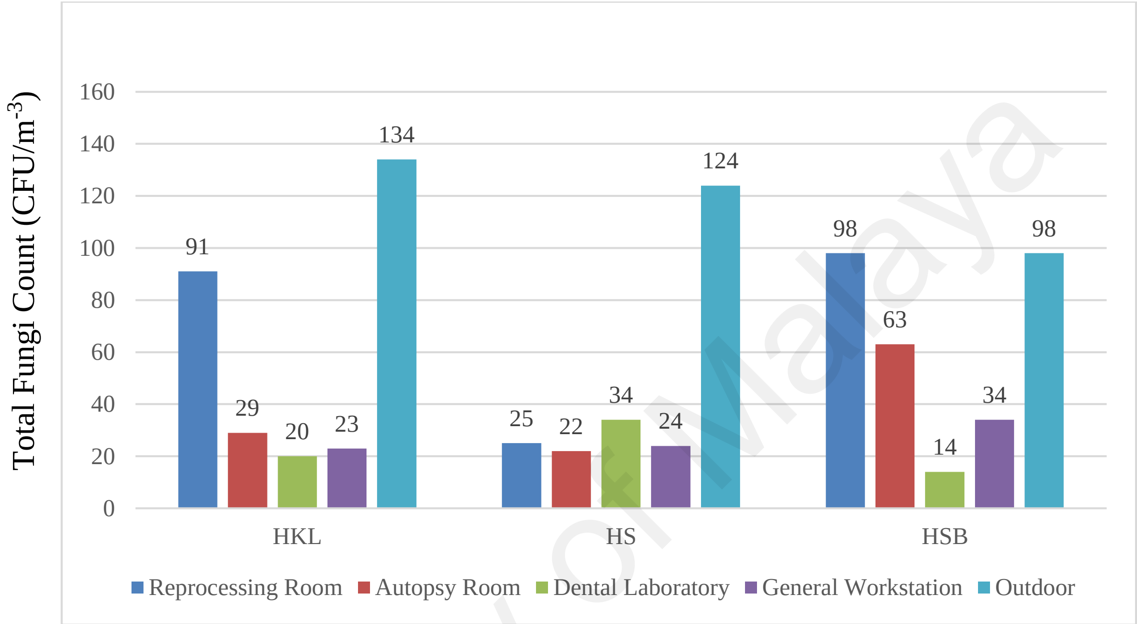

Figure 44 : Total Fungi Count (CFU/m^{-3}) with ICOP on IAQ, 2010 Standard

Even though all areas are found to be complied with the recommended standard, the conditions at some areas during walkthrough inspection depicts otherwise. The Hospital A Autopsy Room was heavily congested and contaminated with fungi. It was found there were lots of fungi spots were found on walls and ceiling, even though the reading shows otherwise.

Table 10 explains the Indoor Air Quality Parameters statistical relationship. In general of all hospital does not show any significant relationship among the locations and the parameters. This might be due to huge gap between one readings to another in a type of parameter. Another reason that might affect the result might be due to the small frequency of reading being taken, that influence the distribution and pattern of the parameter readings.

Table 10 : Indoor Air Quality Parameters Statistical Relationship

Variables	**Acceptable Limit (ICOP 2010)**	**Median (inter Quartile Range)**			**Mean**	**Std Deviation**	***p-value***
		Hospital A	**Hospital B**	**Hospital C**			
CO_2 (ppm)	C1000	591.25 (445 – 792)	627.75 (425 – 955)	587.75 (439 – 829)	610.333	165.038	0.456
CO (ppm)	10	0.2 (0.1 – 0.5)	0.45 (0.1 – 1.5)	0.225 (0.1 – 0.6)	0	0	0
PM10 (mg/m3)	0.15	0.0453 (0.021 – 0.073)	0.0405 (0.017 – 0.093)	0.0385 (0.013 – 0.087)	0.4233	0.0287	0.347
Temperature (^{o}C)	23-26	26.3 (30.2 – 21.2)	21.5 (22.3 – 19.8)	21.2 (19.8 – 23.2)	22.939	3.484	0.397
Relative Humidity (%)	40-70	78.38 (72.6 – 83.5)	69.4 (63.6 – 75.6)	72.83 (66.9 – 77.3)	73.533	6.158	0.347
Air Movement (m/s)	0.15-0.50	0.1 (0.01 – 0.20)	0.24 (0.10 – 0.45)	0.19 (0.12 – 0.20)	0.174	0.117	0.313
Bacteria	500	207 (79 – 540)	176 (76 – 430)	153 (87 – 304)	178.667	157.252	0.347
Fungi	1000	41 (20 – 91)	26 (22 – 34)	52 (14 – 98)	39.750	28.375	0.397

However, the parameters result and reading can be used as a benchmark to the ICOP standard and guideline directly, in order to check, monitor and confirm whether the IAQ standard is in compliance to the ICOP standard or otherwise.

4.3 IAQ Questionnaire Data Set

The following table is the data representation of IAQ questionnaire findings from voluntary staff working in the sampling areas. The questionnaire sampling was conducted by using convenient sampling. In total, 163 questionnaire were sampled comprises of 54 staff from each Hospital A and Hospital B and 53 staff from Hospital C. The visitors and patients were excluded from this exercise as this questionnaire aims to focus on the constant building occupant and how its air quality affecting their health based on the exposure.

4.3.1 Demographic Dataset

Table 11, Table 12 and Table 13 shows the frequency and percentage of the respondents' demographic dataset for Hospital A, Hospital B and Hospital C respectively. The table explain the information of the respondents' gender, age, smoking habit, working years and their workstation types.

Table 11 comprises of the demographic dataset for Hospital A respondents. The amount of respondents are 54 people in total, have answered the questionnaire. As such, the demographic of the respondents are demonstrated below.

Table 11 : Demographic Data Set for Hospital A respondents

Variables	Study Sample N (%) Total Respondents N = 54
Gender	
Male	19 (35.2%)
Female	35 (64.8%)
Age	
<25	7 (13.0%)
26-39	38 (70.4%)
40≥	9 (16.7%)
Smoking Habit	
Yes	6 (11.1%)
No	48 (88.9%)
Working Years	
<5 years	38 (70.4%)
5-10 years	7 (13.0%)
>10 years	9 (16.7%)
Workstation Type	
Enclosed Room	48 (88.9%)
Open Concept	6 (11.1%)

Table 12 comprises of the demographic dataset for Hospital B respondents. The amount of respondents are 54 people in total, have answered the questionnaire. As such, the demographic of the respondents are demonstrated below.

Table 12 : Demographic Data Set for Hospital B respondents

Variables	Study Sample N (%) Total Respondents N = 54
Gender	
Male	20 (37.0%)
Female	34 (63.0%)
Age	
<25	4 (7.4%)
26-39	45 (83.3%)
40≥	5 (9.3%)
Smoking Habit	
Yes	6 (11.1%)
No	48 (88.9%)
Working Years	
<5 years	33 (61.1%)
5-10 years	15 (27.8%)
>10 years	6 (11.1%)
Workstation Type	
Enclosed Room	43 (79.6%)
Open Concept	11 (20.4%)

Table 13 comprises of the demographic dataset for Hospital C respondents. The amount of respondents are 55 people in total, have answered the questionnaire. As such, the demographic of the respondents are demonstrated below.

Table 13 : Demographic Data Set for Hospital C respondents

Variables	Study Sample N (%) Total Respondents N = 55
Gender	
Male	17 (30.9%)
Female	38 (69.1%)
Age	
<25	6 (10.9%)
26-39	44 (80.0%)
40≥	5 (9.1%)
Smoking Habit	
Yes	4 (7.3%)
No	51 (92.7%)
Working Years	
<5 years	39 (70.9%)
5-10 years	10 (18.2%)
>10 years	6 (10.9%)
Workstation Type	
Enclosed Room	47 (85.5%)
Open Concept	8 (14.5%)

Table 14 comprises of the demographic dataset for all respondents. The amount of respondents are 165 people in total, have answered the questionnaire. As such, the demographic of the respondents are demonstrated below.

Table 14 : Demographic Data Set for All respondents

Variables	Study Sample N (%)
	Total Respondents N = 165
Gender	
Male	56 (34.4%)
Female	107 (65.6%)
Age	
<25	17 (10.4%)
26-39	127 (77.9%)
40≥	19 (11.7%)
Smoking Habit	
Yes	16 (9.8%)
No	147 (90.2%)
Working Years	
<5 years	110 (67.5%)
5-10 years	32 (19.6%)
>10 years	21 (12.9%)
Workstation Type	
Enclosed Room	138 (84.7%)
Open Concept	25 (15.3%)

Table 14 shows that majority of the staff respondents were female with 107 respondents (65.5%) and only 56 respondents (34.4%) are male. In general, the majority of the respondents are in range of range between 26 years old to 40 years old, with 127 respondents followed by >40 years old respondents with only 19 respondents (11.7%) and lastly <26 years old with only 17 respondents (10.4%).

Majority of respondents are non-smoker with 147 respondents (90.2%) whereas 16 respondents (9.8%) are smoker. Respondents with experience of less than 5 years is dominating the questionnaire with 110 respondents (67.5%) recorded. Respondents are majority work in an enclosed room with 84.7% (138 respondents) whereas only 15.3% respondents ae working in open concepts workstation.

In general, of the 165 respondents, 65.6% were female, 77.9% were in the age of 26 to 39 years old, 90.2% were not smoking, 67.5% were working less than 5 years and 84.7% were working in enclosed room type workstation.

4.3.2 Work Environment Dataset

The work environment dataset is shown in Table 15. The table explain the information of the responses on the work environment which includes draught, high temperature, low temperature, stuffy air, dry air, unpleasant odor, passive smoking and dusty environment.

Table 15 : Questionnaire Hospital Work Environment Dataset

Work Environment	**Hospital A**			**Hospital B**			**Hospital C**		
	Yes	**Sometimes**	**Never**	**Yes**	**Sometimes**	**Never**	**Yes**	**Sometimes**	**Never**
Draught	7 13%	18 33.3%	29 53.7%	5 9.3%	30 55.6%	19 35.2%	6 10.9%	23 41.8%	26 47.3%
High Temperature	5 9.3%	31 57.4%	18 33.3%	8 14.8%	31 57.4%	15 27.8%	8 14.5%	32 58.2%	15 27.3%
Low Temperature	7 13.0%	38 70.4%	9 16.7%	12 22.2%	36 66.7%	6 11.1%	13 23.6%	34 61.8%	8 14.5%
Stuffy Air	11 20.4%	29 53.7%	14 25.9%	8 14.8%	34 63.0%	12 22.2%	7 12.7%	34 61.8%	14 25.5%
Dry Air	7 13.0%	31 57.4%	15 27.8%	6 11.1%	36 66.7%	12 22.2%	6 10.9%	32 58.2%	17 30.9%
Unpleasant Odor	3 5.6%	34 63.0%	17 31.5%	2 3.8%	41 77.4%	10 18.9%	6 10.9%	35 63.6%	14 25.5%
Passive Smoking	1 1.9%	19 35.2%	34 63.0%	2 3.7%	33 61.1%	19 35.2%	2 3.6%	28 50.9%	25 45.5%
Dust	4 7.4%	39 72.2%	11 20.4%	5 9.3%	37 68.5%	12 22.2%	7 12.7%	33 60.0%	15 27.3%

Table 16 explains the work environment association by using SPSS analysis on the calculated probability p-value and Pearson R value to check the association strength between the two variables which is hospital and the work environment tested.

Table 16 : Questionnaire Hospital Work Environment Dataset Analysis

Work Environment	***p-value***	**Pearson R value**
Draught	0.235	-0.026
High Temperature	0.871	-0.074
Low Temperature	0.598	-0.090
Stuffy Air	0.790	0.47
Dry Air	0.759	-0.086
Unpleasant Odor	0.295	-0.087
Passive Smoking	0.072	-0.141
Dust	0.726	0.012

Table 17 explains the distribution of the respondents' input on the questionnaire. The term Yes depicts the respondents are currently experiencing the work environment issues, Sometimes depicts the respondents had problem earlier in the past 3 months whereas Never depicts that the respondents never encountered the issues.

Table 17 : Questionnaire Hospital Work Environment Dataset

Work Environment	**Hospital**		
	Yes	**Sometimes**	**Never**
Draught	18 11.0%	71 43.6%	74 45.4%
High Temperature	21 12.9%	94 57.7%	48 29.4%
Low Temperature	32 19.6%	108 66.3%	23 14.1%
Stuffy Air	26 16.0%	97 59.5%	40 24.5%
Dry Air	19 11.7%	99 60.7%	44 27.0%
Unpleasant Odor	11 6.8%	110 67.9%	41 25.3%
Passive Smoking	5 3.1%	80 49.1%	78 47.9%
Dust	16 9.8%	109 66.9%	38 23.3%

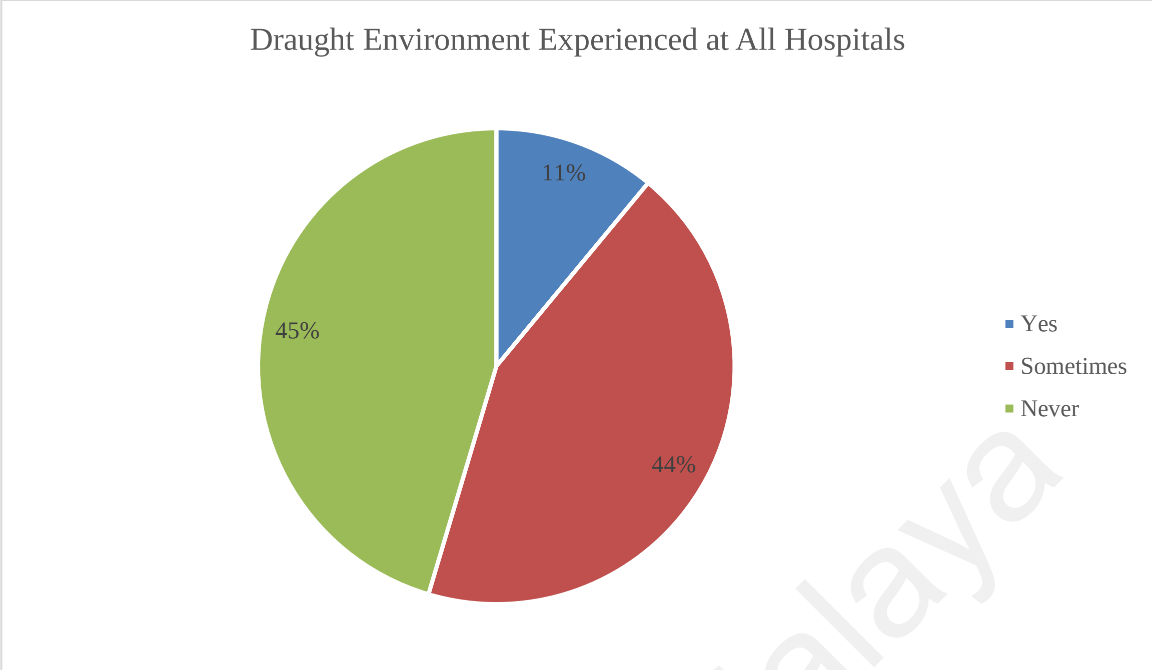

Figure 45 : Draught Environment Experienced at All Hospitals

Draught environment was experienced among staff at all hospital with 55% of them, comprises of 11% who recently experienced the situation and 44% experienced it sometimes. Based on Table 15, the finding between hospitals is varied. Majority of staff in Hospital A did not experienced any draught environment at the workplace by 53.7% whereas majority of staff in Hospital B sometimes experienced the situation by 55.6% and Hospital C staff agreed they were never experienced draught in the workstation by majority of 47.3%. With reference to Table 16, there is no significant relationship between hospitals and the draught work environment was captured as the p-value is 0.235. The Pearson R value shows a weak negative correlation with the value of -0.026.

There are lots of reasons that can contribute to this issues for example, poorly lifting doors and windows panel and open ceiling tiles. This finding is supported with the finding from the walkthrough inspection, where a few spots of the sampled areas has lost some ceiling tiles.

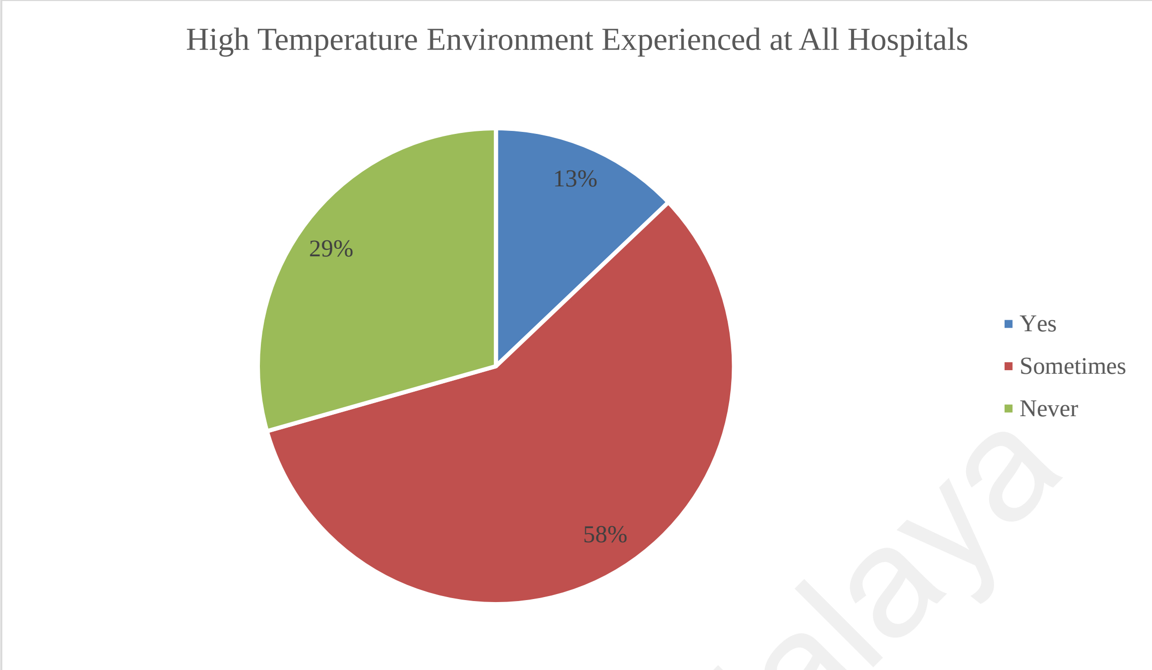

Figure 46 : High Temperature Environment Experienced at All Hospitals

High temperature environment was experienced among staff at all hospital with 71% of them, comprises of 13% who recently experienced the situation and 58% experienced it sometimes. Based on Table 15, the finding between hospitals have the same patterns. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a high temperature environment at the workplace by 57.4.7%, 57.4% and 58.2% respectively. With reference to Table 16, there is no significant relationship between hospitals and the high temperature work environment was captured as the p-value is 0.871. The Pearson R value shows a weak negative correlation with the value of -0.074.

This findings also can be supported by the observation from the walkthrough inspection where some rooms has problem with the air conditioning split unit supplied. As the room size is big, the inadequate of air conditioning supply makes the room less ventilated and has high temperature.

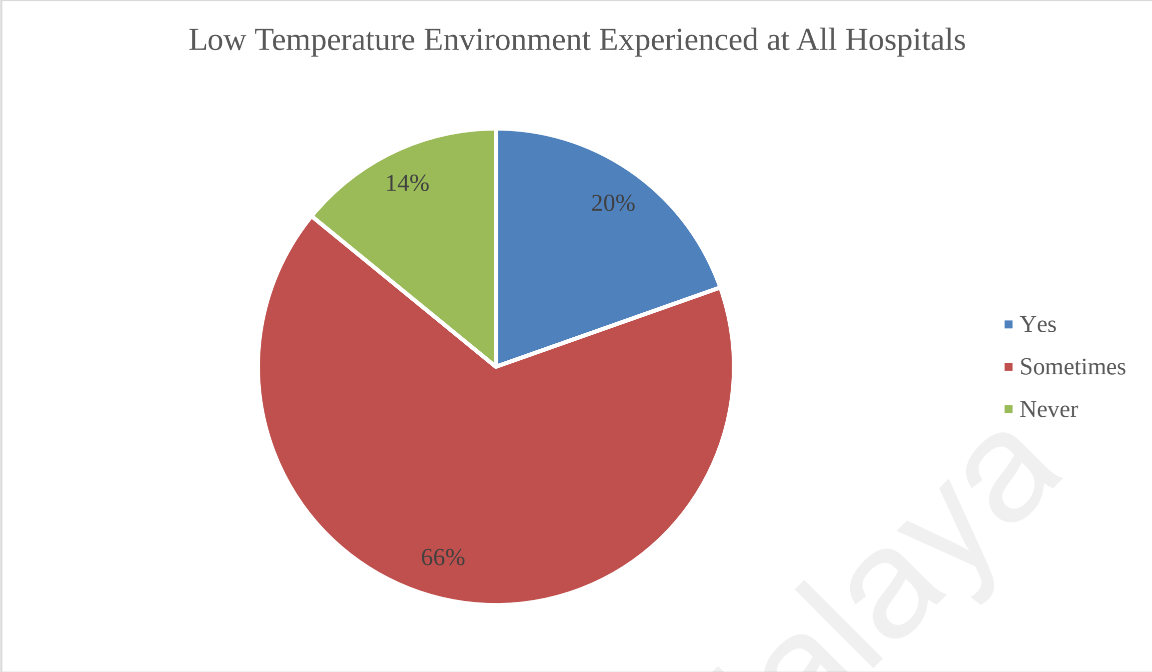

Figure 47 : Low Temperature Environment Experienced at All Hospitals

Low temperature environment was experienced among staff at all hospital with 86% of them, comprises of 20% who recently experienced the situation and 66% experienced it sometimes and only 14% of the staff never experienced the situation. Based on Table 15, the finding between hospitals have the same patterns.

Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a low temperature environment at the workplace by 70.4%, 66.7% and 61.8% respectively. This data set shows the highest issues experienced in unison by all staff in all hospitals, compare to the other issues. With reference to Table 16, there is no significant relationship between hospitals and the low temperature work environment was captured as the p-value is 0.598. The Pearson R value shows a weak negative correlation with the value of -0.090.

Majority of the rooms were reported and found to have low temperature, below the recommended standard. The reason being, the air conditioning were set at low temperature in order to reduce the odor formation. Besides that, most of the medical operations and activities are favorable to be conducted in a low temperature.

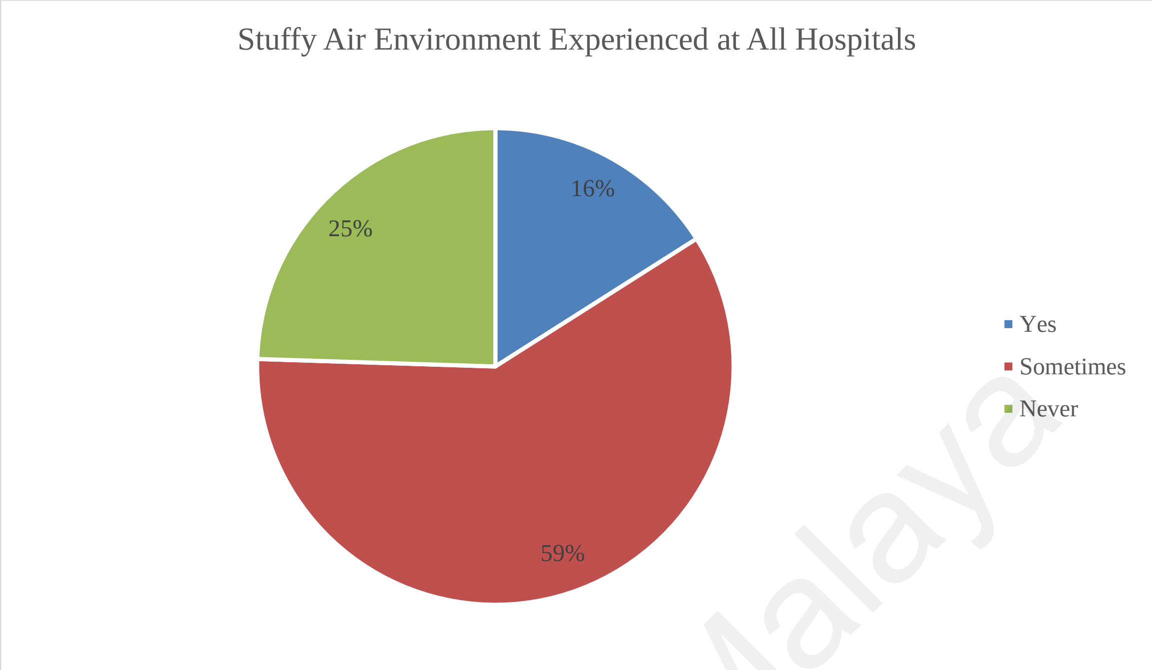

Figure 48 : Stuffy Air Environment Experienced at All Hospitals

Stuffy air environment was experienced among staff at all hospital with 75% of them, comprises of 16% who recently experienced the situation and 59% experienced it sometimes and 25% of the staff never experienced the situation. Based on Table 15, the finding between hospitals have the same patterns.

Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a stuffy air environment at the workplace by 53.7%, 63.0% and 61.8% respectively. With reference to Table 16, there is no significant relationship between hospitals and the stuffy air in the work environment was captured as the p-value is 0.790. The Pearson R value shows a medium positive correlation with the value of 0.47.

The findings was supported with the same air conditioning malfunction found during the inspection. Many reasons that contribute to this conditions for example the missing ceiling tiles, malfunction air condition split unit and imbalance blower power from the ventilation duct.

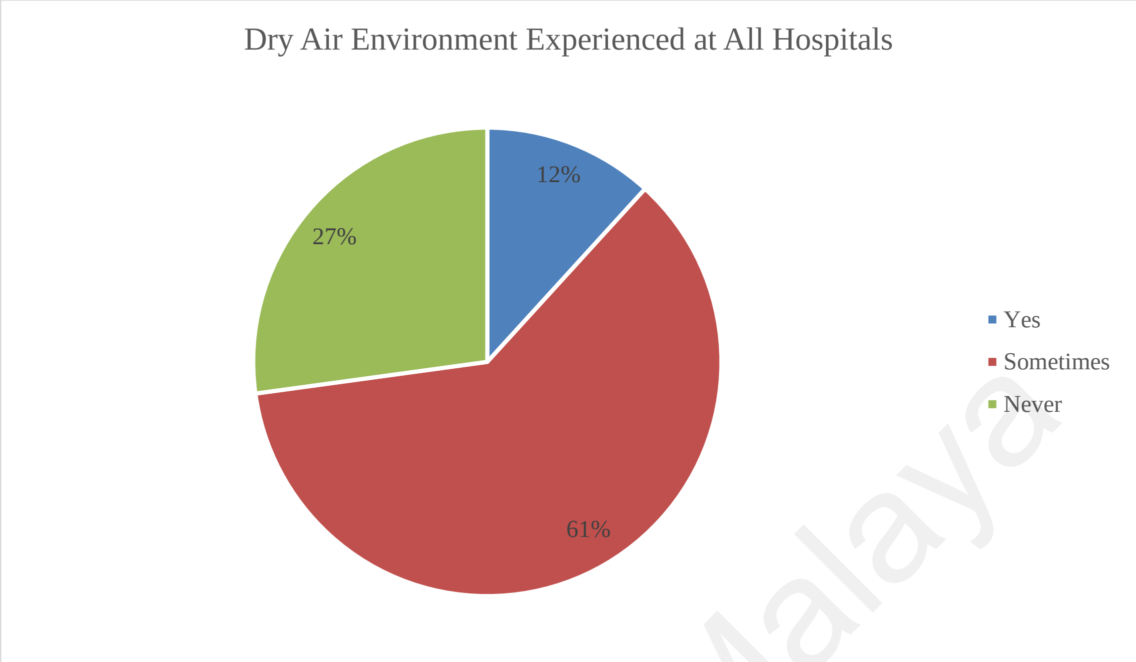

Figure 49 : Dry Air Environment Experienced at All Hospitals

Dry air environment was experienced among staff at all hospital with 73% of them, comprises of 12% who recently experienced the situation and 61% experienced it sometimes and 27% of the staff never experienced the situation. Based on Table 15, the finding between hospitals have the same patterns.

Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a dry air environment at the workplace by 57.4%, 66.7% and 58.2% respectively. With reference to Table 16, there is no significant relationship between hospitals and the dry air in the work environment was captured as the p-value is 0.759. The Pearson R value shows a medium positive correlation with the value of 0.47.

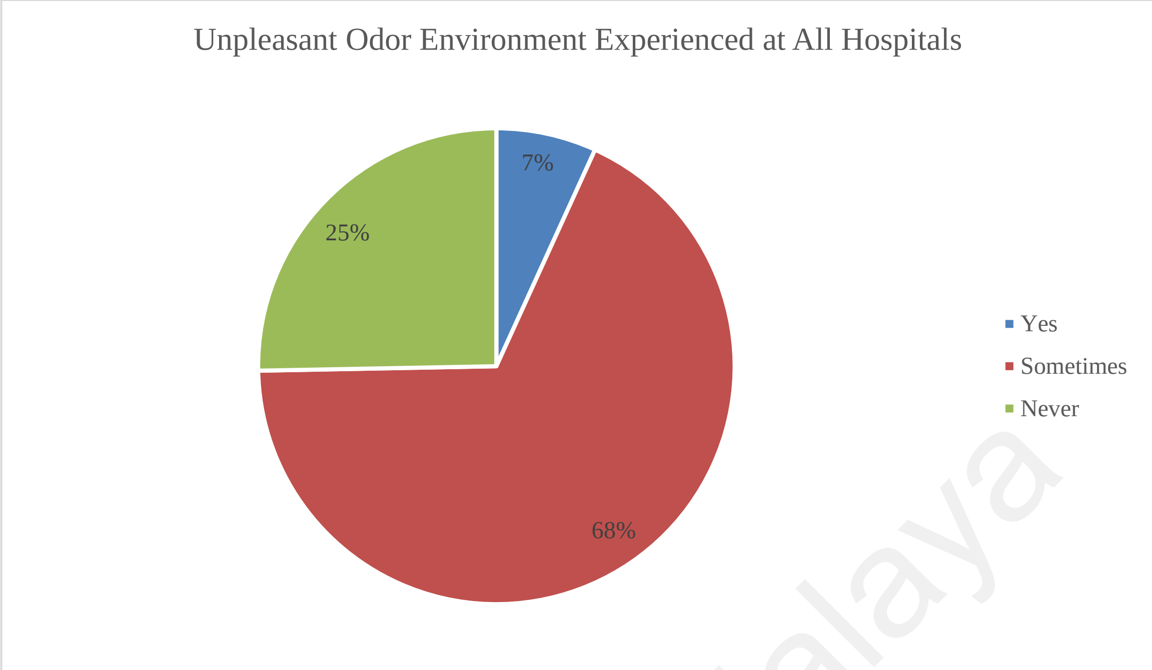

Figure 50 : Unpleasant Odor Environment Experienced at All Hospitals

Unpleasant odor in the working air environment was experienced among staff at all hospital with 75% of them, comprises of 7% who recently experienced the situation and 68% experienced it sometimes and 25% of the staff never experienced the situation. Based on Table 15, the finding between hospitals have the same patterns.

Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced an unpleasant odor in the ambience air environment at the workplace by 63.0%, 77.4% and 63.6% respectively. With reference to Table 16, there is no significant relationship between hospitals and the unpleasant odor in the work environment was captured as the p-value is 0.259. The Pearson R value shows a weak negative correlation with the value of -0.087.

Many reasons from the hospital activities that can contribute to the unpleasant odor. The chemical usage for cleaning purposes such as in endoscopy room was found to be one of the reason that contribute to the unpleasant odor. Besides that, malfunction vacuum chamber as found in many facilities during the walkthrough inspection also contribute to the unpleasant odor condition.

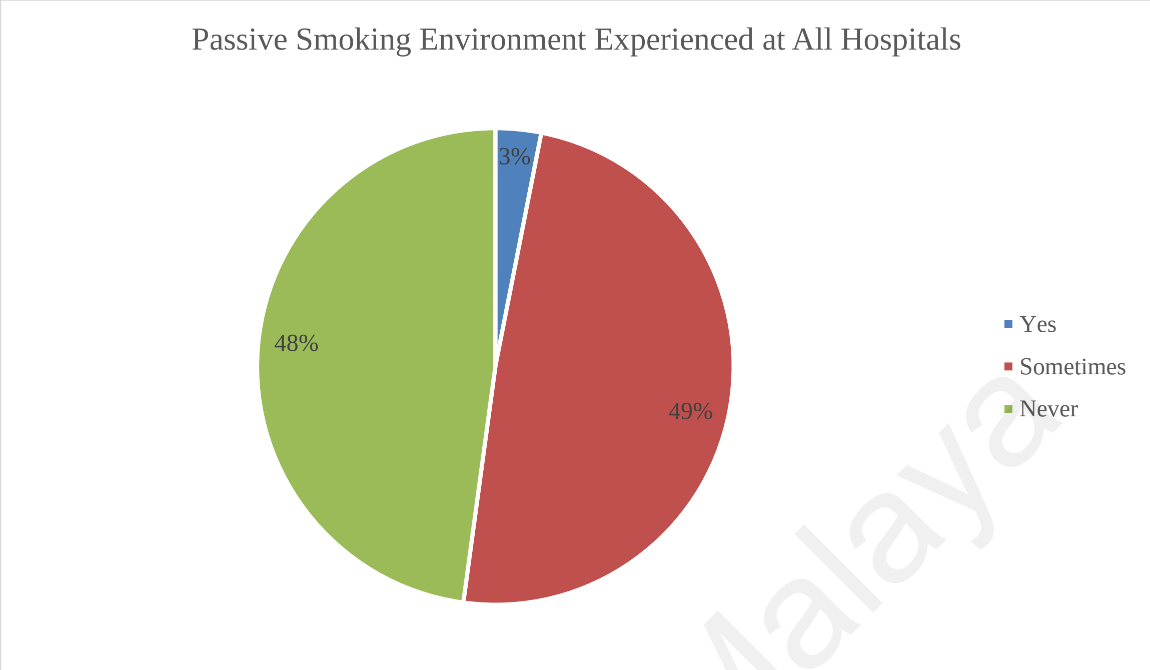

Figure 51 : Passive Smoking Environment Experienced at All Hospitals

Passive smoking in the working air environment was experienced among staff at all hospital with only 52% of them, comprises of 3% who recently experienced the situation and 49% experienced it sometimes and 48% of the staff never experienced the situation. This issues shows the least issues highlighted based on the questionnaire findings. Based on Table 15, the finding between hospitals is varied.

Majority of staff in Hospital B and Hospital C did sometime experienced a passive smoking environment in the ambience air environment at the workplace by 61.1% and 50.9% respectively whereas only Hospital A staff agreed that they were never experienced the issues while working in their workstations by 63.0%. With reference to Table 16, there is no significant relationship between hospitals and the passive smoking in the work environment was captured as the p-value is 0.072. The Pearson R value shows a weak negative correlation with the value of -0.141. In the hospital settings, the passive smoking issues is uncommon.

However, there were some cases where visitors found to be smoking in the staircase and toilet where the smoke indirectly suck into the ventilation ducts and transverse throughout the indoor air in the facilities.

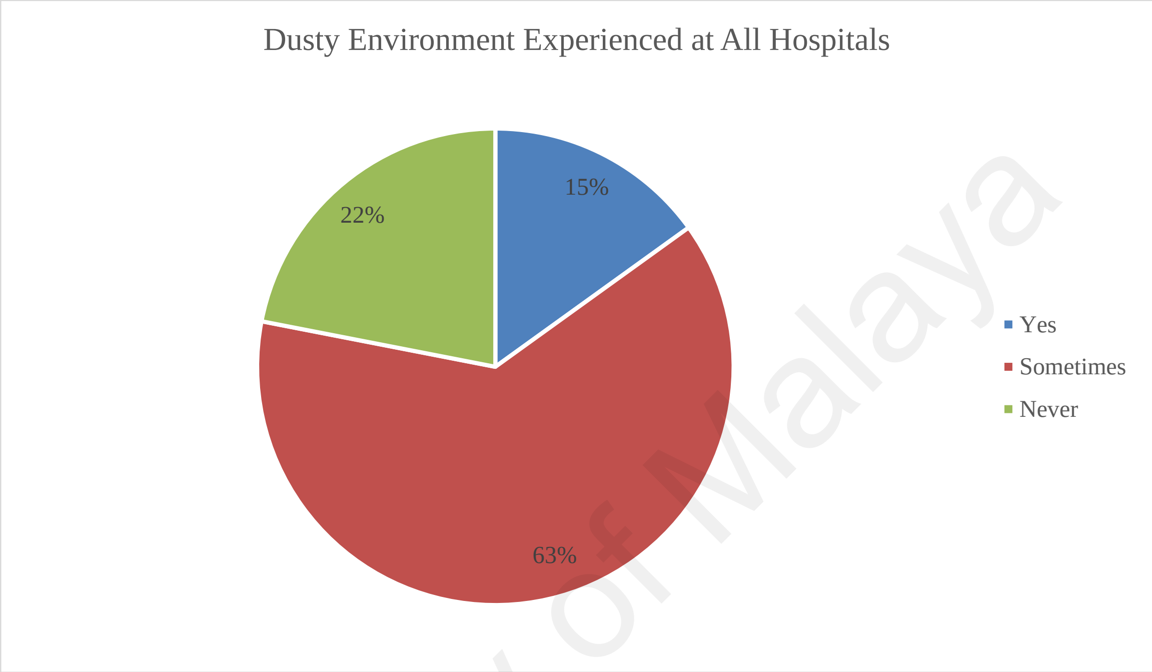

Figure 52 : Dusty Environment Experienced at All Hospitals

Dusty and dirty in the working environment was experienced among staff at all hospital with only 78% of them, comprises of 15% who recently experienced the situation and 63% experienced it sometimes and 22% of the staff never experienced the situation. Based on Table 15, the finding between hospitals is sharing the same pattern and distribution.

Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a dusty working environment at the workplace by 72.2%, 68.5% and 72.7% respectively. With reference to Table 16, there is no significant relationship between hospitals and the dusty work environment was captured as the p-value is 0.726. The Pearson R value shows a weak positive correlation with the value of 0.012.

This condition may come from improper housekeeping. Some of the housekeeping are focusing on floor sweeping and mopping without focusing on the ceiling area. As such, there are a lots of dust accumulation was formed on the ceiling and it shows during the walkthrough inspection where many ceiling ducts opening were dusty.

Table 18 explains the association tests between the respondent's genders and their responses to the indoor air quality issues. Chi square test were used to check the association as portray in table below.

Table 18 : Association Tests between Genders and Responses to IAQ Issues

Work Environment	**Genders**	
	p-value	**Pearson R value**
Draught	0.552	0.082
High Temperature	0.170	0.006
Low Temperature	0.100	0.043
Stuffy Air	0.048	-0.024
Dry Air	0.491	0.043
Unpleasant Odor	0.455	-0.020
Passive Smoking	0.872	-0.021
Dust	0.279	0.036

With reference to the Table 18 above, there were no association proven between genders of the staff and their IAQ issues encountered by them in the workplace except between genders and stuffy air issues with weak positive association at 0048 p-value. Besides that, the Pearson R value shows a very weak association with varies positive and negative association between the IAQ issues tested.

Table 19 explains the association tests between the respondent's age and their responses to the indoor air quality issues. Chi square test were used to check the association as portray in table below.

Table 19 : Association Tests between Age and Responses to IAQ Issues

Work Environment	**Age**	
	p-value	**Pearson R value**
Draught	0.455	0.026
High Temperature	0.770	0.035
Low Temperature	0.240	0.093
Stuffy Air	0.000	0.121
Dry Air	0.443	0.023
Unpleasant Odor	0.292	0.162
Passive Smoking	0.141	0.143
Dust	0.155	0.017

With reference to the Table 19 above, there was one strong positive association proven between age of the staff and the stuffy air issues encountered by them in the workplace with p-value of 0.000. In general, the Pearson R value shows a weak positive association between the staff age and the IAQ issues tested.

Table 20 explains the association tests between the respondent's smoking habits and their responses to the indoor air quality issues. Chi square test were used to check the association as portray in table below.

Table 20 : Association Tests between Smoke and Responses to IAQ Issues

Work Environment	**Smoke**	
	p-value	**Pearson R value**
Draught	0.097	-0.108
High Temperature	0.482	-0.011
Low Temperature	0.003	-0.067
Stuffy Air	0.372	0.012
Dry Air	0.253	-0.012
Unpleasant Odor	0.495	-0.079
Passive Smoking	0.402	-0.105
Dust	0.074	-0.178

With reference to the Table 20 above, there was one strong positive association proven between staff and their smoking habits and the low temperature air issues encountered by them in the workplace with p-value of 0.003. In general, the Pearson R value shows a weak positive and negative association between the staff age and the IAQ issues tested.

Table 21 explains the association tests between the respondent's working years and their responses to the indoor air quality issues. Chi square test were used to check the association as portray in table below.

Table 21 : Association Tests between Working Years and Responses to IAQ Issues

Work Environment	**Working Years**	
	p-value	**Pearson R value**
Draught	0.432	0.007
High Temperature	0.142	-0.017
Low Temperature	0.009	0.180
Stuffy Air	0.004	0.228
Dry Air	0.247	-0.012
Unpleasant Odor	0.106	-0.011
Passive Smoking	0.008	0.262
Dust	0.637	0.031

With reference to the Table 21 above, there were three strong positive associations proven between staff and their working years and low temperature, stuffy air and passive smoking issues encountered by them in the workplace with p-value of 0.009, 0.004, and 0.008 respectively. In general, the Pearson R value shows a weak positive and negative association between the staff age and the IAQ issues tested.

Table 22 explains the association tests between the respondent's working hours and their responses to the indoor air quality issues. Chi square test were used to check the association as portray in table below.

Table 22 : Association Tests between Working Hours and Responses to IAQ Issues

Work Environment	**Working Hours**	
	p-value	**Pearson R value**
Draught	0.009	-0.250
High Temperature	0.092	0.060
Low Temperature	0.504	-0.097
Stuffy Air	0.420	-0.058
Dry Air	0.355	0.026
Unpleasant Odor	0.001	0.002
Passive Smoking	0.010	0.046
Dust	0.134	-0.085

With reference to the Table 22 above, there were three strong positive association proven between staff working hours and the air issues encountered by them in the workplace. The reading of p-value are varies, with strongest association of unpleasant odor (0.001), followed by draught (0.009), and lastly passive smoking issues with 0.010. In general, the Pearson R value shows a weak positive and negative association between the staff age and the IAQ issues tested.

Table 23 explains the association tests between the respondent's workstation type and their responses to the indoor air quality issues. Chi square test were used to check the association as portray in table below.

Table 23 : Association Tests between Workstation Type and Responses to IAQ Issues

Work Environment	**Workstation Type**	
	p-value	**Pearson R value**
Draught	0.864	0.036
High Temperature	0.000	0.131
Low Temperature	0.031	-0.077
Stuffy Air	0.006	-0.031
Dry Air	0.679	-0.011
Unpleasant Odor	0.096	-0.148
Passive Smoking	0.295	-0.067
Dust	0.161	-0.072

With reference to the Table 23 above, there were three strong positive association proven between staff's workstation types the air issues encountered by them in the workplace. Strongest association between the workstation type were shown between high temperature with p-value is equal to 0.000, followed by stuffy air issues with 0.006 and lastly low temperature with p-value of 0.031. In general, the Pearson R value shows a weak positive and negative association between the staff age and the IAQ issues tested.

4.3.3 Indoor Air Quality Related Diseases' Sign and Symptom

The indoor air quality related diseases' sign and symptom dataset is shown in Table 24. The table explain the information of the responses on the work environment which includes headache, heavy-headed, fatigue, drowsiness, dizziness, nausea, cough, stuffy nose, hoarse throat, itchy skin and eyes irritation.

Table 24 : Questionnaire Hospital Work Environment Dataset

IAQ Related Diseases	Hospital A			Hospital B			Hospital C		
	Yes	**Sometimes**	**Never**	**Yes**	**Sometimes**	**Never**	**Yes**	**Sometimes**	**Never**
Headache	3 5.5%	40 74.1%	11 20.4%	1 1.9%	39 72.2%	14 25.9%	4 7.3%	33 60.0%	18 32.7%
Heavy-headed	2 3.7%	34 63.0%	17 31.5%	0 -	35 64.8%	19 35.2%	2 3.6%	35 63.6%	18 32.7%
Fatigue	12 23.1%	27 51.9%	13 25.0%	0 -	39 72.2%	15 27.8%	5 9.3%	37 68.5%	12 22.2%
Drowsiness	10 19.2%	28 53.8%	14 26.9%	13 24.1%	28 51.9%	13 24.1%	10 18.5%	35 64.8%	9 16.7%
Dizziness	7 13.5%	26 50.0%	19 36.5%	6 11.1%	30 55.6%	18 33.3%	5 9.3%	27 50.0%	22 40.7%
Nausea	1 1.9%	21 40.4%	30 57.7%	1 1.9%	22 40.7%	31 57.4%	4 7.4%	14 25.9%	36 66.7%
Cough	3 5.8%	32 61.5%	15 28.8%	0 -	40 74.1%	14 25.9%	3 5.6%	32 59.3%	19 35.2%
Stuffy Nose	5 9.6%	34 65.4%	13 25.0%	0 -	39 72.2%	15 27.8%	3 5.6%	32 59.3%	19 35.2%
Hoarse Throat	2 3.8%	34 65.4%	16 30.8%	0 -	31 57.4%	23 42.6%	3 5.6%	31 57.4%	20 37.0%
Itchy Skin	4 7.7%	27 51.9%	21 40.4%	3 5.6%	26 48.1%	25 46.3%	5 9.3%	28 51.9%	21 38.9%
Eyes Irritation	9 17.3%	22 42.3%	21 40.4%	3 5.6%	25 46.3%	26 48.1%	7 13.0%	26 48.1%	21 38.9%

Table 25 explains the work environment association by using SPSS analysis on the calculated probability p-value and Pearson R value to check the association strength between the two variables which is hospital and the indoor air quality diseases tested.

Table 25 : Questionnaire Indoor Air Quality Diseases Dataset Analysis

Indoor Air Quality Diseases	***p-value***	**Pearson R value**
Headache	0.378	0.084
Heavy-headed	0.659	-0.090
Fatigue	0.004	0.076
Drowsiness	0.605	-0.059
Dizziness	0.905	0.053
Nausea	0.235	0.025
Cough	0.170	-0.132
Stuffy Nose	0.156	0.108
Hoarse Throat	0.383	0.033
Itchy Skin	0.911	-0.021
Eyes Irritation	0.407	0.016

Table 26 explains the distribution of the respondents' input on the questionnaire. The term Yes depicts the respondents are currently experiencing the symptoms, Sometimes depicts the respondents had issue earlier in the past 3 months whereas Never depicts that the respondents never encountered the issues.

Table 26 : Questionnaire Work Environment Dataset

Work Environment	**Hospital**		
	Yes	**Sometimes**	**Never**
Headache	8 4.9%	112 68.7%	43 26.4%
Heavy-headed	4 2.5%	104 63.8%	54 33.1%
Fatigue	17 10.6%	103 64.4%	40 25.0%
Drowsiness	33 20.6%	91 56.9%	36 22.5%
Dizziness	18 11.3%	83 51.9%	59 36.9%
Nausea	6 3.8%	57 35.6%	97 60.6%
Cough	6 3.8%	104 65.0%	48 30.0%
Stuffy Nose	8 5.0%	105 65.5%	47 29.4%
Hoarse Throat	5 3.1%	96 60.0%	59 36.9%
Itchy Skin	12 7.5%	81 50.6%	67 41.9%
Eyes Irritation	19 11.9%	73 45.6%	68 42.5%

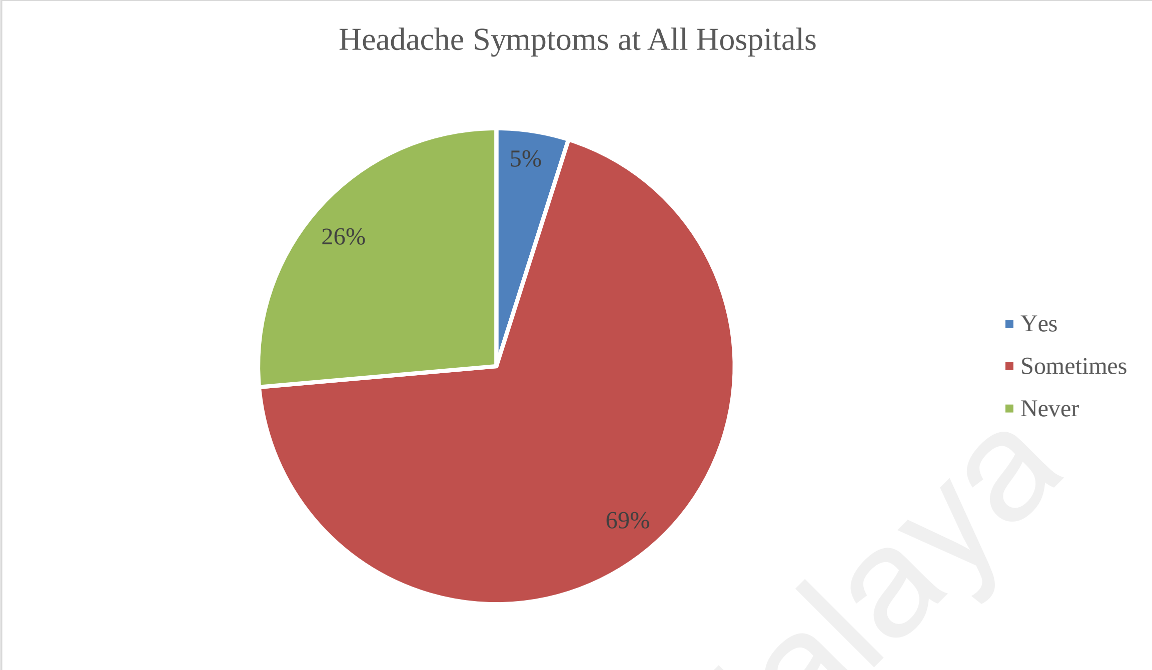

Figure 53 : Headache Symptoms at All Hospitals

Headache syndrome was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 74% of staff have experienced headache symptoms with 5% of them are recently experienced it and remaining of 69% of the staff experienced it sometimes. Only 26% of staff are not experienced headache symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a headache while working at the workplace by 74.1%, 72.2% and 60.0% respectively. With reference to Table 25, there is no significant relationship between hospitals and headache symptom experienced by the staff in all hospitals was captured as the p-value is 0.378. The Pearson R value shows a weak positive correlation with the value of 0.084.

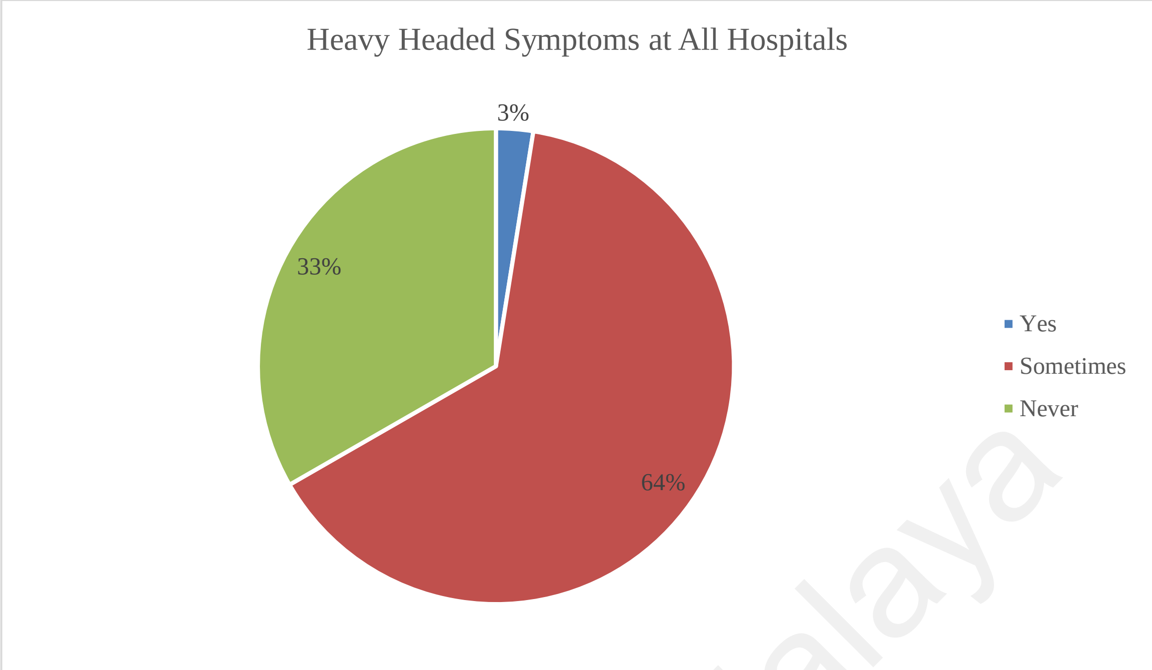

Figure 54 : Heavy Headed Symptoms at All Hospitals

Heavy headed symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 67% of staff have experienced heavy headed symptoms with 3% of them are recently experienced it and remaining of 64% of the staff experienced it sometimes. Only 33% of staff are not experienced heavy headed symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a heavy headed symptoms while working at the workplace by 51.9%, 72.2% and 68.5% respectively. With reference to Table 25, there is no significant relationship between hospitals and heavy headed symptom experienced by the staff in all hospitals was captured as the p-value is 0.659. The Pearson R value shows a weak positive correlation with the value of -0.090.

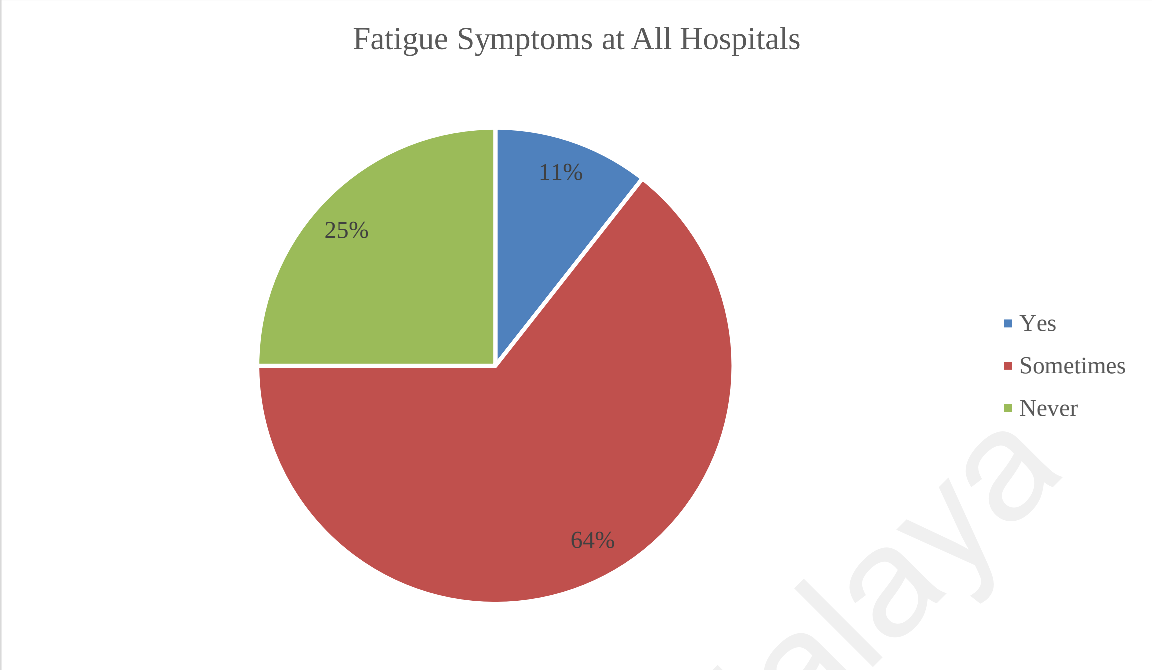

Figure 55 : Fatigue Symptoms at All Hospitals

Fatigue symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 75% of staff have experienced fatigue symptoms with 11% of them are recently experienced it and remaining of 64% of the staff experienced it sometimes. Only 25% of staff are not experienced fatigue symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a fatigue symptoms while working at the workplace by 51.9%, 72.2% and 68.5% respectively. With reference to Table 25, there is a significant relationship between hospitals and fatigue experienced by the staff in all hospitals was captured as the p-value is 0.004. The Pearson R value shows a weak positive correlation with the value of 0.076.

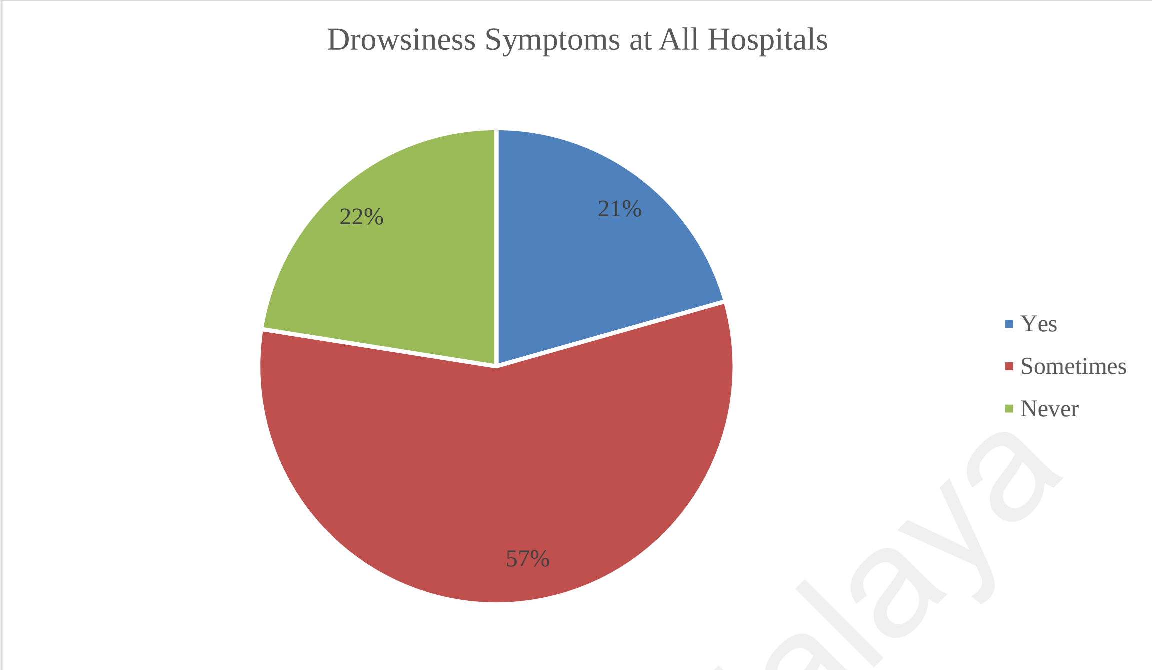

Figure 56 : Drowsiness Symptoms at All Hospitals

Drowsiness symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 78% of staff have experienced drowsiness symptoms with 21% of them are recently experienced it and remaining of 57% of the staff experienced it sometimes. Only 22% of staff are not experienced drowsiness symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a fatigue symptoms while working at the workplace by 53.8%, 51.9% and 64.8% respectively. With reference to Table 25, there is no significant relationship between hospitals and drowsiness experienced by the staff in all hospitals was captured as the p-value is 0.605. The Pearson R value shows a weak negative correlation with the value of -0.059.

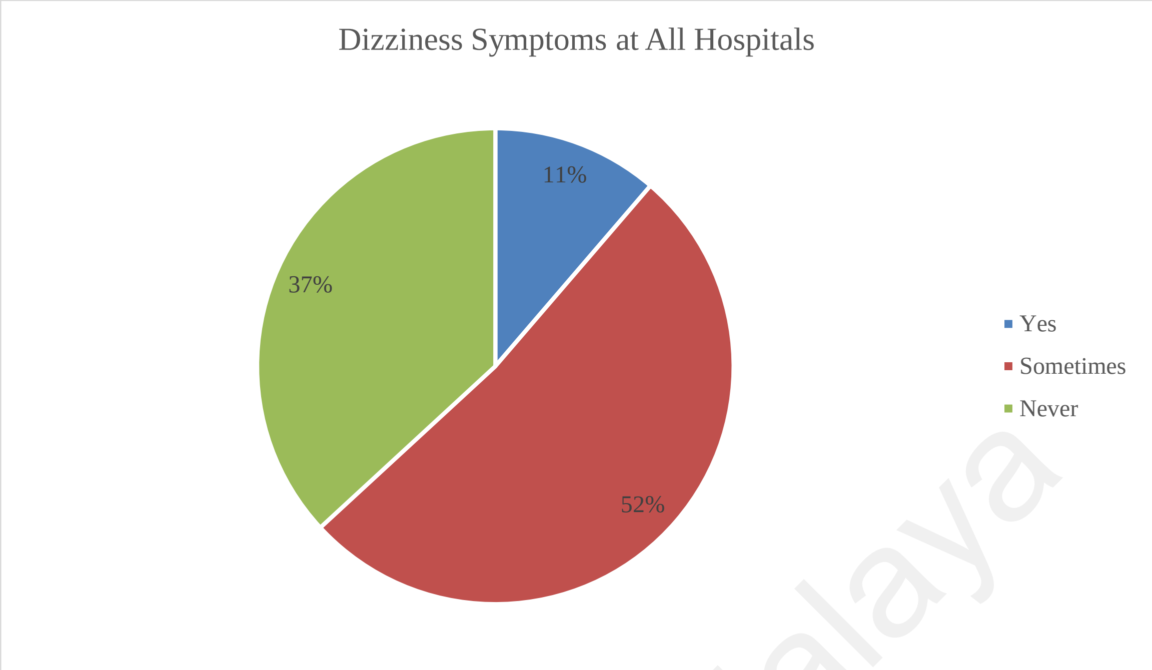

Figure 57 : Dizziness Symptoms at All Hospitals

Dizziness symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 63% of staff have experienced dizziness symptoms with 11% of them are recently experienced it and remaining of 52% of the staff experienced it sometimes. There were 37% of staff are not experienced dizziness symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced a dizziness symptoms while working at the workplace by 50.0%, 55.6% and 50.0% respectively. With reference to Table 25, there is no significant relationship between hospitals and drowsiness experienced by the staff in all hospitals was captured as the p-value is 0.905. The Pearson R value shows a weak positive correlation with the value of 0.053.

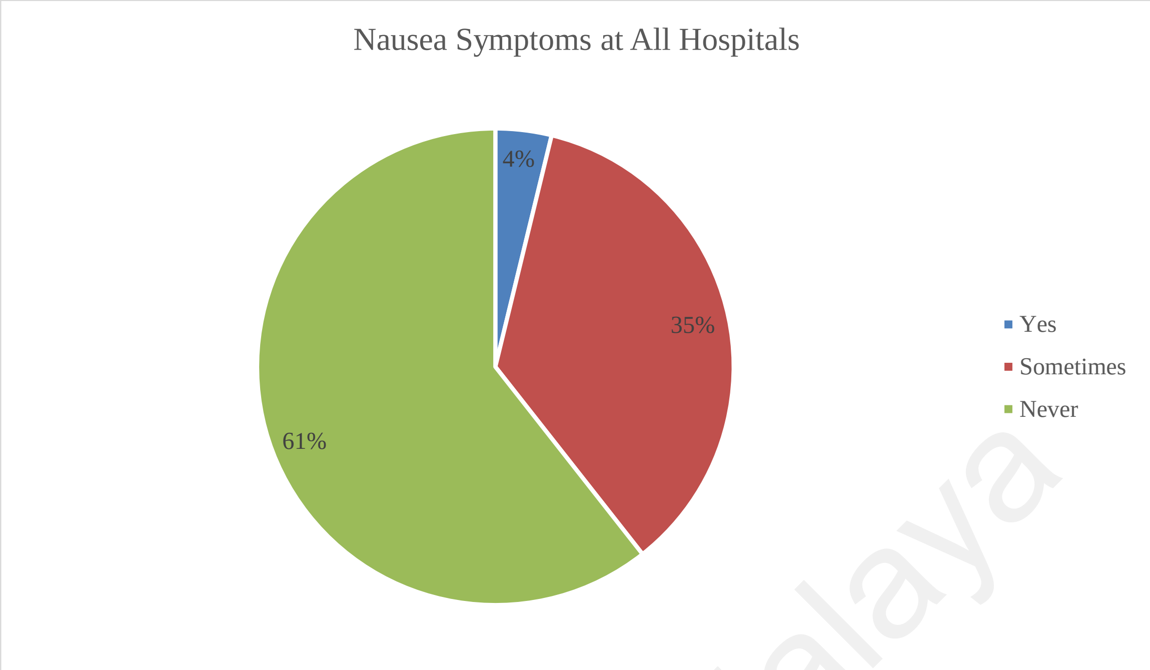

Figure 58 : Dizziness Symptoms at All Hospitals

Nausea symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 61% of staff have never experienced dizziness symptoms while working in the workstation. This is the lowest indoor air quality diseases signs and symptoms identified from the questionnaire posted. The number followed by only 39% of staff have experienced nausea while working at the hospitals with only 35% staff sometimes are facing the issue and only 4% of them are recently experienced it.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C agreed that they had never experienced a nausea symptoms while working at the workplace by 57.7%, 57.4% and 66.7% respectively. With reference to Table 25, there is no significant relationship between hospitals and nausea symptoms experienced by the staff in all hospitals was captured as the p-value is 0.235. The Pearson R value shows a weak positive correlation with the value of 0.025.

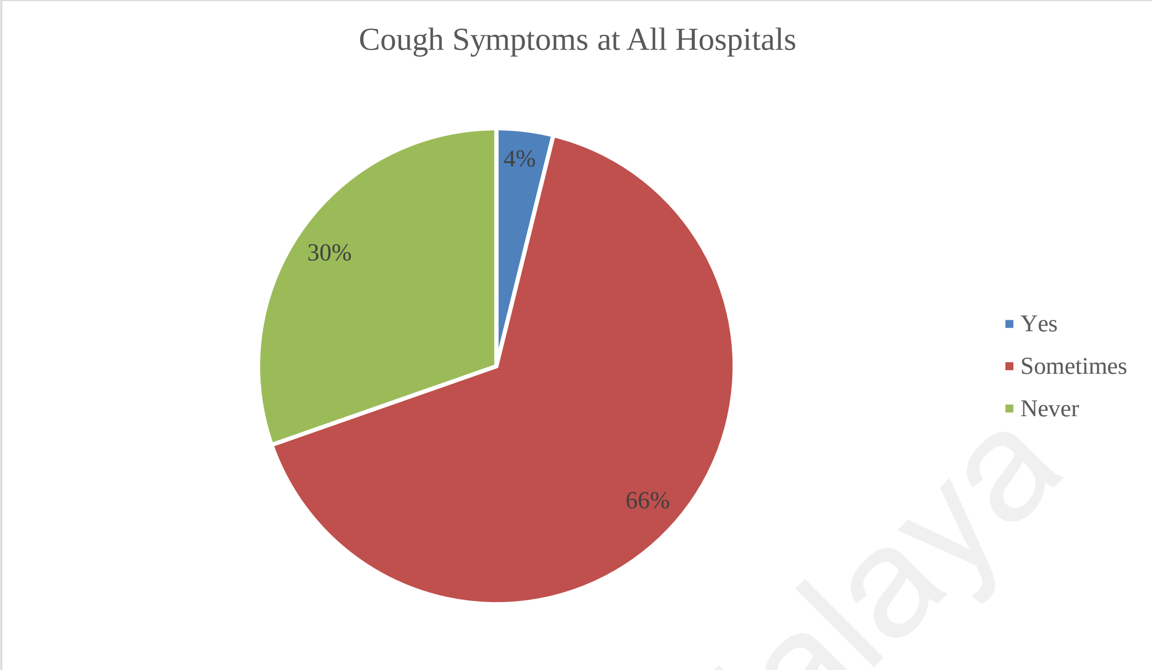

Figure 59 : Cough Symptoms at All Hospitals

Cough symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 70% of staff have experienced coughing symptoms with 4% of them are recently experienced it and remaining of 66% of the staff experienced it sometimes. There were 30% of staff are not experienced cough symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced coughing symptoms while working at the workplace by 61.5%, 74.1% and 59.3% respectively. With reference to Table 25, there is no significant relationship between hospitals and coughing experienced by the staff in all hospitals was captured as the p-value is 0.170. The Pearson R value shows a weak negative correlation with the value of -0.132.

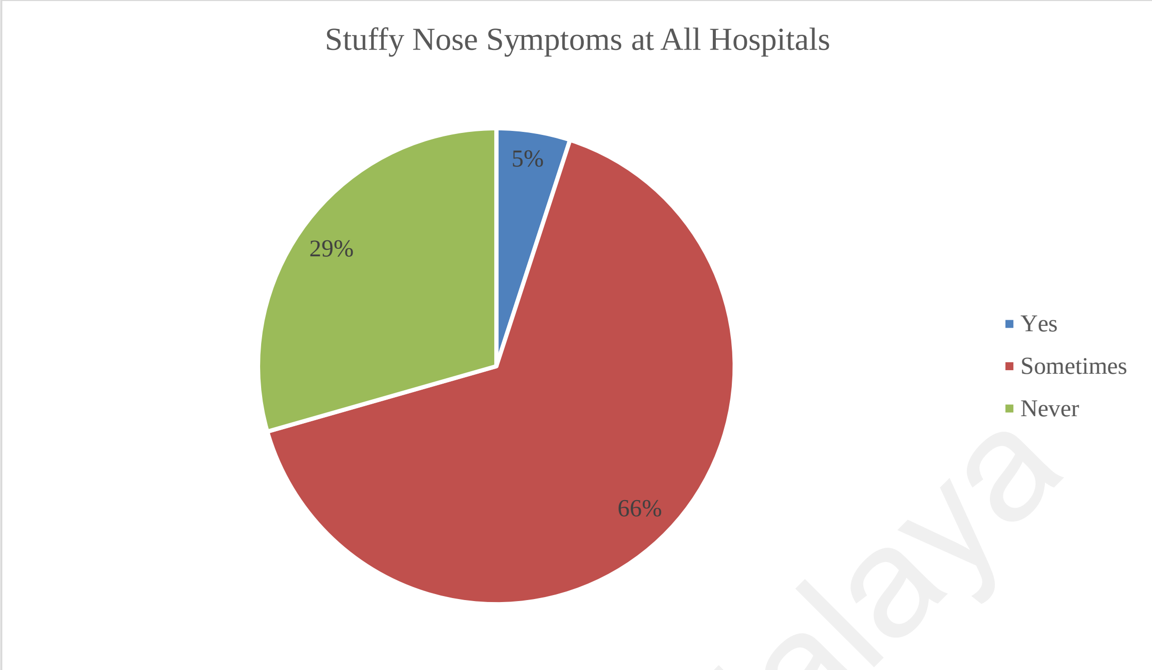

Figure 60 : Stuffy Nose Symptoms at All Hospitals

Stuffy nose symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 71% of staff have experienced stuffy nose symptoms with 5% of them are recently experienced it and remaining of 66% of the staff experienced it sometimes. There were 29% of staff are not experienced stuffy nose symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced stuffy nose symptoms while working at the workplace by 65.4%, 72.2% and 59.3% respectively. With reference to Table 25, there is no significant relationship between hospitals and coughing experienced by the staff in all hospitals was captured as the p-value is 0.156. The Pearson R value shows a weak positive correlation with the value of 0.108.

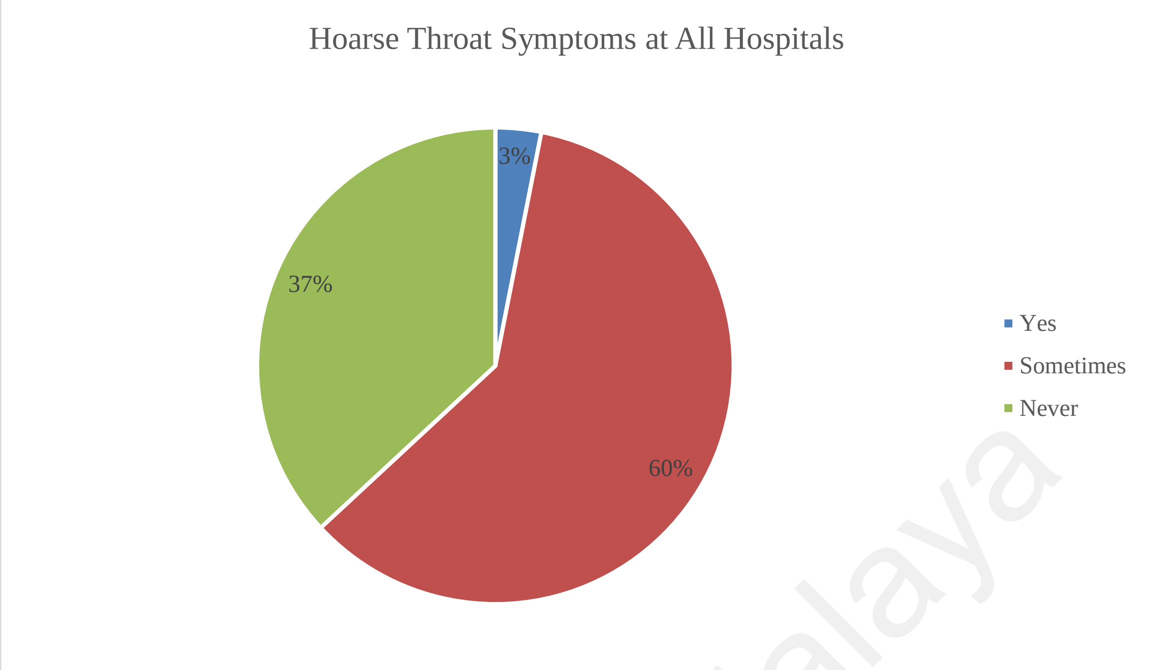

Figure 61 : Hoarse Throat Symptoms at All Hospitals

Hoarse throat symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 63% of staff have experienced hoarse throat symptoms with 3% of them are recently experienced it and remaining of 60% of the staff experienced it sometimes. There were 37% of staff are not experienced stuffy nose symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced hoarse throat symptoms while working at the workplace by 65.4%, 57.4% and 57.4% respectively. With reference to Table 25, there is no significant relationship between hospitals and hoarse throat experienced by the staff in all hospitals was captured as the p-value is 0.383. The Pearson R value shows a weak positive correlation with the value of 0.033.

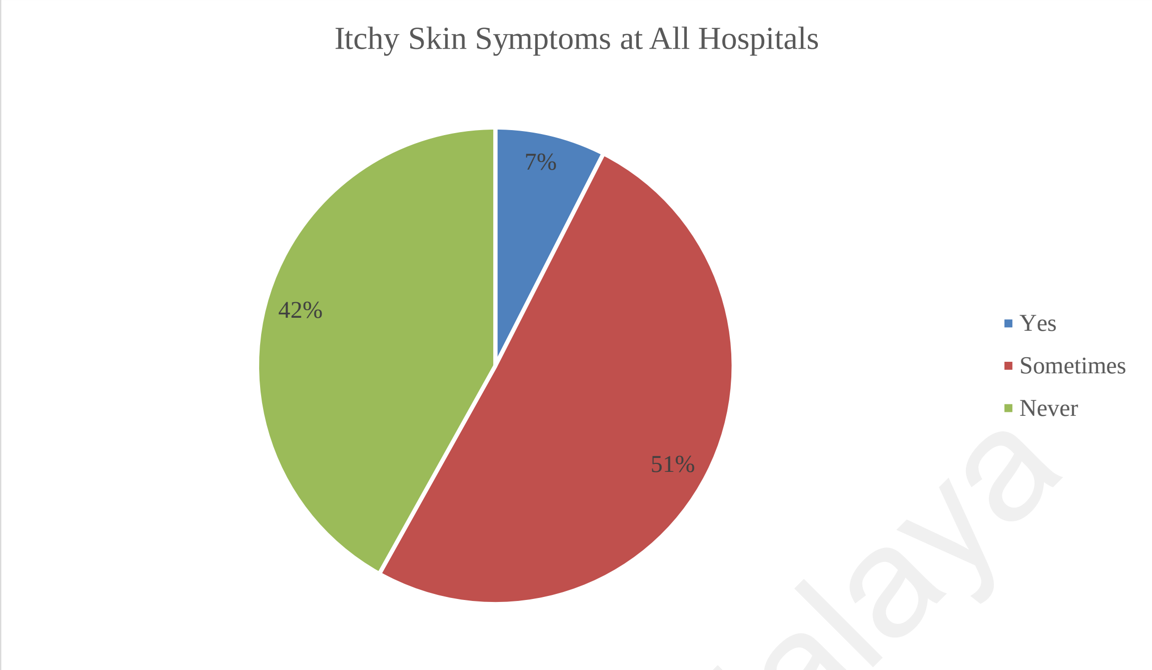

Figure 62 : Itchy Skin Symptoms at All Hospitals

Itchy skin symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 58% of staff have itchy skin symptoms with 7% of them are recently experienced it and remaining of 51% of the staff experienced it sometimes. There were 42% of staff are not experienced itchy skin symptoms in general.

Based on Table 24, the finding between hospitals is sharing the same pattern and distribution. Majority of staff in Hospital A, Hospital B and Hospital C did sometime experienced itchy skin symptoms while working at the workplace by 51.9%, 48.1% and 51.9% respectively. With reference to Table 25, there is no significant relationship between hospitals and itchy skin experienced by the staff in all hospitals was captured as the p-value is 0.911. The Pearson R value shows a weak negative correlation with the value of -0.021.

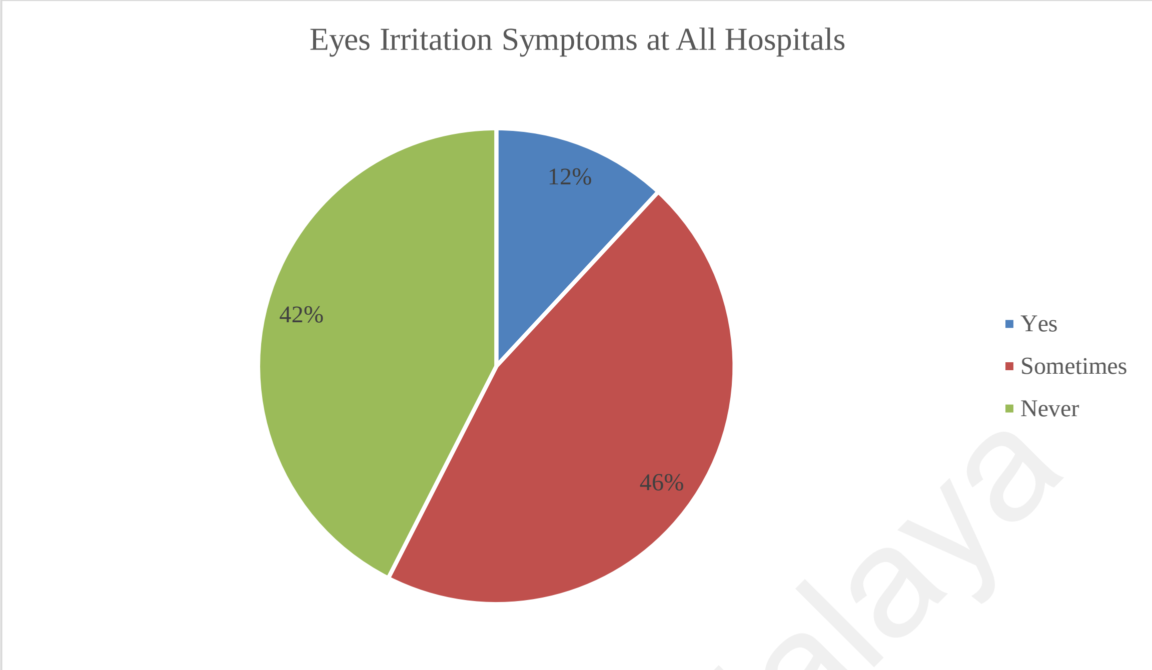

Figure 63 : Eyes Irritation Symptoms at All Hospitals

Eyes irritation symptoms was experienced as above figure in general for all hospital based on the questionnaire results received. In general, a total of 58% of staff have eyes irritation symptoms with 12% of them are recently experienced it and remaining of 46% of the staff experienced it sometimes. There were 42% of staff are not experienced any eyes irritation symptoms in general.

Based on Table 24, the pattern of major issues found is varied between hospitals. Only majority of staff in Hospital A and Hospital C did sometime experienced eyes irritation symptoms while working at the workplace by 42.3%, and 48.1% respectively. On the other hand, majority of staff in Hospital B reported that they never had any eyes irritation. In general, with reference to Table 25, there is no significant relationship between hospitals and eyes irritation experienced by the staff in all hospitals was captured as the p-value is 0.407. The Pearson R value shows a weak positive correlation with the value of 0.016.

Table 27 explains the association tests between the respondent's gender and their responses to the indoor air quality diseases issues. Chi square test were used to check the association as portray in table below.

Table 27 : Association Tests between Genders and Responses to Indoor Air Quality Related Diseases Encountered

Indoor Air Quality Related Diseases Encountered	**Genders**	
	p-value	**Pearson R value**
Headache	0.133	0.082
Heavy Headed	0.425	0.032
Fatigue	0.124	0.157
Drowsiness	0.854	0.041
Dizziness	0.066	0.043
Nausea	0.654	-0.063
Cough	0.258	0.094
Stuffy Nose	0.026	0.035
Hoarse Throat	0.594	-0.060
Itchy Skin	0.236	-0.002
Eyes Irritation	0.178	-0.082

With reference to the Table 27 above, there was one association proven between genders of the staff and the indoor air quality issues encountered by them in the workplace which is between hospitals and stuffy nose with p-value is 0.026. Besides that, the Pearson R value shows a very weak association with varies positive and negative association between the indoor air quality related diseases issues tested.

Table 28 explains the association tests between the respondent's age and their responses to the indoor air quality related diseases issues. Chi square test were used to check the association as portray in table below.

Table 28 : Association Tests between Age and Responses to Indoor Air Quality related Diseases issues.

Indoor Air Quality Related Diseases	**Age**	
	p-value	**Pearson R value**
Headache	0.037	0.141
Heavy Headed	0.740	0.025
Fatigue	0.835	0.043
Drowsiness	0.260	0.040
Dizziness	0.310	-0.005
Nausea	0.009	-0.037
Cough	0.053	0.013
Stuffy Nose	0.003	0.245
Hoarse Throat	0.004	0.042
Itchy Skin	0.692	0.036
Eyes Irritation	0.563	-0.046

With reference to the Table 28 above, there were three associations proven between age of the staff and the indoor air quality diseases issues encountered by them in the workplace. There is a significant relationship between age of staff working at the hospital with nausea, stuffy nose and hoarse throat with p-value is equal to 0.009, 0.003 and 0.004 respectively. Besides that, the Pearson R value shows a very weak association with varies positive and negative association between the indoor air quality diseases issues tested.

Table 29 explains the association tests between the respondent's smoking habits and their responses to the indoor air quality diseases issues. Chi square test were used to check the association as portray in table below.

Table 29 : Association Tests between Smoking Habit and Responses to Indoor Air Quality Diseases Issues

Indoor Air Quality Diseases Issues	**Smoking Habit**	
	p-value	**Pearson R value**
Headache	0.014	-0.222
Heavy Headed	0.727	-0.002
Fatigue	0.330	-0.097
Drowsiness	0.063	-0.181
Dizziness	0.133	-0.158
Nausea	0.065	-0.180
Cough	0.275	0.014
Stuffy Nose	0.518	-0.082
Hoarse Throat	0.662	-0.062
Itchy Skin	0.227	0.017
Eyes Irritation	0.278	-0.065

With reference to the Table 29 above, there was only one association proven between the staff habits of smoking and the indoor air quality diseases issues encountered by them in the workplace which is headache issue with p-value of 0.014. Besides that, the Pearson R value shows a very weak association with varies positive and negative association between the indoor air quality diseases issues tested.

Table 30 explains the association tests between the respondent's working years and their responses to the indoor air quality diseases syndrome issues. Chi square test were used to check the association as portray in table below.

Table 30 : Association Tests between Working Years and Responses to Indoor Air Quality Diseases Issues

Indoor Air Quality Diseases Issues	**Working Years**	
	p-value	**Pearson R value**
Headache	0.012	0.085
Heavy Headed	0.769	-0.009
Fatigue	0.073	0.010
Drowsiness	0.049	-0.058
Dizziness	0.003	-0.210
Nausea	0.640	-0.092
Cough	0.643	-0.068
Stuffy Nose	0.016	-0.075
Hoarse Throat	0.319	-0.038
Itchy Skin	0.269	0.175
Eyes Irritation	0.220	0.104

With reference to the Table 30 above, there were three significant associations proven between the staff working years and the indoor air quality diseases issues encountered by them in the workplace which is headache issue with p-value of 0.012, 0.003 and 0.016 where it refers to headache, dizziness and stuffy nose. Besides that, the Pearson R value shows a very weak association with varies positive and negative association between the indoor air quality diseases issues tested.

Table 31 explains the association tests between the respondent's working hours and their responses to the indoor air quality diseases syndrome issues. Chi square test were used to check the association as portray in table below.

Table 31 : Association Tests between Working Hours and Responses to Indoor Air Quality Diseases Issues

Indoor Air Quality Diseases Issues	**Working Hours**	
	p-value	**Pearson R value**
Headache	0.001	0.068
Heavy Headed	0.306	0.009
Fatigue	0.076	0.124
Drowsiness	0.000	-0.097
Dizziness	0.000	-0.219
Nausea	0.023	-0.164
Cough	0.591	-0.037
Stuffy Nose	0.027	0.074
Hoarse Throat	0.004	0.099
Itchy Skin	0.008	-0.061
Eyes Irritation	0.015	0.028

With reference to the Table 31 above, there were seven significant associations proven between the staff working hours and the indoor air quality diseases issues encountered by them in the workplace with p-value of 0.001, 0.000, 0.000, 0.023, 0.027, 0.004, 0.008 and 0.015 where it refers to headache, drowsiness, dizziness, nausea, stuffy nose, hoarse throat, itchy skin and eyes irritation. This shows that working years does play a significant role with the significant of indoor air quality diseases issues encountered by the staff. Besides that, the Pearson R value shows a very weak association with varies positive and negative association between the indoor air quality diseases issues tested.

Table 32 explains the association tests between the respondent's workstation types and their responses to the indoor air quality diseases syndrome issues. Chi square test were used to check the association as portray in table below.

Table 32 : Association Tests between Workstation Type and Responses to Indoor Air Quality Diseases Issues

Indoor Air Quality Diseases Issues	**Workstation Type**	
	p-value	**Pearson R value**
Headache	0.001	0.285
Heavy Headed	0.524	0.003
Fatigue	0.884	0.012
Drowsiness	0.114	-0.117
Dizziness	0.675	-0.064
Nausea	0.558	0.054
Cough	0.142	-0.021
Stuffy Nose	0.455	0.062
Hoarse Throat	0.605	0.050
Itchy Skin	0.298	0.068
Eyes Irritation	0.740	0.060

With reference to the Table 32 above, there was only one association proven between the staff workstation type and the indoor air quality diseases issues encountered by them in the workplace which is headache issue with p-value of 0.001. Besides that, the Pearson R value shows a very weak association with varies positive and negative association between the indoor air quality diseases issues tested.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The Indoor Air Quality at the hospital is one of the important aspect need to be considered and maintained as it affect all staff, patients and visitors that are presence in the environment. This study concentrated to determine the indoor air quality in the selected Klang Valley hospitals. This indoor air quality reading collected are compares and tested against following guidelines :

1. Guideline on Indoor Air Quality for Hospital Support Services (MOH 2015)
2. Industry Code of Practice on Indoor Air Quality 2010 (ICOP on IAQ 2010)

Based on the findings collected from the walkthrough inspection, indoor air quality assessment and questionnaire, the conclusions were drawn based on objectives, with the following information :

1. Eight indoor air parameter have been assessed in this study which includes the concentration of carbon dioxide, carbon monoxide, respirable particulates, temperature, relative humidity, air movement, bacteria and fungi. All parameters are in compliance to the standard in all hospital tested except the temperature setting in the hospital which were either too high or too low and the condition creates unfavorable environment to the healthcare providers, patients and visitors.

   Generally, the main IAQ issues found were low temperature, high relative humidity and low air movement in all sampling areas. TVOC is below the recommended standard (<3) with reading of <0.01ppm at all locations. There is a concern on carbon dioxide (792ppm – 955ppm) and carbon monoxide

(0.5ppm – 1.5ppm) concentration where it was detected in dental laboratory in all three hospitals.

The highlighted issues on IAQ assessment are low temperature, high relative humidity and low air movement has recorded that majority of the hospitals. Low temperature ranging from 19.8^{o}C, below the Indoor Air Quality Codes of Practice (ICOP), 2010 standard (23^{o}C - 26^{o}C). One sampling point which is HOSPITAL A Endoscopy room is above the recommended standard with 30.2 ^{o}C, due to air conditioning malfunction. This conditions create unfavorable environment and discomfort among the building occupant. The IAQ parameters for comfortable temperature weren't well maintained in most areas assessed in all hospitals. It was found that the temperature taken were usually lower than recommendation temperature as per the standard. The reason being, it aims to suits the operation of the hospital i.e. to reduce the smell, safekeeping the medicines, etc. It was also found that the majority of the area sampled has exceed the relative humidity recommended by the standard (40% - 70%) ranging from 60% to 83.5%. This high humidity condition can increase the growth of fungi and bacteria in the environment. Lastly, low air movement (m/s) was also found where the reading were below the recommended standard between 0.15m/s to 0.50m/s.

2. Working condition issues responses was collected from respondents through questionnaire. Of the 165 respondents, 65.6% were female, 77.9% were in the age of 26 to 39 years old, 90.2% were not smoking, 67.5% were working less than 5 years and 84.7% were working in enclosed room type workstation. Low temperature issues is the highest issues in the working environment

highlighted with a total of 85.9% respondents agrees to experience the condition (19.6% respondents are experiencing the condition and 66.3% respondents are experiencing in that month). The finding was supported from with the IAQ assessment findings. The dusty work environment is the second issues highlighted from the respondents with a total of 76.6% respondents agrees to experience the condition (9.8% respondents are experiencing the condition and 66.9% respondents are experiencing in that month). Followed by unpleasant odor issues experienced by the respondents with a total of 74.7% (6.8% respondents are experiencing the condition and 67.9% respondents are experiencing in that month). The least issues highlighted from respondents is passive smoking condition with majority of 52.2% of the total respondents (3.1% respondents are experiencing the condition, 49.1% respondents are experiencing in that month and 47.9% respondents never experienced the condition). Based from the statistical analysis, it can be conclude that there is a significant relationship (p-value <0.05) between the variable is stuffy air condition experienced by respondents and their gender (p value, 0.048), age (p value, 0.000), years of working (p value, 0.004), and workstation type (p value, 0.006).

Besides working condition issues, IAQ related diseases responses was also collected from respondents through questionnaire. Drowsiness issues is the highest symptoms experienced by the respondent, with h a total of 77.5% respondents agrees to experience the condition (20.6% respondents are experiencing the condition and 56.9% respondents are experiencing in that month). The fatigue symptoms is the second issues highlighted from the respondents with a total of 75.0% respondents agrees to experience the condition (10.6% respondents are experiencing the condition and 64.4% respondents are experiencing in that month). Followed by headache symptoms experienced by the respondents with a total of 73.6% (4.9% respondents are experiencing the condition and 68.7% respondents are experiencing in that month). It is related to the IAQ finding where majority of the sampling area were found in low temperature below the recommended standard. Cold temperature claims to affect the trigeminal nerve which causes the blood vessels to be constricted. This will also affect the brain blood vessels which indirectly creates the headache issue (Rios JL, 2009) The least IAQ related disease highlighted from respondents is nausea with majority of only 39.4% of the total respondents (3.8% respondents are experiencing the condition, 35.6% respondents are experiencing in that month and a majority of 60.6% respondents never experienced the condition). Based from the statistical analysis, it can be conclude that there is a significant relationship (p-value <0.05) between the demographic variable and headache. There is an association between the headache experienced by respondents and their age (p value, 0.037), smoking habit (p value, 0.014), years of working (p value, 0.012), hours of working (p value, 0.001) and workstation type (p value, 0.001).

3. Proposal and recommendation was focused on two mechanisms, immediate action and preventive plan. The immediate action covers the initiative to resolve the identified issues during the walkthrough inspections i.e. high fungi and mold contamination, presence of water stains, poor ventilation and high chemical exposure control for some work activities. On the other hand, the

plan preventive measure focuses on the controlling the pollutant source, improve the housekeeping practice, and continuous IAQ status monitoring.

4.2 Proposal Plan

4.2.1 Immediate Action

The major AQI related issues found that high number of mold and fungal contamination in the environment. There a lots of visible mold growth and fungal stains on wall surfaces and ceiling panels. As such, it is very crucial for the hospital management to conduct detailed fungal inspection which may help in determining the root cause of the fungal growth. If severe fungal contamination is found, an immediate fungal decontamination process is required. Contaminated ceiling panels is recommended to be removed, replaced and the area should be sterilized especially in high risk area i.e. red zone area, laboratory, wards, etc. As prevention tips, anti-fungal surface protection application on wall surfaces, ceiling, and office fixtures can reduce the occurrence of fungal growth. The area of concern shall be kept well ventilated and in good air movement at all times to prevent the fungal and mold formation.

Any presence of water stains need to be immediately inspected as increase of humidity may invites a favorable environment for fungal and mold formation. The maintenance team is advised to investigate and check the above ceiling condition to identify any potential water leakages that contribute to the situation.

Highest chemical exposure comes from Sterile Room where it involves with the cleaning and sterilization of used endoscopy. As such, the identified rooms shall be installed with a proper LEV where it helps to reduce the exposure the staff. Besides that, the LEV shall be maintained adequately and in a timely manner to ensure the efficiency. Any defects in local exhaust ventilation (LEV) at the locations shall be carried out immediately, as the malfunction of the system might accumulate the chemical vapors in the environment which might danger the person in the ambience. Besides that, Chemical Health Risk Assessment (CHRA) is best recommended to be carried out for any activities that use chemical in order to assess the chemicals used and its exposure to the occupants.

Poor ventilation can be due to low air movement which indirectly increase the high carbon dioxide in the concern area. Low air movement might create unfavorable surrounding especially in high populated area. It is recommended to check the supply or return air grilles at the area of concern in accordance to its design air flow capacity and to always check the adequacy of the ventilation capacity against occupancy and workplace usage pattern in order to maintain the ventilation efficiency at the optimum condition. In dense populated area, it is suggested to install exhaust ventilators to improve the air circulation and carbon dioxide level. Regular monitoring on the carbon dioxide level also helps in ensuring the good air ventilation is maintained.

Poor ventilation may create imbalance temperature where the temperature is too high or too low and / or effect the relative humidity in the environment. It is highly recommended to rectify and repair any problematic split air conditioning units to allow adequate air ventilation and to ensure the thermal comfort to the occupants. Besides that, it is also recommended to readjust the thermostat or controls the set point of the AHU system at the recommended ranged between 23.0 – 26.0 ^{o}C as per acceptable range specified in ICOP on IAQ 2010.

4.2.2 Plan Preventive Measure

There are three strategies to minimize the Indoor Air Quality problems which is controlling the pollutant source, improve the housekeeping and maintenance by conducting ventilation and air cleaning, and continuous monitoring on Indoor Air Quality status.

With aim to control the pollutant source, the choosing of free or low volatile organic compound emission materials or furniture for any events of future renovation, indoor decorating and refurbishing is best recommended. Europe and United States has established a labelling schemes for majority of the indoor decorating and refurbishing materials which can be leveraged to improve the indoor air quality with good effect (Liu, 2012). The consideration of using non-wood based panels, wood-based composites, laminated furniture, laminate flooring, and engineer flooring will help to reduce the exposure of VOCs as these materials are proven to emit large concentration of VOCs (Duy, 2011).

Other preventive measure shall include the periodically IAQ monitoring. IAQ monitoring can help in detecting any problematic areas that require attention and to check the parameters' improvement after any remediation has been carried out. Besides that, any complaints reported regarding IAQ problems shall be taken into consideration and to carry out the IAQ monitoring for issues confirmation. The IAQ shall be carried our whenever there are any changes in the indoor environments or prescribed activities such as any re-carpeting, partitioning, installation of air-conditioning and renovation that will affect the condition of present IAQ. It is highly recommended to re-conduct the air monitoring at the problematic areas as part of monitoring.

MVAC system maintenance to all AHU Room is also helps to improve the IAQ in a building. Through this maintenance, the component of the MVAC system shall be cleaned and maintained to ensure the performance of the MVAC system in filtering air, maintaining sufficient air replacement and ventilation. In general, the components of air-handling units such as fans and dampers shall be cleaned / decontaminated at least in every six months, depending on the condition of the incoming air and usage rate of the system. Filters shall be cleaned or replaced to prevent from any obstructions or clogged that will block the airflow. Inspection on the cooling coils, condensate pipes and water trays shall be checked once a month to ensure no contaminants build up (i.e. sludge, algae formation or rust build up), blockages and leaks where water could enter the airstream. The coils and condensate pipes shall be cleaned and decontaminated at least in every six months whereas the tray shall be cleaned and decontaminated at least once a month. Any ferrous metal surface used in the MVAC shall be treated with anti-corrosion coating. Recirculating water shall also be treated to prevent contaminated water i.e. with rust, contaminants to enter the airstream system and disseminates to the building occupant. The MVAC shall be sealed appropriately to prevent any unfiltered air or gases enter the occupied space without being tested and screened.

Housekeeping is very important in which it reduces the pollutant presence in the working environment. It helps to keep floor dust levels low and removes dirt which could otherwise become sources of contamination. Whenever any chemical based detergents are in used for any housekeeping activities, the management shall ensure the availability of SDSs to the building management and other occupant on each detergent identified, in used and / or stored. Installation of air purifier / cleaner can also help to increase the indoor air quality.

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