AIR QUALITY IN LIBRARY: ASSESSMENT OF PM_{10} AND $PM_{2.5}$ CONCENTRATIONS AT DIFFERENT FLOOR LEVELS OF USM HEALTH CAMPUS'S LIBRARY

BY

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Dissertation submitted in partial fulfillment of the requirements
for the degree of Bachelor of Health Science (Honours)
(Environmental and Occupational Health)

JUNE 2016

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful. Praise to Him the Almighty that in His will and given strength, I had managed to complete this thesis. I take this opportunity to express my profound gratitude and deep regards to my supervisor, Dr Nurulilyana Binti Sansuddin for her exemplary guidance, monitoring, and constant encouragement throughout the course of thesis. I really appreciate the blessing, help and guidance given by her during the whole period of study.

My sincere thanks go to all lecturers and Environmental and Occupational Health laboratory staffs for their co-operation and supports during the study. I also take this opportunity to express a deep gratitude to my family for their cordial support and guidance, which help me in completing this thesis through various stages.

I am obliged to my friends and other classmates for their co-operation and full commitment during the period of my thesis. A heartfelt gratitude goes to the management of Perpustakaan Hamdan Tahir for giving me permission to conduct the study over there.

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LIST OF ABBREVIATIONS AND SYMBOL

ASHRAE	American Society of Heating, Refrigating and Air Conditioning Engineers
BRI	Building Related Illness
CDC	Centre for Disease Control and Prevention
DOSH	Department of Safety and Health
EPA	Environmental Protection Agency
IAQ	Indoor Air Quality
ICOP	Industry Code of Practice
HVAC	Heating, Ventilation and Air-Conditioning
m^2	Meter square
mg/m^3	Milligram per meter cube
PHT	Perpustakaan Hamdan Tahir
PM	Particulate matter
SBS	Sick Building Syndrome
SPSS	Statistical Package for the Social Sciences
UNEP	United Nations Environment Programme
USM	Universiti Sains Malaysia
WHO	World Health Organisation
$\mu g/m^3$	Microgram per metre cubic
%	Percentage
>	More than
<	Less than

KUALITI UDARA DI DALAM PERPUSTAKAAN: PENILAIAN TERHADAP KEPEKATAN PM_{10} DAN $PM_{2.5}$ DI ARAS LANTAI YANG BERBEZA DI PERPUSTAKAAN KAMPUS KESIHATAN USM

ABSTRAK

Perpustakaan merupakan salah satu tempat yang sering dikunjungi oleh pelajar universiti setiap hari. Kebanyakan pelajar gemar menghabiskan masa mereka di perpustakaan. Pendedahan kepada bahan pencemar udara dalaman boleh berlaku di dalam perpustakaan. Tujuan kajian ini dijalankan adalah untuk menilai kualiti udara dalaman (IAQ) di dalam perpustakaan di Kampus Kesihatan USM, Kota Bharu, Kelantan. Perbandingan kepekatan PM_{10} dan $PM_{2.5}$ antara aras tingkat perpustakaan telah ditentukan. Kajian ini juga dijalankan untuk mendapatkan hubungan antara kepekatan PM_{10} dan $PM_{2.5}$ dengan jumlah bilangan penghuni, suhu, kelembapan relatif dan jumlah bilangan buku. Kepekatan zarah terampai diukur di perpustakaan dengan menggunakan 'Handheld 3016 IAQ Particle Counter'. Data dicerap selama lapan jam di setiap aras dengan selang masa selama limit minit. Berdasarkan ujian Kruskal Wallis, terdapat perbezaan yang signifikan bagi kepekatan $PM_{2.5}$ dan PM_{10} antara aras setiap tingkat (p<0.05). Jumlah bilangan penghuni mempunyai perkaitan dengan kepekatan $PM_{2.5}$ dengan menggunakan ujian Kolerasi Spearman (p<0.05). Selain itu, terdapat juga perkaitan yang signifikan antara suhu dan kelembapan relatif dengan kepekatan PM_{10} dan $PM_{2.5}$. Walaubagaimanapun, perkaitan antara kepekatan zarah terampai dengan suhu dan kelembapan relatif tersebut adalah lemah (r-PM_{10}=0.22, r-$PM_{2.5}$=-0.15; r-PM_{10}=-0.17, r-$PM_{2.5}$=0.2). Jumlah bilangan buku dan perbezaan luas lantai setiap aras di perpustakaan juga boleh menjadi faktor penyumbang. Kesimpulannya, aktiviti pembersihan dan pengemasan secara berkala di dalam perpustakaan hendaklah dilakukan untuk mengurangkan masalah IAQ dan untuk mewujudkan persekitaran dalaman yang lebih sihat.

AIR QUALITY IN LIBRARY: ASSESSMENT OF PM_{10} AND $PM_{2.5}$ CONCENTRATIONS AT DIFFERENT FLOOR LEVELS OF USM HEALTH CAMPUS'S LIBRARY

ABSTRACT

Library is one of the most frequent visited place by university students everyday. Many students favor to spend their time in library. Indoor exposure to air pollutants may occur in library. The purpose of this study is to assess the indoor air quality (IAQ) in library at USM Health Campus, Kota Bharu, Kelantan. The comparison of PM_{10} and $PM_{2.5}$ concentrations between floor levels of library was determined. This study was also conducted to obtain the associations between PM_{10} and $PM_{2.5}$ concentrations with number of occupants, temperature, relative humidity and total number of books. Particulate matter concentrations were measured at library by using Handheld 3016 IAQ Particle Counter. The data was collected for eight hour for each floor with five minutes time interval. Based on Kruskal Wallis test, there was significant differences of $PM_{2.5}$ and PM_{10} concentrations between floor levels ($p<0.05$). Number of occupants had significant associations with $PM_{2.5}$ concentration through Spearman Correlation test ($p<0.05$). Furthermore, there was also a significant association between temperature and relative humidity with PM_{10} and $PM_{2.5}$ concentrations. However, the correlation between particulate matter concentration with temperature and relative humidity were poor (r-PM_{10}=0.22, r-$PM_{2.5}$=-0.15; r-PM_{10}=-0.17, r-$PM_{2.5}$=0.2). Number of books and different floor surface area of library can be contributing factor too. In conclusion, regular cleaning and housekeeping activities in library need to be done to minimize IAQ problems and to provide a healthier indoor environment.

CHAPTER 1

INTRODUCTION

1.1Indoor Air Pollution

Air is the most important component or element that is necessary for human life. Thus, clean air is needed in order to prevent the health effect problems that may arise due to the unhealthy air in the environment. Due to the arising concern on the health effects because of the indoor air quality (IAQ) and tendency of people to spend more time in indoor than outdoor, several studies about indoor air quality were performed (Canha, 2010). IAQ means quality of air around and within the building or structures and that is concerned to the occupant's health and comforts (Environmental Protection Agency (EPA), 2015[a]). American Society of Heating, Refrigating, and Air Conditioning Engineers (ASHRAE) is defined acceptable IAQ as air in which there is no known contaminant at harmful concentration as determine by cognizant authorities and with which a substantial majority (80% or more) of people exposed do not express dissatisfaction (Malaysian Green Building Confederation, 2014).

One of the indoor air pollutants that may contribute to poor IAQ is particulate matter. Particulate matter is formed of mixture from tiny particles and droplets of liquid (EPA, 2015[b]). Particulate matter is varying from primary particles and also secondary particles. As for primary particle, it is directly release from the sources while for secondary sources, it is formed based on gases through the reactions of chemicals (Araujo and Nel, 2009). Particulate matter could be generated from several sources in which it could come from outdoor or indoor environment. The performed activities in the buildings also could be as the contributor factors for the formation of particulate

matter in indoor air (Fromme *et al.*, 2007). Particulate matter consists of inhalable coarse particles and fine particles (EPA, 2015[b]).

Particulate matter could poses health effects towards human. From various study, particulate matter may triggered to the respiratory systems and asthma problems (EPA, (2015[b]); World Health Organization (WHO), (2013)). Particulate matter also could trigger adverse health effects for instance premature deaths and mortality of infants and other parts of susceptible population (Eštoková *et al.*, 2010).

1.2 Problem Statement

Indoor air quality needs to be in a good condition due to 90% of people are always stayed inside the buildings instead of used time outdoors (Lee and Chang, 2000). According to Law *et al.* (2001), people all over the world give all their concern about IAQ problems (Kamaruzzaman and Razak, 2011). It happens due to potential health effects that might poses people especially towards the susceptible groups. The health and well being of people might be disturbed by indoor air in which humans are inhale about $10m^3$ for their daily life and 80-95% of them were spend their time inside the buildings (Dacarro *et al.*, 2003).

Poor IAQ is known to be associated with health problems for occupants in unhealthy building such as respiratory problems, eye irritation, bronchitis, sinusitis and pneumonia (Department Occupational Safety and Health (DOSH), 2010). These health problems might affect the performance of occupants in the buildings. The poor air quality in library could be classified according to their effects in several categories such as mild, allergic and look like, or feel like influenza (Robertson, 2015). The biodeterioration

could take place, and for long period of time, it could stimulate to the producing of microbial agents and propagules into the surrounding (Karbowska-Berent, 2011). Based on the study that conducted at National Library, Prague, it showed that fine particles on the book surface were deposited on an empty shelf (Smolík *et al.*, 2013).

The level of indoor air pollutants and indoor air quality inside the buildings are related to the prevalence of Sick Building Syndrome (SBS) symptoms (Fadilah and Juliana, 2012). Previous study that was conducted at Perpustakan Sultanah Zanariah,UTM and Perpustakaan Sultan Ismail in Johor found the association between IAQ and sick building syndrome (SBS) (Sulaiman and Mohamed, 2011).

This study was conducted in Perpustakaan Hamdan Tahir (PHT), focused on two different size of particulate matter since it was known as major indoor air pollutants. Therefore, to give a healthy and clean environment to the occupants in libraries, a study regarding indoor air quality particularly in particulate matter need to be carried out.

1.3 Research Objectives

General Objective

To assess the indoor air quality in library at USM Health Campus, Kota Bharu, Kelantan.

Specific Objectives

1. To determine the concentration of PM_{10} and $PM_{2.5}$ in library at USM Health Campus, Kota Bharu, Kelantan.
2. To compare the concentration of particulate matter (PM_{10} and $PM_{2.5}$) between floor level of library at USM Health Campus, Kelantan.
3. To obtain the factors that associates with concentration of particulate matter (PM_{10} and $PM_{2.5}$) at library in USM Health Campus, Kelantan.

1.4 Hypotheses

Alternative Hypothesis I: There is a significant difference concentration of PM_{10} and $PM_{2.5}$ between levels of floor in library a USM Health Campus in Kota Bharu, Kelantan.

Alternative Hypothesis II: There is significant factors associate with PM_{10} and $PM_{2.5}$ concentrations at USM library campus in Kota Bharu, Kelantan

1.5 Significant of Study

Poor IAQ by particulate matter is causing concerns to potential effects on human health. This study is important to provide better IAQ to the occupants. It can help occupants by given a notice if the IAQ was poor to avoid any health effects that were related to particulate matter. Besides that, the findings from this study will reveal status of IAQ indicated by $PM_{2.5}$ and PM_{10} concentrations in library at USM Health Campus. Thus, further action can be carried out to reduce the concentration of PM_{10} and $PM_{2.5}$ in library. This study was important to identify whether the concentration of particulate matter was exceeded the permissible exposure limit (PEL). It can help to provide clean air and safe working environment in library to the staff and occupants in library. Safe air in environment can prevent environmental health problems and provide comforts to the people.

CHAPTER 2

LITERATURE REVIEW

2.1Indoor Air Quality (IAQ)

The experiencing of poor IAQ issues among people is made the air quality that comprises of indoor and outdoor air become the major of environmental problems (Krupinska *et al.*, 2013). According to WHO (1986), the arising of complaints made by 30% of employees that work in new or renovated buildings were related to the working environment. The poor IAQ can lower the working efficiency at workplace and it can contribute to the diseases and work-related diseases (Reijula and Haahtela (1998), Lahtinen *et al.*, (2004)). The impact of IAQ towards occupants in indoor environment may be varying from short or long term effects (Chartered Institution of Building Services Engineers (CIBSE), 2011). The performance of occupants such as workers or staffs may be influenced by IAQ in the building (Leung, 2015).

Air quality in indoor environment has a close relationship with number of factors ranging from the properties of pollutants, the characteristics of a building and human behavior (Nazaroff, 2013). There are various types of air pollutants present in the indoor environments which are released in various sources. The quantities of air pollutants in building have an affinity with human activity and materials that are used in (Leung, 2015). The level of air pollutants were higher in indoors compared to outdoor due to the contribution which comes from internal sources and outdoor pollutants which comes in through the ventilation (Nazaroff, 2013).

Indoor air pollution may be vary from many forms range from smoke release from solid fuel combustion in developing countries to modern buildings present in form of complex mixtures of volatile and semi-volatile organic compounds (Zhang and Smith,

2003). They can be released by fabric and building or it also may be formed from activities that have been performed inside the place (Srivastava and Jain, 2007). The potential contaminants of air inside the building are also come from renovation and remodeling materials likes paints, carpets, flooring, insulation materials, office machines or cleaning products (Redlich *et al.*, 1997). Indoor air pollution also can be influenced by inadequate ventilation. Inadequate ventilation is contributed by poor design and construction of buildings with more number of offices cramped in a building (Joshi, 2008).

According to Hudgson (2002), indoor environment in a restricted space is a complex and dynamic combination of physical, biological, and chemical factors that affect the occupants' health and physical reactions anytime whether people realize it or not. Moreover, based on Cheong and Chong (2001), the only aspect to achieve high IAQ is by providing a comfortable and clean environment for the building occupants.

2.2 Library

Indoor air pollution can occur in variety of places including library. Library is a place of enclosed environment that having collections of books, films and recorded music for purpose to use or borrowed by students, public or the institution members (Oxford Dictionary, 2015). Library is also known as a place that collects, gather and store numerous types of books and documents all over the world in various centuries (Karbowska-Berent, *et al.*, (2011); Skóra *et al.*, (2015)). Books are rich with nutritional substances and can trigger to the presence of microorganisms (Karbowska-Berent *et al.*, 2011). The dust from books can give effects towards human health and for instance it can cause an allergies and irritation to nose and throat.

Normally, libraries contain number of bookshelves and providing seating area and service desks. The designs of work area in library are same as commercial offices. The designation of library is considering the movement of people inside and the materials providing in libraries (Brown, 2002). The general sources of poor air quality in library are caused by mechanical system. Poor maintenance of the mechanical system such as heating, ventilation and air-conditioning (HVAC) leads to the circulation of larger quantities of dust and other particles throughout the buildings (Robertson, 2015).

2.3 Particulate Matter (PM)

A combination of tiny solid particles and liquid droplets that are found in air are known as particulate matter (PM). Dust, dirt, soot or smokes are few of the examples of particles that can be seen through naked eye, while several particles need to be detected through by using an electron microscope (EPA, 2015[b]). The particulate matter in indoor environment are depend on ambient concentration, the rates of air exchange, deposition factors and activities that might triggered to the generation of particulate matter (Fromme *et al.*, 2007). The factors that contribute to the poor indoor air quality are particulate matter that have source from outdoor air, room dust, furniture and the equipment including surface material (Bluyssen, 2009).

The significance of particulate matter as a determinant of indoor air quality is strongly related to the airborne particle concentration, size distribution and chemical or biological composition. This attributes depend on several factors, broadly classified as sources, removal mechanisms and transformation process (Nazaroff, 2004). Particulate matter can act as medium of hazardous substances and chemicals into the human respiratory systems and may react to human health with their characteristic ability

(Gaidajis and Angelakoglou, 2014). Several studies shown that particulate matter can triggered to the adverse health effects among people (Roy and Singh, (2014); Schwarze *et al.*, (2006)).Based on particulate matter aerodynamic diameter, the particles can be classified into size fractions that were included coarse particles, fine particles and ultrafine particles in which all of these particles were come from many sources and mechanism (Araujo and Nel, 2009).

The particles consist of diameter less than 10 microns are known as PM_{10}. It was referred as coarse particles. PM_{10} was in aerodynamic diameter range from 2.5μm to 10μm (Health Canada, 2012) and generated by disruption of mechanical including crushing, grinding abrasion of surface, the sprays evaporation and dust suspension (Fierro, 2000). According to the size, coarse particles are able to penetrate in the trachea or in bronchi (United Nations Environment Programme (UNEP), 2009). People tend to get various respiratory illnesses due to excessive exposure to high concentration of PM_{10} (Roy and Singh, 2014).

The particles consist of diameter less than 2.5 microns is normally known as $PM_{2.5}$ and it is a respirable particle. $PM_{2.5}$ is acknowledge as fine particles with the aerodynamic less than 2.5μm differ from coarse particle are generated from gas and condensation of vapors in high temperature during the combustion (Fierro, 2000). $PM_{2.5}$ is easily able to penetrate into the alveoli of lung (UNEP, 2009). As known, PM can contribute to poor health status. The particles that may cause greatest threat to human health are fine particles because they will be able to penetrate deepest into lungs (Health Canada, 2012).

According to EPA (2016), there are acceptable levels for both sizes of particulate matter were given as standard. However, those standards are used as a guidelines for outdoor air (refer Table 2.1). Bernstein et al. (2008) proposed to use half of the value from the standard in order to perform the indoor air quality. Thus, the IAQ standard level for PM_{10} is stated at 75μg/m^3 and $PM_{2.5}$ at 17.5μg/m^3, respectively.

2.4 Health Effects

Several health problems due to poor indoor air quality might arise. For example pneumonia, stroke, ischemic heart disease, chronic obstructive pulmonary disease, and lung cancer (WHO, 2014). Moreover, irritation to eyes, nose and throat, headaches, dizziness and fatigue are the example of health effects that might come up due to exposure of pollutants in enclosed environment (Kapahi, 2011).

Table 2.1 National Ambient Air Quality Standards (NAAQS) for Outdoor Air by EPA

Pollutant		**Primary/ Secondary**	**Averaging Time**	**Level**	**Form**
Carbon Monoxide		primary	8-hour	9 ppm	Not to be exceeded more than once per year
			1-hour	35 ppm	
Lead		Primary and secondary	Rolling 3 month average	0.15 $\mu g/m^3$	Not to be exceeded
Nitrogen Dioxide		primary	1-hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Primary and secondary	Annual	53 ppb	Annual Mean
Ozone		Primary and secondary	8-hour	0.075 ppm	Annual fourh-highest daily maximum 8-hr concentration, averaged over 3 years
Particle Pollution	**$PM_{2.5}$**	primary	Annual	12 $\mu g/m^3$	Annual mean, averaged over 3 years
		secondary	Annual	15 $\mu g/m^3$	Annual mean, averaged over 3 years
		Primary and secondary	**24-hour**	**35 $\mu g/m^3$**	98th percentile, averaged over 3 years
	PM_{10}	**Primary and secondary**	**24-hour**	**150 $\mu g/m^3$**	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide		primary	1-hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3-hour	0.5 ppm	Not to be exceeded more than once per year

(Source: EPA, 2016)

There are several factors that can influence people perceptions towards health status. Health effects vary from genders and largely depend on genetic constitution, lifestyle, environmental status and the morale of and individual (Weetman and Munby, 1994). Based on Table 2.2, Weetman and Munby (1994) have suggested a new classification of the adverse effect on health of indoor air pollution that can be divided into several categories.

Table 2.2: Adverse health effects of indoor air pollution

Category	Health effects
1	Comforts reactions
2A	Acute biological effects
2B	Acute chemical effects
3	Chronic grave hazards

(Source: Weetman and Munby, 1994)

Category 1 includes comfort responses such as Sick Building Syndrome (SBS), in which irritant symptoms that arise among occupants in enclosed environment. The cause of these symptoms remains unknown, and may have association with psychological factors, inadequate ventilations and level of hygiene in a building (Weetman and Munby, 1994).

Category 2A is classified for acute effects that caused by biological derived materials. This includes serious cases such as Legionnaires's disease, asthma and other allergic conditions. All health effects may arise due to inhalations or in contacts with allergens and other pathogenic organisms that caused sensitization to people and thus cause inflammations to their respiratory tracts (Weetman and Munby, 1994).

Meanwhile category 2B is for acute intoxication that resulting from interactions with chemicals. These include chemicals or intoxicants that exist in the air such as carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compound (VOCs) and ozone (O_3). The effect of all these chemical to human health rely on the concentrations inhaled by human and different intoxicants differs in their nature and effects on human (Weetman and Munby, 1994).

Category 3 perceive chronic grave risks, for example cancer causation. These include exposures to radon, VOCs, formaldehyde, particles and fibres, and also environmental tobacco smoke (ETS). All of these toxicants reported in many cases related with lung cancer. Radon has been related with high incidence of lung cancer among uranium miners (Samet, 1989).

2.4.1 Health Effects of Exposure to Particulate Matter

The exposures to particulate matter lead to the health consequences towards humans. Particulate matters, parts of air pollution have the significant relationship with human disease. Particulate matter is triggered to the cardiovascular and cerebrovascular disease through the mechanism of systemic inflammation, direct and indirect coagulation activation and direct translocation to the circulation of systemic. The long term exposure of to the PM can cause strong cardiovascular incident and increased the mortality rate (Anderson *et al.*, 2012). Particles have significantly association with their sizes that lead to the health problems. The size of particles is directly associated to their potential for triggering health problems. Particles sizes that are less than 10 micrometers in diameter tend to pose the greatest problems because they can penetrate deep into lungs and even get into bloodstream (EPA, 2016).

Particulate matter can trigger respiratory morbidity, insufficiency in lung functions including slow down lung function and lung cancer. Chronically particulate matter can causes emphysema among urban population (UNEP, 2009). The short term exposure to coarse particles triggered the respiratory health problems towards people while long term exposure to the fine particles triggered mortality consequences. It is due to the strong risk factor when people exposed to fine particles compared to coarse particles (WHO, 2013).

Fine particles which are small in size are likely to triggered health problems among people. The particles can pass through deep part of the lung and it may cause respiratory problems, worsen the asthma symptoms, decreased the growth of lung in children, lung cancer and cause of early births. Susceptible people are likely to get an impact due to the contact with fine particles, (Centers for Disease Control (CDC), 2013[a]). The exposure to the fine particles for a long period of time triggered people to get heart or lung problems higher than people who did not faced the poor air quality (CDC, 2013[b]).

In the early 2000s, more research attention has focused on determining which components of respirable particulate matter ($PM_{2.5}$) are more strongly related with adverse health impacts. Majority of the studies examined herein yielded significant findings for specific components of particulate matter, but not for particulate matter mass concentration, showing that particulate matter alone does not trigger health responses (Annete and Ronald, 2012).

Health consequences differ with the size, mass concentration and other contaminants acting in concern with particles. EPA found that respirable particles at concentrations of 250 to 350 µg/m3 increase respiratory symptoms in compromised individuals. Due to their adsorption properties, particles bring semivolatile chemicals such as pesticides,

dioxins and PCB into humans as they inhale or ingest them. Health consequences normally related with these chemicals, including cancer, can be assigned to respirable particles as well (Burroughs and Hansen, 2011).

2.4.2 Sick Building Syndrome (SBS)

Poor air quality inside the building has relationship with several respiratory healths such as Sick Building Syndrome (SBS) and building related illnesses (BRI) (Crook and Burton, 2010). Illnesses occurring among occupants that are resulted from poor indoor air quality in the building were called as SBS.

These symptoms are most common cases reported in all populations regardless of building occupancy. In order to decide for a building to be claimed as sick, about 20% of the occupants should be complaints for having those symptoms, and as they leave the building those symptoms should be relieved in shot time (Molina *et al.,* 1989).

SBS can be described as a situation when occupants in buildings experience acute health or comfort effects that are appear during spending time in certain buildings and the identification of specific illness or cause are unknown. The complaints of these effects may be occurring in certain room, zone or throughout the building (DOSH, 2010). It seems to be linked with the time spent in the building (Joshi, 2008).

Symptoms that are experienced by occupants normally vanish within hours or right after they were away from the enclosed place (Passarelli, 2009). Sick building complaints associated with symptoms of mucous membrane irritation such as burning eyes, nose, throat, and sinuses. Itching and rashes may be occur (Seltzer, 1994). The symptoms are

more common in air-conditioned buildings than in naturally ventilated buildings (Joshi, 2008).

The indicators of SBS including complaints of symptoms associated with acute discomfort from building occupants such as headache, eye, nose or throat irritation, dry cough, itchy skin, dizziness and nausea, fatigue and difficulty in concentrating. Most of the symptoms are relief soon after leaving the building (EPA, 1991). SBS can slow down the productivity of work when the rates of absenteeism among workers are increasing (Joshi, 2008). SBS happen when the condition indoor is poor and no active maintenance arrangements in building as well as have inappropriate furnishings and building fabric (Passarelli, 2009).

Factors that can contribute to the SBS include problems with temperature, humidity control, lighting, sound or vibration, overcrowding, stress, and task dissatisfaction. SBS may arisen due to the air quality factors such as inadequate ventilation, poor building maintenance, increased dust, volatile organic compounds, bioaerosols, endotoxin and fungal contamination (Bernstein *et al.,* 2008). According to United States National Institute of Occupational Safety and Health (NIOSH) (2012), the main areas that concern for SBS isa including inadequate ventilation, significant inside pollution, microbial contamination and building materials and furnishings.

Inadequate outdoor air ventilation rates found to be insufficient to maintain health and comfort of the building occupants. The failure Heating, Ventilation and Air Conditioning (HVAC) systems to operate lead to the reduction of ventilation and ineffectively distribute the air to people in the building and becomes the important factor to SBS (EPA, 1991).

2.4.3 Building Related Illness (BRI)

Building related illness (BRI) is linked to the environment of modern air tight or energy buildings. These buildings are characterized by sealed windows and depend on heating, ventilation and air conditioning systems for air circulation. Most of the cases happen in nonindustrial office buildings, but illnesses can happen in apartment buildings, schools, museum and libraries (Newman, 2016).

BRI is referring as well characterized human illness caused by indoor environmental factors. It can be related to the clinical and laboratory findings in those building occupants with health complaints according to principles of pathophysiology (Seltzer, 1994). Exposure to substances within airtight buildings that have poor ventilation can cause BRI.

The symptoms of BRI may include fever, difficulty breathing, runny nose or congestion, skin problems and difficulty concentrating (Newman, 2016). Legionnaire's disease humidifier fever, pneumonia and occupational asthma are also known to occur. Legionnaire's disease is occurring due to contamination of cooling towers by legionella organisms. Legionnaire's disease occurs predominantly in the middle aged and elderly adults (Joshi, 2008). All those symptoms are come with identifiable causes and can be clinically defined. The symptoms also may recover after several days leaving the building. For instance, the bacterial contamination of an air-conditioning system that causes humidifier fever or Legionnaire's disease, and a high dust levels that can cause allergic reaction to the building occupants (Kaiser, 2002). By breathing in water droplets from humidifiers heavily contaminated with microorganisms causing respiratory infections, asthma and extrinsic allergic alveolitis can lead to humidifier fever. The patient may have flu-like symptoms (Joshi, 2008). Although these problems

might not be serious, the productivity and performance of occupants may be affected if no actions are taken to solve the problems.

2.5 Relative Humidity and Temperature

Relative humidity and temperature is important because some of the complaints regarding poor indoor air quality underlie the thermal comfort (Occupational Safety and Health Administration (OSHA), 2011). Thermal comfort can be influenced by heat, convection of heat, radiation and absorption of heat loss and the retained that were generated by body metabolism. The heat will cause discomfort if any gain or loses outside of this range (Puteh *et al.*, 2012).

The specific acceptable range for temperature and relative humidity was stated in Industry Code of Practice 2010 can be referred in Table 2.3

Table 2.3: Acceptable range for specific physical parameters

Parameter	Acceptable Range
(a) Air Temperature	23-26°C
(b) Relative Humidity	40-70%
(c) Air Movement	0.15-0.50 m/s

(Source: DOSH, 2010

2.6 Heating, Ventilation, and Air Conditioning System (HVAC)

HVAC systems are highly prevalent in new or renovated professional settings. Their advantages are including energy efficiency and advertised as develop high productivity through improvement of workers' comfort in hot weather. HVAC system also may help to avoid heat-related illness in weakened subjects (Preziosi *et al.*, 2004).

The HVAC distribution system is the air pathway within the building (Burroughs and Hansen, 2011). The HVAC system includes all heating, cooling and ventilation equipment serving building including furnaces or boilers, chillers, cooling towers, air handling units, exhaust fans, ductwork, filters and steam piping. A properly designed and functioning HVAC system provides thermal comfort, distributes adequate amounts of outdoor air to meet ventilation needs of all building occupants, isolates and removes odours and contaminants through pressure control, filtration and exhaust fans (Mathews *et al.*, 2002).

Active humidity system is formed by an ultrasonic vapouriser. The vapour is controlled for a control system that has a humidity sensor. This can causes a control of closed mesh. Thus, the relative humidity of air is measured and compared with a value of reference. This difference is used as way of control. Meanwhile, active humidity control devices can create concervator-approved microenvironments in display, storage, or other sealed enclosures (ASHRAE, 2007).

CHAPTER 3

METHODOLOGY

Figure 3.1 shows the overall methodology that was conducted in this study. This study was started from August 2015 until May 2016

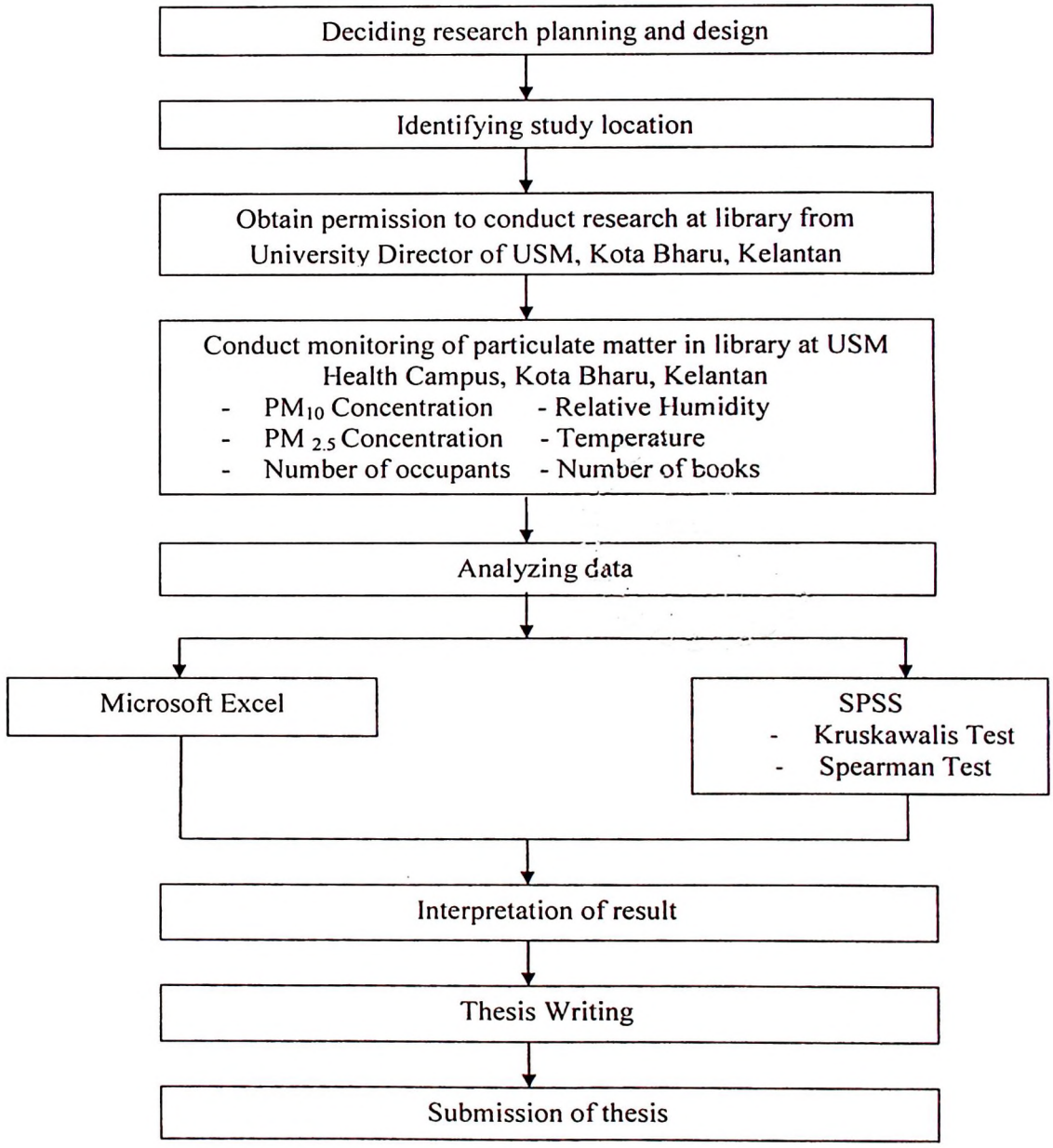

Figure 3.1: Flow chart of the study

3.1 Study Design

The study design for this research was cross sectional study. Cross sectional study was an observational study that was carried out at one time or within the short period of time (Mann, 2003). The cross sectional study also determines the relationship between the factor and the outcome (Levin, 2006). It was used to identify the relationship between the contributing factors (number of occupants, relative humidity and temperature, and number of books) and the concentration of particulate matters (PM_{10} and $PM_{2.5}$) in the library.

3.2 Study Location

This study was conducted at Perpustakaan Hamdan Tahir (PHT) that was located at Universiti Sains Malaysia (USM), Health Campus in Kota Bharu, Kelantan. PHT was selected since it was the only one of the university libraries in Kelantan that opened during the semester break. This study was covered each level of floor in PHT in which this library was consist three floor level. Those were ground floor, first floor and second floor. The function for each floor was differed with each other. As for ground floor, it was function as media service department and more towards relaxing area that consist of games and rest area. As for first floor, it was setup as main area for this library. It consists counter for students to borrow books, computer room, and reading area. Meanwhile, on second floor it was consist of multipurpose rooms, and reading area.

3.3 Sampling Points

The minimum numbers of sampling points to carry out an assessment on IAQ were based on Table 3.1.

Table 3.1: Minimum number of sampling point recommended for indoor air quality samplings

Total floor area (served by MVAC system)(m^2)	Minimum number of sampling points
<3,000	1 per $500m^2$
3,000 - <5,000	8
5,000 - <10,000	12
10,000 - <15,000	15
15,000 - <20,000	18
20,000 - <30,000	21
≥30,000	1 per $1{,}200m^2$

(Source: DOSH, 2010)

As shown in Figure 3.1, the total floor area for each floor in PHT was less thana 3000m^2. The total area for ground floor was 900.48m^2. While for the first and second floors were 2161.16m^2 and 1891.01m^2, respectively. As followed by the requirement given by DOSH (2010), the minimum number of sampling points for each floor level in PHT was considered as one point.

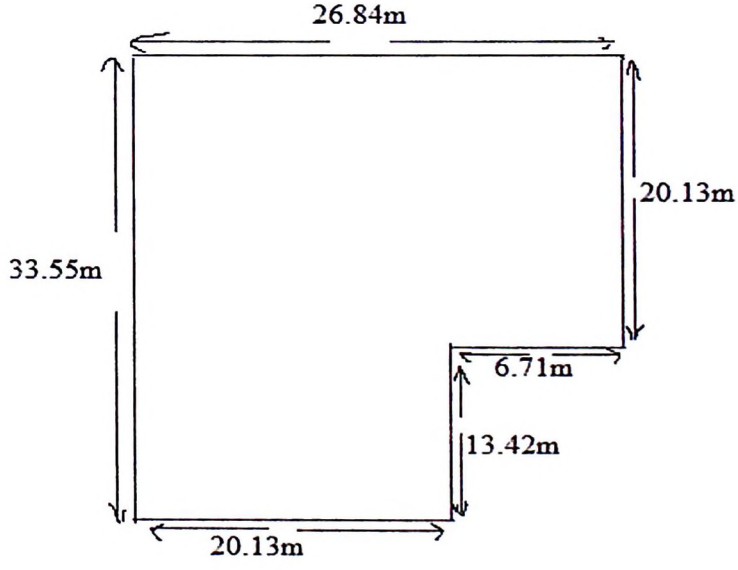

Figure 3.2(a) Floor area at ground floor

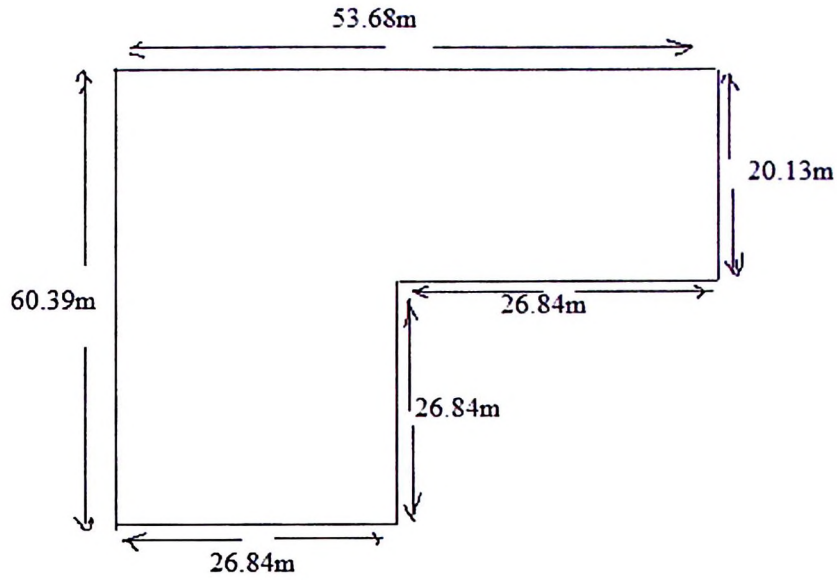

Figure 3.2(b): Floor area at first floor

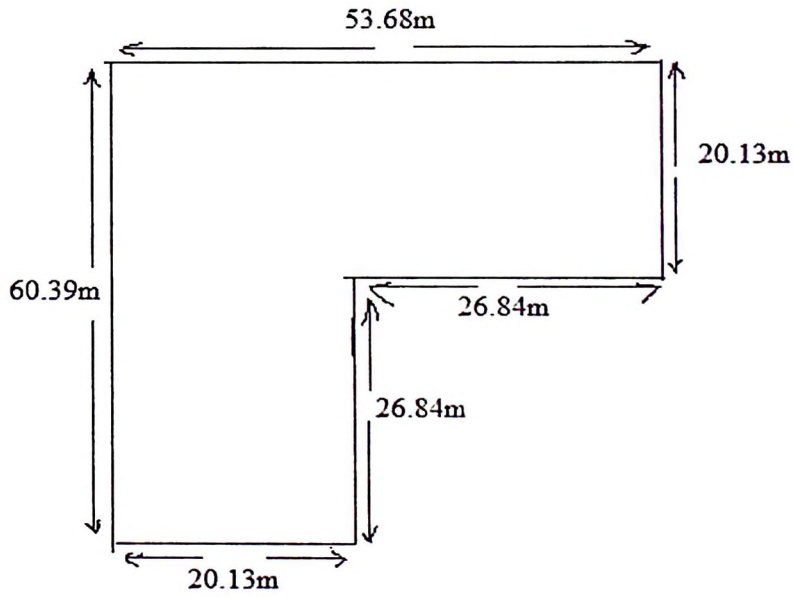

Figure 3.2(c): Floor area at second floor

3.4 Sampling Instruments

3.4.1 Lighthouse Handheld 3016 IAQ

Instrument that was used in this study was named as Handheld 3016 IAQ Particle Counter (Figure 3.2). It was used to measure the concentration of particulate matter (PM_{10} and $PM_{2.5}$) in the library. It also can displays temperature and relative humidity data.

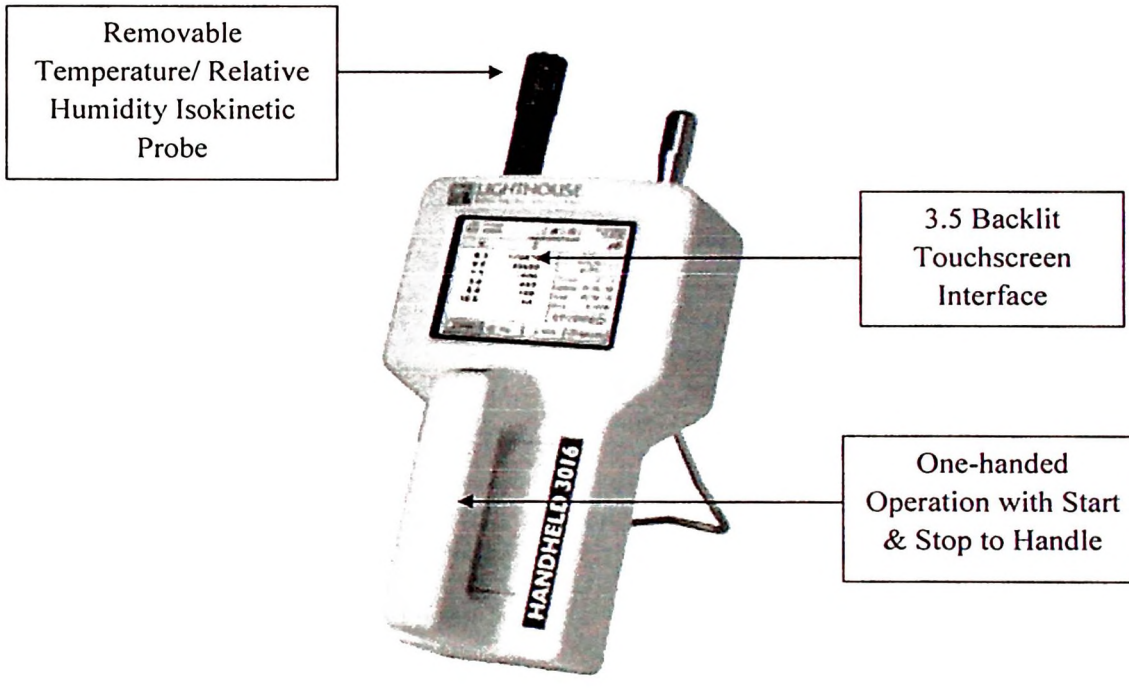

Figure 3.3: Lighthouse HANDHELD 3016 IAQ
(Source: Lighthouse Worldwide Solution, 2014)

3.4.2 Tripod

Tripod was used to place and support the Handheld 3016 IAQ Particle Counter. It was also used to provide static measurement for Lighthouse Handheld IAQ Particle counter in order to standardize the height of the Handheld IAQ Particle Counter. The standard high to place the instrument was at 110 cm height from the floor.

3.4.3 Checklist

Checklist was used for inspection of libraries and to provide the information about the other contributing factor that might relate with poor indoor air quality in libraries. The modification checklist was obtained from Industrial Code of Practice on Indoor Air Quality 2010. In this checklist, there were several factors that contributed to the concentration of PM_{10} and $PM_{2.5}$ such as the number of occupants, relative humidity, temperature, areas, and the presence of furniture. Details for checklist can be referred in Appendix D.

3.4.4 Measuring Tape

The measuring tape was used to measure the length and width of libraries. From the measurement, the area to place Lighthouse Handheld IAQ Particle Counter was determined.