PARTICULATE MATTER CONCENTRATIONS AT SELECTED MOSQUES IN KUBANG KERIAN, KELANTAN

By

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LIST OF ABBREVIATIONS AND SYMBOLS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BRI	Building Related Illness
CO_2	Carbon Dioxide
DOSH	Department of Safety and Health
d_p	Diameter of Particulate
EPA	Environmental Protection Agency
IAQ	Indoor Air Quality
ICOP	Industrial Code of Practice
HVAC	Heating, Ventilation and Air-Conditioning
km	Kilometres
m^2	Metre Square
MAIK	Majlis Agama Islam dan Adat Istiadat Negeri Kelantan
mg/m^3	milligram per metre cube
PM	Particulate Matter
ppm	Parts per million
SBS	Sick Building Syndrome
SO_2	Sulphur dioxide
SPSS	Statistical Package for the Social Sciences
USEPA	United State of Environmental Protection Agency
VAC	Ventilation and Air-Conditioning
VOC	Volatile Organic Compound
WHO	World Health Organisation
$\mu g/m^3$	Microgram per metre cubic
%	Percentage
>	More Than
<	Less Than

KEPEKATAN ZARAH TERAMPAI DI DALAM MASJID TERPILIH DI KUBANG KERIAN, KELANTAN

ABSTRAK

Masjid merupakan tempat awam bagi yang beragama Islam untuk beribadah, menunaikan solat 5 waktu berjemaah, mendengar ceramah dan aktiviti lain. Pendedahan kepada bahan pencemar udara dalam bangunan boleh berlaku di dalam persekitaran dalaman masjid. Tujuan kajian ini dijalankan adalah untuk menyiasat tahap kualiti udara dalaman (IAQ) [kepekatanzarah terampai ($PM_{2.5}$ dan PM_{10}) di dalam masjid terpilih di Kubang Kerian. Perbandingan kepekatan $PM_{2.5}$ dan PM_{10} antara masjid telah ditentukan. Kajian ini juga dijalankan bagi mencari perkaitan antara kepekatan $PM_{2.5}$ dan PM_{10} dengan bilangan penghuni; suhu; dan kelembapan relatif. Perbezaan kepekatan $PM_{2.5}$ dan PM_{10} antara waktu sembahyang; dan antara sembahyang Jumaat dan sembahyang Zuhur turut dilakukan. Kepekatan $PM_{2.5}$ dan PM_{10} ini diukur di sepuluh masjid yang terpilih di Kubang Kerian menggunakan 'Handheld 3016 Particulate Counter'. Alat ini diletakkan di tengah masjid selama 30 minit pada setiap lima waktu sembahyang melalui tiga sesi penyampelan. Senarai semak IAQ juga digunakan untuk menyokong dan mengukuhkan keputusan yang diperoleh daripada kajian ini. Bacaan tertinggi diperoleh di M4 (56.41 ± 10.09) $\mu g/m^3$ bagi $PM_{2.5}$ dan di M2 (141.88 ± 19.70) $\mu g/m^3$ bagi PM_{10}. Keputusan menunjukkan 98% daripada data yang diperoleh melebihi had IAQ yang disyorkan bagi $PM_{2.5}$ (17.5 $\mu g/m^3$) dan 90% bagi PM_{10} (75 $\mu g/m^3$). Berdasarkan ujian Kruskal Wallis, terdapat perbezaan yang signifikan bagi kepekatan $PM_{2.5}$ ($p=0.001$) dan PM_{10} ($p=0.006$) antara masjid. Dengan menggunakan ujian Kolerasi Spearman, bilangan penghuni mempunyai perkaitan yang signifikan dengan $PM_{2.5}$ dan PM_{10} ($p=0.046, p=0.047$). Selain itu, terdapat korelasi antara suhu dengan PM_{10} ($p=0.002$) dan kelembapan dengan $PM_{2.5}$ ($p=0.035$). Walaubagaimanapun, korelasi antara kepekatan zarahan terampai dengan parameter tersebut amat lemah ($r\text{-}PM_{10}=0.247$; $r\text{-}PM_{2.5}=-0.172$). Bilangan penghuni yang berbeza dan pergerakan mereka semasa setiap waktu sembahyang menyumbang kepada peningkatan tahap zarahan terampai di masjid yang berlainan. Saiz masjid yang berbeza turut menjadi faktor penyumbang. Kesimpulannya, penyelenggaraan bagi sistem pengudaraan dan pembersihan permaidani perlu dilakukan secara berkala untuk mengurangkan masalah IAQ dan menyediakan persekitaran dalaman yang lebih sihat.

PARTICULATE MATTER CONCENTRATIONS AT SELECTED MOSQUES IN KUBANG KERIAN, KELANTAN

ABSTRACT

Mosque is a public place where Muslim and worship, pray five times a day in congregation, and attend Islamic talk and other activities. Indoor exposure to air pollutants may occur in the mosque indoor environment. The purpose of the study is to investigate the level of indoor air quality (IAQ) [particulate matter ($PM_{2.5}$ and PM_{10}) concentrations] at selected mosques in Kubang Kerian. The comparison of $PM_{2.5}$ and PM_{10} concentrations between selected mosques was determined. This study was also conducted to find the relationship between $PM_{2.5}$ and PM_{10} concentrations with number of occupants; temperature, and humidity. The difference of $PM_{2.5}$ and PM_{10} concentrations between prayer times; and between Friday and Dhuhr prayers were carried out. $PM_{2.5}$ and PM_{10} concentrations were measured at 10 selected mosques in Kubang Kerian using Handheld 3016 Particulate Counter. The equipment was located at the center of every mosque for 30 minutes each of the five praying times per day throughout three sampling sessions. An IAQ checklist was also used to support and strengthen results obtained from this study. The highest readings were recorded in M4 (56.41±10.09) $\mu g/m^3$ for $PM_{2.5}$ and M2 (141.88±19.70) $\mu g/m^3$ for PM_{10}. Results showed that about 98% of data collected were exceeded the recommended IAQ limit for $PM_{2.5}$ (17.5 $\mu g/m^3$) and 90% for PM_{10} (75 $\mu g/m^3$). Based on Kruskal Wallis test, there was significant differences of $PM_{2.5}$ ($p=0.001$) and PM_{10} ($P=0.006$) concentrations between mosques. Number of occupants had significant association with $PM_{2.5}$ and PM_{10} concentrations through Spearman Correlation test ($p=0.046$, $p=0.047$). Other than that, there was also a significant association between temperature and PM_{10}; and humidity and $PM_{2.5}$. However, the correlation between PM concentration and these parameters were very weak ($r\text{-}PM_{10}=0.247$; $r\text{-}PM_{2.5}=-0.172$). Different number of occupant and their movement during each prayer times contribute to the increase of PM level at different mosques. Different size of mosques can be the contributing factor too. In conclusion, regular maintenance of the ventilation system and cleaning of carpets need to be done to minimise IAQ problems and to provide a healthier indoor environment.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Indoor air quality (IAQ) has become the ongoing hot topic since 2001 until present. Since the higher energy cost in 1970s, new construction and building modifications increasing reliance on mechanical ventilation. By reducing the intake of outside air, pollutants that were already there have been concentrated and their effects on human have become more obvious. At the same time, construction materials and furnishing, such as carpeting and work stations have brought more contaminants into homes, workplaces (Burroughs & Hansen, 2011) and public buildings such as mosques. Poor IAQ can make people seriously ill. But more often, it is a nuisance factor can lead to loss of work days, reduced productivity, unhappy tenants, broken leases, vacant properties and strained management-owner relations (Bas, 2004).

IAQ can be defined as the air in which there are no known contaminants at harmful concentrations with a substantial majority (≥80%) of the people exposed do not express dissatisfaction as determined by cognizant authorities (ASHRAE Standard, 2007). It also the physical and chemical nature of indoor air, as delivered to the breathing zone of building occupants, which produces a complete state of mental, physical and social well-being of the occupants, and not merely the absence of disease or infirmity (World Health Organisation (WHO), 2014).

People nowadays spend approximately 90% of their time indoors and potential health effects experienced by building occupants are included irritation and allergic reaction (Ellen and Gunderson, 2006). It is easy to understand why there is a growing concern about the quality of the air that human breathes. Contaminants of indoor can be emitted from many sources, such as occupants, building materials and furnishings, appliances, biological organisms, and personal activities (e.g., from pet dander, cooking, and tobacco smoke). The types of household products used and general housekeeping practices employed can greatly influence the levels of indoor air contamination. Soil gases can also be a source of contaminants in buildings (American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), 2013).

Although the main source of particulate matter was thought to be the outdoor air, there were a lot of secondary indoor sources that involved human activities such as walking, sitting, dusting, vacuuming that result in the resuspension of dust (Fromme et al., 2008).

One of the indoor buildings is mosque. Mosques represent a place of great importance and unique function. The activities of worshipers in the mosque need comfortable and calm feeling as they will be able to leave with a feeling of tranquility and peace. Mosques also represent one type of building that is characterised by their unique intermittent operating schedule determined by prayer times, which vary continuously according to the local solar time (Mohammad, Adel & Ismail, 2009). According to Yilmaz et al. (2012), mosques often become fully occupied raising the occupant density to more than 1.5 persons/m^2 during worship hours.

Carpets are a sink for particulate matter. Small rugs called prayer mats are often used to make sure that the mosque floor is clean for pray. In the mosque, most prayer rugs are tacked down to the floor. This helps Muslims form a straight line during large gathering for prayer (Aisha et al., 2008). However, shoeless entrance would reduce transport of particles from outdoors to indoors. Carpet vacuuming is performed regularly, usually two to four times per month, which should minimise the amount of particles available for resuspension. Nevertheless, particulate matter exposure during prayers may be a health concern for sensitive population subgroups such as people with respiratory diseases and elderly (Yilmaz et al., 2012).

Woods, Kraftherfer & Jansen (1986) mentioned that poor indoor air quality might cause indoor air pollution which is an indication of acceptable limits of air pollutants, how air satisfies the thermal comfort, and standard concentration of gases for respiration. Yet, it has been found that a range of subjective symptoms, which are recognised as the 'sick building syndrome' (SBS) by WHO (2014). SBS occurs in a high proportion which is around 20% or more of occupants of specific buildings. $PM_{2.5}$ and PM_{10} is inhalable course particles. These particles include rural windblown dusts, agricultural dusts, and mining dust. Inhalable course particles can travel longer distances, especially in extreme cases, such as storm (John and James, 2008).

Carpet is one of the IAQ problems in a building. The relationship between carpet, indoor air quality and health has received considerable attention among people. Many people are exposed to carpet on their daily routine. In fact, more than 1 billion yd^2 of carpet to be used as floor covering are sold each year in the United States. This would concern to people if exposure to carpet can causes adverse health effects. Modern carpet is usually made from synthetic fibers. Most of the carpets are used in residential, commercial, or public building including mosque. It is common to thought that carpet is a contributor to dust problems. Either new or existing carpet however does not create dirt and dust (Mendell, 2007).

1.2 Problem Statement

PM_{10} and $PM_{2.5}$ are categorised as inhalable particles that are small enough and able to penetrate the thoracic region of the respiratory system. The health effects of inhalable PM are due to exposure over both the short term (hours, days) and long term (months, years) and include: respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions; mortality from cardiovascular and respiratory diseases and from lung cancer (WHO, 2013).

Modern design of mosque and hot weather contributed mosque to be equipped with carpet and air conditioning system to prepare a conducive environment for the occupants. Both carpeting and air conditioning system if not well manage will contribute to poor IAQ, thus will affect the health of the occupants.

A survey has been done to identify the study location based on the characteristics of the mosques and sources of indoor air particles at each mosque. Based on the survey, all mosques using carpet on its floor and have air-conditioning system. When people come into the mosques, the carpets were emitted noticeable odour.

The carpet were vacuum-cleaned once or twice for a week and the heating, ventilation, and air-conditioning (HVAC) system did not get any maintenance since installed. Even some of the air-conditioners have been installed for two years. An air conditioners' filters, coils and fin required regular maintenance either once a month or once for every six months to function effectively throughout its years of service (DOSH, 2010). Furthermore, all components of the air-conditioning system did not get inspected for any leaks. Most of the mosques were located near the main road where all transports get in and out from the mosques and the doors were open-closed. The number of occupants also changed for every prayer times and sometimes in a big numbers when Friday prayer or any events being held.

From these various conditions, it shows that people who visit and pray in the mosques can also expose to PM due to the factors or source of the indoor air pollutants found in the surveyed mosques. Therefore, this study was conducted to investigate the indoor air quality status at the mosques in Kubang Kerian.

1.3 Research Objectives

1.3.1 General Objective

To investigate the concentration of particulate matter (PM_{10} and $PM_{2.5}$) as indicative of IAQ level at selected mosques in Kubang Kerian.

1.3.2 Specific Objectives

i. To determine PM concentrations at selected mosques in Kubang Kerian.
ii. To compare PM_{10} and $PM_{2.5}$ concentrations between the selected mosques in Kubang Kerian.
iii. To determine the relationship between the number of occupants with concentration of $PM_{2.5}$ and PM_{10}.
iv. To determine the correlation between temperature and humidity with concentration of $PM_{2.5}$ and PM_{10}.
v. To determine the difference of $PM_{2.5}$ and PM_{10} concentrations between prayer times.
vi. To determine difference of $PM_{2.5}$ and PM_{10} concentrations between Friday and Dhuhr prayers.

1.3 Alternative Hypothesis

HA_1 There is a significant difference of concentration of PM_{10} and $PM_{2.5}$ between selected mosques in Kubang Kerian.

HA_2 There is a significant relationship between the number of occupants with the concentration of $PM_{2.5}$ and PM_{10}.

HA_3 There is a significant relationship between temperature and humidity with concentration of $PM_{2.5}$ and PM_{10}.

HA_4 There is a significant difference of concentration of $PM_{2.5}$ and PM_{10} between prayer times.

HA_5 There is a significant difference of concentration of $PM_{2.5}$ and PM_{10} between Friday and Dhuhr prayers.

1.5 Significance of Study

People generate significant amounts of indoor pollutants, which may have an important impact on short-term exposures (Afshari et al., 2005). Risk of inhaling air pollutants depends on how much it is presence in the air and how long and how often a person enters the building. The degree of health effects are depending on period of exposure to the pollutants, either for short or long time. Numerous studies reported adverse health effects of all three sizes of PM (Loomis, 2000; Pope, 2000; Hauser et al., 2001; Pope and Dockery, 2006). PM may be responsible for producing or exacerbating pulmonary inflammation (Ghio et al., 2000) and asthma in children and elderly (Andersen et al., 2008). The indoor environmental management is to reduce exposure of people and materials to harmful substances. The findings from this study will reveal status of IAQ indicated by $PM_{2.5}$ and PM_{10} concentrations in the mosques at Kubang Kerian. Hence, further action can be implemented to reduce the concentration of PM to people who attending the mosque. For example, increase the frequency of cleaning the carpet and maintenance of the HVAC systems should be increased to provide a better indoor environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Indoor Air Quality (IAQ)

Most countries in the world have acknowledged indoor air as a significant health, environmental and economic problems. Researchers have found that pollutants in indoor air occur more regularly and at higher concentrations than in outdoor air. Therefore, it is clear that indoor air has created major sources for environmental exposure to air pollutants rather than outdoor (Afroz et al., 2003).

IAQ issues can be complex and should be properly assessed to identify problems and their solutions. Most often IAQ problems are the result of poor ventilation in a building. There are three primary factors that affect IAQ which are the nature of indoor pollutant sources, ventilation of the building and occupant behaviors (Hoek et al., 2013).

2.2 Particulate Matter

PM is one of the six criteria of pollutants. It is particle pollution in complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (United State of Environmental Protection Agency, (USEPA), 2013). These particles originated from a variety of sources, such as power plants, industrial processes, and diesel trucks, and they are formed in the atmosphere by transformation of gaseous emissions. PM is composed of both coarse and fine particles. Coarse particles (PM_{10}) have an aerodynamic diameter between 2.5 and 10 µm. They are formed by mechanical disruption such as crushing, grinding, abrasion of surfaces, evaporation of sprays and suspension of dust. PM_{10} is composed of aluminosilicate and other oxides of crustal elements and major sources including fugitive dust from roads, industry, agriculture, construction and demolition and fly ash from fossil fuel combustion. The lifetime of PM_{10} is from minutes to hours, and its travel distance varies from less than 1 to 10 km (Hudgson, 2002).

PM can be categorised into three sizes, ranging from ultrafine (d_p < 0.1 mm, UFP), fine (0.1 < d_p < 2.5 mm), and coarse (d_p > 2.5 mm) particles which d_p stands for diameter particulate (Hinds, 1999). However, due to their potential for human health effects the coarse PM size range is generally restricted to 2.5 < d_p < 10 mm. Previous studies reported adverse health effects, of all three sizes of PM (Loomis, 2000; Pope, 2000; Hauser et al., 2001; Pope and Dockery, 2006).

Fungi, bacteria, and dust mites do not grow on carpet constituents, and allergens do not proliferate in carpet. Dust mites, however, can be found in carpet. 60% of dust mites are found in mattresses, 20% in carpet, and 18% in soft furnishings. When the humidity is high (above 70%), dust mite are more often a problem. In United States, approximately 15% of people are allergic to dust mites. For these people, carpets may be a problem because of the presence of dust mites (Ferro, Kopperud & Hildemann, 2004).

In Malaysia, Department of Occupational Safety and Health (DOSH) have launched the Code of Practice on IAQ in July 2005 and being amended in 2010. However, the scope of this only applies to all non-industrial places of work in industries listed under Scheduled 1 of the Occupational Safety and Health Act 1994 (**refer Appendix A**) (Act 514). Furthermore, indoor air contaminants such as PM limit given are without specific sizes, in which the concentration limit provided is 150 μg/m^3 for 8 hour weighted average airbome concentration for particulate matter only. There is very little information available regarding the permissible exposure limit (PEL) of known indoor air pollutants, especially in Malaysia. However, many experts recommended indoor air pollutant levels to be maintained at 50% or less than the National Ambient Air Quality Standards (NAAQS) for outdoor air pollutants established by the Environmental Protection Agency (EPA) (**Table 2.1**). Thus, based on the standards given for $PM_{2.5}$, the outdoor air limit should be 35 μg/m^3 for 24 hours. The limit should be 50% of the value which is 17.5 μg/m^3. Similarly for PM_{10} outdoor limit should be 150 μg/m^3 for 24 hours and indoor air limit recommended should be 75 μg/m^3, which is also 50% of the outdoor air limit (Bernstein et al., 2008).

Table 2.1 NAAQS by EPA for Outdoor Air

Pollutant		Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide		primary	8-hour 1-hour	9 ppm 35 ppm	Not to be exceeded more than once per year
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 fourth-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

(EPA, 2013)

2.3 Mosque and its Potential Sources of Indoor Air Pollutant

The most frequently identified sources of odours in IAQ were carpet or fumiture and people (Huizenga et al., 2006). These major sources of IAQ can be found in almost all mosques.

Mosque is one type of building that symbolises Islamic architecture (Zaki, 1995). The word 'mosque' is derived from French language, which means 'mosque'e'. The origin of this word was from Spanish, mezquita'. In Arabic language, this word is known as 'masjid' coming from the word 'sajd' (Gazalba, 1975), which means 'sujud' (prostration) and 'sejadah' (prayer mat) (Nasir, 1984). The combination of these two words means an act of prostration by a person on a prayer mat. This act of prostration is necessary when Muslim is performing prayers. So the person has direct contact with prayer mat or carpet from which the occupant might inhale the particulate matter directly from it.

The elements and space function are very important in the mosque design. Their main reference is originated from the Prophet Mosque known today as Nabawi Mosque in Madinah. The space function and elements consists of the building orientation to qiblat direction, entrance gate, ablution area (*wuduk*), veranda area (*serambi*), prayer hall, niche area (*mihrab*), sermon podium (*mimbar*), main roof design, and minaret (Syed Ariffin & Syed Ahmad Iskandar, 2005).. After ablution, the water will contribute dampness and moist condition especially with carpet floor which is mold that cause unpleasant odour in the mosques

Clean and comfortable environment with a good IAQ at every mosque in Malaysia is very important to make sure the health condition of people who perform their prayer inside the mosque.

As reported by EPA (1997), indoor environments can have pollutant levels higher than outdoor. According to Hudgson (2002), indoor environment in a restricted space is a complex and dynamic combination of physical, biological, and chemical factors that can affect the occupants' health and physical reactions anytime whether people realise it or not. Furthermore, Cheong and Chong (2001) mentioned that the only aspect to achieve high IAQ is by providing a comfortable and clean indoor environment for the building occupants. Since the location of Malaysia is in the tropical climate region, the Malaysia's climate is hot and humid (Abdul Rahman, 1995). So, majority of buildings in Malaysia are using mechanical ventilation systems such as ventilation and air-conditioning (VAC) to maintain the building indoor air and environment. However, the mechanical ventilation system will only provide fresh air if it is in good condition and well-maintained. If not, they will convey unclean air to the indoor environment of the building and that will have a bad effect to the occupants as their health will probably be affected such as SBSand 'Building Related Illnesses' (BRI) to building occupants.

2.4 Health Effects of Exposure to Particulate Matters

In the early 2000s, much research attention has focused on determining which components of fine particulate matter ($PM_{2.5}$) are more strongly associated with adverse health impacts. It is noteworthy that the majority of the studies examined herein yielded significant findings for specific components of PM, but not for PM mass concentration, demonstrating that PM alone does not drive health responses (Annette & Ronald, 2012).

Other than that, relatively high PM air pollution levels have also found an association between infant mortality and PM air. Until recently, studies evaluating the relationship between air pollution and mortality in adults and infants have focused on PM <10 pm in aerodynamic diameter (PM_{10}). Since the late 1980s, this PM has been the focus of health studies because it is respirable pollution (Bobak and Leon, 1999).

Health consequences vary with the size, mass concentration and other contaminants acting in concern with the particles. EPA has found that respirable particles at concentrations of 250 to 350 $\mu g/m^3$ increase respiratory symptoms in compromised individuals. Because of their adsorption properties, particles carry semivolatile chemicals such as pesticides, dioxins and PCB into humans as they inhale or ingest them. Health effect normally associated with these chemicals, including cancer, can be attributed to respirable particles as well (Burroughs & Hansen 2011).

2.5 Temperature and Relative Humidity

Different individuals may desire different temperatures for their personal comfort and most people are comfortable when the air temperature is about 22°C. Temperature is one of the basic IAQ measurements that has a direct impact on perceived comfort, concentration and productivity. Comfortable relative humidity levels range from about 30 to 60%. When humidity is too low, people are tend to get eye, nose or throat irritation, dry skin or chapped lips. Then, the high relative humidity levels may cause condensation on surfaces, mold growth and unhealthy work conditions. People also will think it feels "sticky." But if too little humidity in a space may create static build-up and people will sense that their skin feels dry. However, indoor relative humidity levels should be maintained between 30% and 65% for optimum comfort (ASHRAE Standard 55, 2011).

In Malaysia, DOSH has provided guideline on indoor air temperatures and relative humidity. The acceptable range for these two parameters should be maintained (**Table 2.2**). These ranges should be acceptable for sedentary or slightly active persons (DOSH, 2010).

Table 2.2 Acceptable range for specific physical parameters

Parameter	Acceptable Range
Air Temperature (°C)	23-26
Relative Humidity (%)	40-70

(DOSH, 2010)

2.6 Heating, Ventilating and Air Conditioning (HVAC) System

The HVAC distribution system is the air pathway throughout the building (Burroughs, & Hansen, 2011). The HVAC system includes all heating, cooling and ventilation equipment serving a building: furnaces or boilers, chillers, cooling towers, air handling units, exhaust fans, ductwork, filters, and steam (or heating water) piping. Most of the HVAC discussion applies both to central HVAC systems and to individual components used as stand-alone units. 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. Therefore, the relative humidity of air is measured and compared with a value of reference and this difference, it is used as way of control. Meanwhile, active humidity control devices can create conservator-approved microenvironments in display, storage, or other sealed enclosures (ASHRAE, 2007).

CHAPTER 3

METHODOLOGY

3.1 Study Design

The study design used was a cross sectional study mainly to investigate the PM concentration in mosques and find the contributing factors. The most important advantage of cross sectional studies was quick and cheap. As there is no follow up, fewer resources are required to run the study. Cross sectional studies are the best way to determine prevalence and are useful at identifying associations that can then be more rigorously studied using a cohort study or randomised controlled study (Levin, 2014). The most important problem with this type of study is differentiating cause and effect from simple association (Mann, 2003).

3.2 Study Location

Kubang Kerian, Kelantan was chosen due to the highest number of mosques from the other zones which were 29 mosques compared to Kota Bharu (24), Pengkalan Chepa (22), Telipot (28), and Kampung Sireh (25) as shown in **Table 3.1**. Public buildings such as mosques were fall under responsibilities of Majlis Agama Islam Kelantan (MAIK) and they were categorised within zone.

Table 3.1 The total number of mosques according zone in Kota Bharu

Zone	Total Number of Mosque
Kota Bharu	24
Pengkalan Chepa	22
Telipot	28
Kubang Kerian	**29**
Kampung Sireh	25

(Majlis Agama Islam dan Adat Istiadat Melayu Kelantan, 2014)

3.2.1 Walk Through Survey

A walkthrough survey was carried out for each sampling location. The checklist of walk through survey had been taken from Industrial Code of Practice of Indoor Air Quality 2010 (ICOP DOSH) (**Appendix E**). The purposes of this walk through survey were to identify the characteristics of each mosque and identify the potential factors that may influence the $PM_{2.5}$ and PM_{10} concentrations. The information were obtained from the observation checklist and the mosque committee. **Table 3.2** shows the characteristics of each selected mosque. These ten mosques were selected due to the use of air conditioning and performing Friday prayer (**Appendix G**).

From 29 mosques in Kubang Kerian, ten mosques were selected as shown in **Table 3.2**. All mosques had air-conditioning system and open-closed door for occupants to enter and exit from the mosque. The air-conditioning system of all mosques did not get any maintenance since installation.

Table 3.2: Characteristics of selected mosques in Kubang Kerian

Mosque	Code	Characteristics
'Masjid Mukim Pulau'	M1	1. Coordinate : N 06^{O}06.423' E 102^{O}15.721' 2. Size area : 27.2m x 27.0m 3. Exhaust fan absent
'Masjid Mukim Kampung Huda'	M2	1. Coordinate : N 06^{O}06.101' E 102^{O}16.292' 2. Size area : 14.0m x 14.0m 3. Exhaust fan present
'Masjid Mukim Binjai'	M3	1. Coordinate : N 06^{O}04.649' E 102^{O}17.955' 2. Size area : 23.3m x 12.6m 3. Exhaust fan present
'Masjid Mukim Parit Lama'	M4	1. Coordinate : N 06^{O}03.432' E 102^{O}16.504' 2. Size area : 18 m x 22.5m 3. Exhaust fan absent
'Masjid Mukim Kedai Melor'	M5	1. Coordinate : N 05^{O}57.744' E 102^{O}17.761' 2. Size area : 27.4 m x 21.5m 3. Exhaust fan absent
'Masjid Mukim Peringat'	M6	1. Coordinate : N 06^{O}01.313' E 102^{O}17.163' 2. Size area : 10.2m x 19.4m 3. Exhaust fan absent
'Masjid Mukim Guntong'	M7	1. Coordinate : N 06^{O}02.218' E 102^{O}17.050' 2. Size area : 21.4m x 19m 3. Exhaust fan absent
'Masjid Mukim Chicha'	M8	1. Coordinate : N 06^{O}04.415' E 102^{O}16.599' 2. Size area : 20.3m x 26.3m 3. Exhaust fan absent
'Masjid Mukim Bechah Mulong'	M9	1. Coordinate : N 06^{O}00.426' E 102^{O}18.415' 2. Size area : 19.3m x 14.7m 3. Exhaust fan absent
'Masjid Mukim Bukit Marak'	M10	1. Coordinate : N 06^{O}06.101 E 102^{O}16.292' 2. Size area : 27.2 m x 27.0m 3. Exhaust fan absent

3.3 Research Tools

3.3.1 Lighthouse HANDHELD 3016 IAQ

The ergonomically designed and lightweight Lighthouse HANDHELD 3016 IAQ (**Figure 3.1**) counters feature 0.2, 0.3 and 0.5 µm sensitivities and are the most advanced handheld particle counters on the market. Providing up to 6 particle size channels of simultaneous counting, Lighthouse can displays cumulative and differential particle count data as well as temperature/relative humidity data on the fast and easy to read colour touch screen. Removable batteries and an optional charger help to maximise the uptime. Data is very easily downloaded using the Lighthouse Data Transfer Software. The Lighthouse HANDHELD 3016 IAQ can also be used as a mobile particle monitor or become a part of a large facility monitoring and management system (Lighthouse Worldwide Solution, 2014).

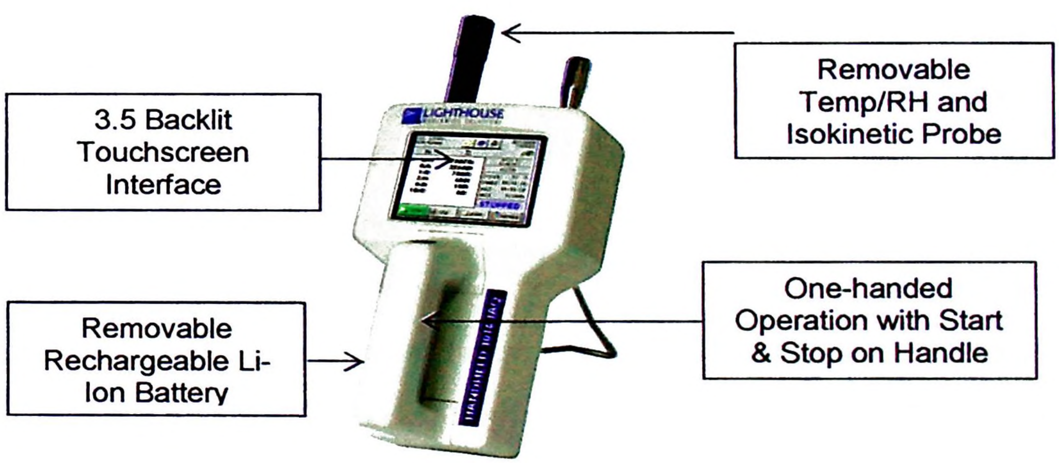

Figure 3.1 : Lighthouse HANDHELD 3016 IAQ

(Lighthouse Worldwide Solution, 2014)

3.3.2 Three legs tripod

Three legs tripod was used to place Lighthouse HANDHELD 3016 IAQ. The function of the tripod was to provide a stable mount for Lighthouse HANDHELD 3016 IAQ. Three-point support can always stand solid, stable, and non-wiggly on any surface, no matter how uneven the surface.

3.3.3 Measurement tape

The measurement tape was used to measure the length and width of the room. The total area of the room was calculated from the length and width of the room. Hence, the minimum numbers of sampling points were decided according to recommended minimum number of sampling points **(Table 3.3)** for IAQ parameters measurement (DOSH, 2010).

3.3.4 Checklist

Checklist was used to monitor the activity and surrounding environment when the sampling is ongoing. The checklist contained four sections. Firstly, 'general' part which include the present of odour, dirty or sanitary conditions, uneven temperature, etc. For 'human exposure and comfort level' part, the checklist was identified the number of occupants in the bulding and the temperature, relative humidity rates was checked regularly, etc. For the 'potential source of contaminants' include present of furniture, detergent, maintenance of HVAC system, carpet and others. The last part of checklist was 'ventilation and air-conditioning' which include the number of supply air present and the location of supply air located, etc. This checklist was taken from ICOP IAQ, (DOSH, 2010) (**Appendix** E).

3.4 Data Collection

Sampling method for this study was simple random sampling. It was a basic type of sampling, which is often used as a sampling technique itself or as a building block for more complex sampling method (Thompson, 2012).

Sampling point was determined in all selected mosques according to the Recommended Minimum Number of Sampling Points for IAQ Assessment (DOSH, 2010). The lighthouse equipment was set for 30 minutes for every prayer time. Readings were recorded for every one minute. So, with 5 times of measurement per day, there were total of 150 readings taken for a day. Every sampling point was repeated for three times alternately including weekends and weekdays. **Table 3.3** shows that the total floor area to be certified (m^2) in a building and the minimum number of sampling points required. The total floor area to be certified for all mosques was <3000 m^2. So, one sampling point was appointed.

Table 3.3 Recommended minimum number of sampling points for IAQ assessment

Total Floor Area to be certified (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

(DOSH, 2010)

During data collection, the Lighthouse HANDHELD 3016 IAQ was positioned in the middle of mosques which were sheltered from direct sunlight and moisture. It was located not within 2 m of doors and must not obstructive to, or interfering with, occupant egresses from the study area under normal or emergency situations. The sampling point was located at position that had minimal disturbance of work activities. The equipment used was also placed at a height 110 cm from the floor (**Appendix G**) (DOSH, 2010).

3.5 Statistical Analysis

3.5.1 Descriptive Statistics

For descriptive statistics, the simplest software Microsoft Office Excel Version 2007 had been used in this study. The mean concentration and standard deviation of particulate matter ($PM_{2.5}$ and PM_{10}) for every mosque were presented in bar graphs.

3.5.2 Inferential Statistics

The Statistical Package for Social Sciences (SPSS) Version 21.0 software was used to analyse the data.For this study, since the data was not normally distributed, so that non-parametric test was used. Spearman Correlation test was used to determine the relationship between the number of occupants and concentration of $PM_{2.5}$ and PM_{10}. Other than that, this test was also used to find the relationship between temperature and humidity towards concentration of $PM_{2.5}$ and PM_{10}. For difference of $PM_{2.5}$ and PM_{10} concentrations between Friday and Dhuhr prayers, the Mann Whitney test was used. Besides that, Kruskal Wallis test was used to identify the differences of $PM_{2.5}$ and PM_{10} concentrations between prayer times; and between mosques. Next, Post-hoc analysis using Mann Whitney test was used for individual test for every pairs to identify which pair was significant.

CHAPTER 4

RESULTS

4.1 Descriptive Statistics

4.1.1 Mean Concentration of Particulate Matter ($PM_{2.5}$ and PM_{10})

Graph of mean concentration of $PM_{2.5}$ and PM_{10} for all prayers in selected mosques are listed in Figure 4.1 until Figure 4.5. From the results, 98% of the data collected exceeded the recommended IAQ limit for $PM_{2.5}$ (17.5 $\mu g/m^3$) and 90% for PM_{10} (75 $\mu g/m^3$).

(a) The Mean Concentration of Particulate Matter ($PM_{2.5}$ and PM_{10}) for Fajr Prayer

For fajr prayer (**Figure 4.1**), M3 recorded the highest reading for $PM_{2.5}$ concentrations which was (50.0±8.57) $\mu g/m^3$ followed by M8 (49.61±9.21) $\mu g/m^3$). For PM_{10} concentration M2 was recorded the highest reading (139.96±12.70) $\mu g/m^3$ followed by M3 with reading (120.98±9.76) $\mu g/m^3$.

Meanwhile, M1 recorded the lowest readings for both PM concentrations which were (17.63±1.87) $\mu g/m^3$ for $PM_{2.5}$ and (55.10±24.61) $\mu g/m^3$ for PM_{10}. However, the data for PM_{10} concentrations recorded still did not exceed the recommended IAQ limit.

From the graph, all the readings for $PM_{2.5}$ concentration during fajr prayer exceeded the recommended IAQ limit and eight of the ten mosques exceeded the PM_{10} limit. The mean $PM_{2.5}$ concentration for fajr prayer for all mosques was 36.11 $\mu g/m^3$ and PM_{10} was 97.44 $\mu g/m^3$ which were exceeded the recommended IAQ limit.