THE ASSESSMENT OF CURRENT 'AS BUILT' CONDITION AND IMPROVEMENT OF FUTURE DESIGN OF MOSQUE'S WATER CLOSET

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by

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LIST OF ABBREVIATIONS

AB	Ablution Area
CI	Cleanliness Index
GF	General Facilities
GNB	Gram Negative Bacteria
HILM	High Intensity Light Measurement
IAQ	Indoor Air Quality
ICOP	Industry Code of Practice
JKR	Jabatan Kerja Raya
MS	Malaysian Standard
NIOSH	National Institute of Occupational Safety and Health
PC	Percentage Compliance
SBS	Sick Building Syndrome
SDA	Sabouraud Dextrose Agar
SHW	Shower
TSA	Trypcase Soy Agar
UBBL	Uniform Building By Law
WC	Water Closet
WCC	Water Closet Cubicle
WCD	Water Closet for Disabled
WHO	World Health Organization

PENILAIAN KEADAAN SEMASA 'TERBINA' DAN PENAMBAHBAIKAN REKA BENTUK BILIK AIR DI MASJID UNTUK MASA HADAPAN

ABSTRAK

Bilik air merupakan istilah lama bagi tandas. Ia seharusnya merangkumi semua kemudahan seperti tempat pembuangan air besar dan air kecil, kawasan mandian, dan kawasan mencuci, sinki membasuh tangan dan segala kemudahan yang berkaitan di dalam bilik air. Di Malaysia, tiada garis panduan yang khusus untuk reka bentuk kemudahan bilik air di masjid. Tambahan lagi, reka bentuk bilik air masjid sepatutnya menunjukkan kelestarian yang unggul berkaitan dengan konsep, keperluan, garis panduan, skala dan fungsi reka bentuknya. Ia seharusnya menyediakan ruang yang selesa untuk semua pengguna termasuk orang kurang upaya, warga tua dan juga kanak-kanak. Walau bagaimanapun, binaan kemudahan ini sering diabaikan. Oleh iu, kajian ini memberi tumpuan kepada bilik air di masjid dan matlamatnya adalah untuk menilai keadaan bilik air yang telah dibina dan dibandingkannya dengan piawaian, garis panduan dan undang-undang Malaysia. Peratus Pematuhan dan Indeks Kebersihan telah dihasilkan berdasarkan penilaian, manakala perbandingan kebersihan dan keadaan bilik air dengan pencemar mikrob telah dikenalpasti. Berdasarkan keapda dua (2) penunjuk iaitu Peratus Pematuhan dan Indeks Kebersihan di 31 masjid Qariah/Jamek terpilih dari tiga (3) negeri yang berlainan (Pulau Pinang, Melaka, dan Perlis) telah dinilaikan. MQS12 dilaporkan mempunyai Peratus Pematuhan tertinggi (64%) manakala tiga belas daripada tiga puluh satu masjid mencapai tahap (peratus pematuhan) yang boleh diterima untuk reka bentuk dan kemudahan bilik air. Sementara itu, MQS03 mencatatkan Indeks

Kebersihan tertinggi (CI), yang mencapai tahap kebersihan "Baik" (83%). Seterusnya, perbandingan Indeks Kebersihan dengan pencemar mikrob menunjukkan bahawa empat (4) masjid terpilih telah menunjukkan pencemar bakteria yang tinggi melepasi garis panduan ICOP yang dibenarkan mempunyai tahap kebersihan "Tidak Memuaskan" dan "Teruk". Hal ini mungkin disebabkan oleh reka bentuk kemudahan yang kurang sesuai, yang boleh membawa kepada indeks kebersihan yang buruk. Susun atur baru yang mengandungi tiga kriteria asas (kawasan wuduk, bilik air bertutup dan bilik air untuk orang kurang upaya) telah dibangunkan bagi membantu pengguna kurang upaya dengan meningkatkan kepuasan, keselamatan dan tuntutan pengguna Islam. Lebih kurang 50% masjid yang dipilih menunjukkan pematuhan minimum terhadap kemudahan dan reka bentuk. Walau bagaimanapun, tiada masjid yang berjaya mencapai tahap pematuhan yang maksimum, kerana bilik air yang dibina tidak mematuhi dengan piawaian, garis panduan dan undang-undang Malaysia. Kemudian, kebersihan bilik air bukanlah satu-satunya sumber yang boleh menjejaskan pertumbuhan mikrob di ruang utama solat. Namun, terdapat faktor lain yang mempengaruhi peningkatan pencemaran mikrob iaitu pemindahan melalui sentuhan secara lansung oleh tangan manusia dari bilik air ke ruang solat utama. Sebagai satu cadangan reka bentuk bilik air dan kemudahan baru, pengguna Islam termasuk warga tua, orang kurang upaya dan kanak-kanak perlu dijadikan sebagai sasaran untuk pembinaan bilik air pada masa akan datang agar dapat menyediakan keadaan bilik air yang lebih baik.

THE ASSESSMENT OF CURRENT 'AS BUILT' CONDITION AND IMPROVEMENT OF FUTURE DESIGN OF MOSQUE'S WATER CLOSET

ABSTRACT

The water closet is an old expression to the toilet. It should include all defecation, urinal, showering and washing facilities. It also refers to water closet cubicle, wash hand basin, shower and all related facilities in the water closet. In Malaysia, there no specific guidelines focusing in mosque water closet facilities and design. A mosque design including its water closet should demonstrate sustainable soundness in design concepts, design requirements, design guidelines, scale, and function. It should provide convenient spaces for all attendees, including the disabled, elderly and children. Ironically, the communal ancillary spaces such as a water closet was frequently ignored. Therefore, this study focuses on mosque water closet and aims at accessing the "as-built" water closet conditions and compared it against Malaysian standards, guidelines, and legislation. Percentage of Compliance and Cleanliness Index were develop based on multicriteria assessment, while the possible causal relationships between water closet cleanliness and condition of microbial contaminants were identified. Based on Percentage Compliance and Cleanliness Index of thirty (31) selected mosques at Pulau Pinang, Melaka, and Perlis, MQS12 reported the highest percentage of compliance (64%) while another thirteen out of thirty-one mosques achieve the acceptable compliance level for water closet design and facilities. Meanwhile, Cleanliness Index (CI), MQS03 recorded the highest, which scored "Good" cleanliness level (83%). Then, the causal relation between Cleanliness Index and microbial contaminants shows that four mosques which

recorded higher bacterial contaminants (exceeding the allowable limit of ICOP) has "Not Satisfied" and "Bad" cleanliness level. This may be due to improper design of facilities, which could lead to lower cleanliness index. The new layout which contains three basic facilities (ablution area, water closet cubicle and water closet for disabled) were developed to improve satisfaction level of disabled user with increasing safety and demands of Muslim users. Generally, 50% of mosques has provided minimum compliance on facilities and design, with none scored maximum. The 'as built' water closet did not fully comply with Malaysian standards, guidelines and legislation. Cleanliness of water closet could have an effect of microbial growth in the main prayer hall via direct contact of 'not very clean' human hand after visiting water closet to the carpet at the main prayer hall. Upgraded design and facilities for water closet being proposed as drawings and modification has shown some positive response from the users hence giving a good 'signal' that upcoming water closet should be designed and built with these new features to ensure better conditions in our mosques.

CHAPTER ONE

INTRODUCTION

1.1 Background

Mosque design should sustainably demonstrate soundness in design concepts, design requirements, design guidelines, scale and function (Abdul Rahim and Abdul Samad, 2014; Baharudin and Ismail, 2014). It should provide convenient spaces for all attendees, including the disabled, elderly and children. In addition to the main prayer hall, communal ancillary spaces, such as water closets that provide general facilities (e.g., wash-hand basin, ablution area, shower areas and water closet cubicles, including those for persons with disabilities), should be considered. Unlike shared water closets in urban, Tumwebaze and Mosler (2014) stated that the responsibility to clean water closets in mosques are often carried by a designated person, although collective participation was still practiced to ensure hygiene.

The Malaysian Standard (2006) MS 2015: Part 1, stated that water closet facilities should have six-(6) design considerations, which are safety, privacy, hygiene, equality, convenience and vandal resistance. Safety and security of a water closet can be defined as, water closet should be placed in a hidden and obscure location in order to provide safe and secure environment for the user from unexpected assault and harassment. Moreover, Afacan and Gurel (2015) explained that safety in the water closet could overcome feeling fear of falling and run over. Privacy of a water closet should have fully enclosed and lockable (MS2015:Part1:2006) facilities to ensure the user is able to carry out their task privately. Hygiene is defined as the

water closet facilities that are clean, appropriate and with sufficient ventilation provided. Equality required all normal adult, disabled, elderly and children could reach, visit, access and use the facility independently. Convenience and vandal resistance can be interpreted as the condition of water closet shall remain usable for the user while maintaining pleasant surroundings.

1.2 Problem Statement

In our daily life, the frequent use of water closets can lead to a healthy living. Even though, the water closet was perceived as dirty, smelly and unhygienic place in a building structure, it plays an important role in human daily activity. However, the water closets facilities currently provided 'as built' in mosques have many observable inadequacies. There are a numbers of available design guidelines for the mosque but still lacking in especially for supporting area such as ablution space and water closets (Besari et al., 2009). Furthermore, the current 'as built' condition of water closets tends to exhibited some disadvantages, such as the facilities were not compatible with disable users, children and senior citizens (Abdul Rahim, 2005). In addition, the improper built of water closets could lead to a lower level of cleanliness that bring unfavourable biological contaminants inside mosques praying area while walking or prostrating on their carpets.

Numerous studies focused only on water closet facilities for the disabled (Mamee and Sahachaisaeree, 2010; Dawal et al., 2016; Abdul Rahim, 2005; Ramli, 2017) without giving insight into the real condition 'as built' water closets. Dawal et al. (2016) investigated the performance of wudu' (ablution area) for the disabled,

especially those on wheelchairs, and suggested correct water tap positions within the reachability of the disabled. However, there are no ample attention was seen to be given on improving the facilities provided for elderly and children. Ramli (2017) listed the important physical features in a mosque water closet for disabled including ramps, water closet facilities for the disabled, and handrails. Mamee and Sahachaisaeree (2010) studied the effectiveness of appropriate design for water closet bowls and wash hand basin for disabled in public lavatories in Bangkok and found that the circulation (turning of wheelchair) areas and height of wash-hand basins are the important factors that determine the appropriate design of disabled public toilets.

Unfortunately, there is insufficient information reported for study that has been conducted on the comfort, safety and accessibility of different users for general facilities in water closets in mosques, namely wash-hand basins, shower areas and cubicles. Most designers' have neglected ancillary area in non-residential water closet as they prioritize the aesthetic aspect of building design (Aman et al., 2017). Generally, there are a few available guidelines which have been set by Malaysian standards, related acts and by-laws for water closet design.

Kadir and Jamaludin (2012) have conducted a study on the applicability of Malaysian standards and universal design to water closet facilities in public buildings. In addition, Abdul Rahim and Abdul Samad (2014) depicted that developed countries, such as Korea and Japan, have already achieved considerable progress in providing proper facilities, including the upgrading of water closets for the benefit of sanitation as well as toilet users. Afacan and Gurel (2015) explored the

demands, needs and expectations for water closets in Turkey and found that a sustainable design for public toilets were based on familiarity, legibility, distinctiveness, accessibility, comfort and safety. Therefore, this study seek to assess the current 'as built' condition against all relevant legislations and procedure and then propose improvement on future mosque's water closet design. Some of the proposed future design were implemented and the feedback from the users were gathered.

1.3 Objectives

The objectives of this research are as follow:

1. To evaluate the current condition of water closet in mosque in accordance to Malaysian Standard of Minimum Public Water closet Design (MS2015:2014) and Malaysian Standard of Universal Design and Accessibility in The Built Environment - Code of Practice (MS1184:2014).
2. To study the effects of water closet cleanliness based on water closets 'as built' condition on biological contaminants inside mosques.
3. To improve design of water closets in mosque for Muslim and disability requirements.

1.4 Scope of Research

This study will focus on public area mainly water closets at Qaryah Mosques in Malaysia. Mosque is classified as a foundation to Muslim user as it has high Muslim density for five times per day praying session (Discover Islam, 2018). Besides that,

mosque also classified as a Muslim community centre as religious instruction, political issue and educational discussion were indispensable appendage to the mosque (Zaimeche, 2002). After reorganizing criteria and elements of water closet facilities and design, 31 mosques were selected which representing Qariah/Jamek mosque (town/village mosque) in Malaysia from Pulau Pinang, Melaka and Perlis states. Qariah mosques are usually defined as community self-funded mosque for one specific area of conurbations.

The ignorance of people on the quality and facilities at water closet and their design at mosque become the main issue for this study. It is divided into three sections in order to identify the Percentage of Compliance (PC) and Cleanliness Index (CI) in mosque water closet, by determining the microbial contaminant related to existing water closet cleanliness and design, and then develop a friendly water closet design as a potential improvement to existing water closet in Qaryah mosque.

For the first section, 7 criteria with 72 elements will be considered in this study. The criteria include general facilities, wash hand basin, ablution area, shower, water closet cubicle, water closet for disabled and water closet cleanliness. Five (5) compliance rating score will be given for the first six (6) criteria with 55 assessment elements representing water closet facilities and design. Meanwhile, the last criteria (the seventh) which is water closet cleanliness with 17 assessment elements were rated based on another five (5) different cleanliness rating score for mosque water closet. Consequently, the PC and CI were developed based on each score from the assessment.

The second section is important to inform Muslim user on the importance of cleanliness in term of water closet condition at mosque. Cleanliness could have influence the incidences of microbial contaminants resulted from their 'transfer' from mosque water closet. Microbial sampling (bacterial and fungal) were carried out in the main prayer hall of mosque. The samples were later incubated for calculating the colony forming unit as parameter for gauging microbial contaminants and then determine the relationship between current cleanliness conditions of mosque water closet with existing bacterial and fungal in mosque.

Lastly, third section in this study focusing on developing new friendly design, as improvements criteria to current 'as built' condition of water closet facilities and design in mosque. The new layout focuses on water closet facilities, which enable elderly and disabled to carry out their hygienic activities individually; this will goes to the children as well. The criteria considered in this section were water closet cubicles, ablution area and water closet for disabled. The results of PCs and CIs gauged the compliance of 'as built' condition, of which, the proposed improvement were used as informed guide.

1.5 Thesis Layout

This thesis has five important parts and brief outlines of the study which shown as the following point below:

- Chapter 1 gives introduction of water closet condition in Malaysia and water closet disclosure in public building (mosque), while drawing problem statement, objectives and scope of research.

- Chapter 2 provided literature reviews on the national standards, guidelines and legislations on water closet facilities (features) and design, in order to have better future water closet at mosque. This chapter also discussed the lighting level needed in public building which imply to overcome visual disability and facilitated the user. Moreover, it also defines microbial contaminants and their effect on mosque users.

- Chapter 3 described the methodologies applied in this research. Seven (7) criteria with 72 elements were accessed to developed Percentage of Compliance (PC) and Cleanliness Index (CI). Percentage of Compliance (PC) was determined via assessment of water closet facilities condition and design which display in six (6) criteria with 55 elements. Meanwhile, Cleanliness Index (CI) focused on water closet cleanliness by considering eleven (11) elements from '*Garis panduan kebersihan tandas masjid dan surau*' (SIRIM, 2014a) and '*Garis panduan penaiktarafan tandas masjid dan surau*' (SIRIM, 2014b).

- Chapter 4 presents the results obtained from the assessment and their analysis. from thirty (31) mosques water closet at Pulau Pinang, Melaka and Perlis. Malaysian standards, guidelines and legislation were used to ensure either "as-built" condition of water closet provided was in compliance with those stipulated recommendations.

- Chapter 5 conclude the overall study on this research and summarize all of the findings, while proposing recommendation for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter gives overview on water closet facilities and design according to Malaysian standards, guidelines and legislation (Malaysian Standard MS 2577: 2014 -Architecture and Asset Management of Masjid – Code of Practice; Malaysian Standard MS 2015: Part 1: 2006 -Public Toilet – Part 1: Minimum Design Criteria; Malaysian Standard MS 1184: 2014 -Universal Design and Accessibility in the Built Environment – Code of Practice, Second Revision; JKR 19/99 – Guidelines on Building Requirement for Disabled; and UBBL: 1984 – Part III -Uniform Building By-Laws, 1984). It also discuss on previous study regarding mosque water closet for Muslim user, elderly and disabled and children. The definition of microbial contamination and the concept of indoor air quality related to microbial air pollution. The Industry Code of Practice (ICOP) on Indoor Air Qulity (DOSH, 2010) for allowable limit of microbial contamination were also explained with overview on the health effects of exposure to indoor biological contaminants.

2.2 Standards, Guidelines, and Legislation for Facilities and Design Compliance

Several standards were developed to enhance safety, comfort and accessibility for water closet user. Malaysian Standard MS2015:2014 (Public Toilet – Part 1: Minimum Design Criteria) emphasized on the requirement, design, location, number, type and quality of water closet either at stand-alone public water closet or in a building. Five criteria (i.e. general facilities, wash hand basin, shower, water closet cubicles and water closet for disabled) were adopted to as the requirement needed to assess water closet. Meanwhile, Malaysian Standard MS1184:2014 (Universal Design and Accessibility in the Built Environment – Code of practice; Second revision) outlined the details and requirements that were intended to be applied for assessing the needs of disabled person and children. The elements of construction, fittings and air circulation and turning of wheelchair were selected to suits the physical need for disabled. All the information on outreached positions of relevant elements for water closet was stated in MS1184:2014. Therefore, light level, shower area, gradient of floor, foldable seat, grab rails, shower head, shower soap dispenser and all elements for water closet for disabled was adapted from this standard to assess either the needs elderly, disabled and children while using the toilet facilities were fulfilled.

Then, JKR (1999) - Guidelines on Building Requirement for Disabled Person listed all points of management in order to provide all basic requirement for disabled. Signage for disabled and height of top wash hand basin were pointed out to ensure that the existing and future proposed design and construction of water closet are

adequate for disabled. While, Malaysian Standard MS2577:2014 (Architecture and Asset Management of Masjid-Code of Practice) illustrated the specific requirement for mosque wellbeing, safety and security in term of designing, planning and maintaining mosque operations. Seven (7) main parameters elaborated in this standard were *qiblat* direction, prayer hall, *mimbar*, *mihrab*, dome/minaret, ablution facilities and toilets. Ablution area and water closet in mosque were given emphasised in this study. Water closet separation and ablution elements were important to maintain user satisfaction. The details is shown in detail in Appendix A.

As for UBBL (1984) - Uniform Building By Law 1984- Part III on Space, Light and Ventilation; the natural lighting and ventilation, air wells and minimum dimension of water closet were important elements required for good water closet. Natural ventilation of water closet shall be provided for total area of not less than 0.2 square meter per water closet. For air wells in water closet, 2 meter as the minimum width for allowable air wells in any direction. Size of water closet, the UBBL (1984) recommended that the water closet with pedestal-type closet fitting, shall not have dimension less than 1.5 m by 0.75 m. Nevertheless, if the water closet with fittings other than pedestal-type closet fitting, the size shall not be less than 1.25 m by 0.75 m. It is important to enable adequate airflow with enough air –well inside water closet.

2.3 Standard and Guidelines for Water Closet Cleanliness

Water closet cleanliness is a role of health and well-being society. Cleanliness is defined as the situation of being clean or kept clean (Oxford Dictionary, 2018). Water closet cleanliness is clarified as a crucial issue in mosque as many people access these facilities. For that reason, '*Garis panduan kebersihan dalam tandas masjid dan surau*' (SIRIM, 2014a) and '*Garis panduan penarafan kebersihan dalam tandas dan surau*' (SIRIM, 2014b) was developed. SIRIM (2014a) was used to guide the user in maintaining the cleanliness of mosque water closet, while specifying the responsibility of mosque management. It also spell out the equipments needed to carryout good practice in maintaining hygiene.

In addition, SIRIM (2014a) tend to guide appointed responsible person (siak) in maintaining the cleanliness of mosque water closet with an assessment of water closet detail with specific elements relation to cleanliness matter. Five (5) categories of water closet cleanliness assessment points were mentioned. In nut shell, seventeen elements from SIRIM (2014a) and SIRIM (2014b) were slippers, storage equipment, appoint specific contractor, clean WC at least once a day, no water pooling, surface of floors, walls and ceilings, water closet fowl work, wash hand basin, door condition, drain condition, waste bin, lamps, mirror, pipe hose, window for sufficient ventilation and daily and weekly cleaning works.

2.4 Lighting Level

Lighting level is the measurement of light performance on selected area which need to considered visual needs of task, visual capabilities, time duration of work and potential visual hazards (Wentz, 1999). Good lighting level ensures safety and promotes better visual environment. Malaysian Standard MS1525:2007 (Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings) has been established to provide guidance on lighting levels that are suitable for visual comfort i.e. lighting for infrequently used area, lighting for working interiors and localised for exacting task and applications. Meanwhile, Malaysian Standard MS1184: 2014 (Universal design and accessibility in the built environment - Code of practice) provided acceptable lighting level for top of wash hand basin. In electrical implementation of a building, lighting level shall be installed with adequate visual performance. Table 2.1 shows the recommended lighting level in water closet of a mosque according to Malaysian Standards. Wash hand basin area in water closet and water closet for disable shall provide 200lux (minimum lighting level), while shower and water closet cubicle shall provide 150lux and 100lux, respectively, as the minimum required lighting level.

Table 2.1 Recommended lighting level in water closet according to Malaysian Standards

Application	Lighting Level (lux)	Malaysian Standard
Wash Hand Basin	200	MS 1184:2014
Shower	150	MS1525: 2007
Water Closet Cubicle	100	MS1525: 2007
Water Closet for Disable	200	MS 1184:2014

2.5 Microbial Contaminants

There have been studies related to indoor microbial contaminants such as at hospital (Claro et al., 2015; Openshaw et al., 2016) and school (Lee and Chang, 2000). Indoor microbial study was common as people knew that contaminated air caused diseases such as asthma, sick building syndrome (SBS) and others that related to respiratory system. As early as 1500 BC, the Egyptians realized that silicate dust produced by the cutting of construction stone can cause respiratory diseases called *papyrusebers* (Brooks and Davis, 1991). Indoor Air Quality (IAQ) investigation was first performed by the National Institute of Occupational Safety and Health in 1971. After that, the record regarding IAQ issue has increased from year 1978 onwards (Burge and Hodgson, 1988). Thus, the details on information about the IAQ is important.

Microbial contamination such as bacteria, viruses and fungal could cause many diseases by airborne transmission. They are very tiny organisms found in just about every ecosystem and could be associated with other diverse types of biota. Bacteria and viruses readily become airborne and remain suspended in air for hours. While fungal are composed of networks of long hollow tubes called hyphae that bordered by a rigid wall usually made of chitin the same material that forms the exoskeletons of insects (Godish, 2000). According to WHO (2010), microbes identified in the air include bacteria (either in vegetative status or spores), fungal, yeasts, microbial toxins and secondary metabolites like bacterial endotoxin, peptidoglycans or fungal β(1,3)-glucans, volatile organic compounds, pollens, pet and insect allergens, other allergens, viruses, protozoa and others.

2.5.1 Bacteria

According to Godish (2000), bacteria are single-celled organisms that characterized by their lack of true nucleus and their relatively small size. The bacteria species had their own historically characterized group which the cells assume as three distinct morphological shapes such as spherical (*coccus*), rod-shaped (*bacillus*), and spiral/curved (*spirillum*, *spirochete*, *vibrio*).

Figure 2.1 shows the bacteria shapes from a few studies regarding bacterias. These organisms dependence on the availability of nutritional substrates, availability of oxygen, moisture levels, pH and temperature for their growth. Furthermore, water has become the major contributor for the growth of individual cell of bacteria (Godish, 2000).

Human activities promotes prevalence of common building-associated bacteria called saprophytic bacteria from skin, mouth and nose. Other common bacteria of indoor environments include heterotrophic bacteria that grow in the water reservoirs or sites of the building with high moisture. However, for moist building condition *Actinobacteria* (especially *Streptomycetes*), and *Bacillus* species grow rapidly (Nevalainen et al., 2009), hence require specific actions to control growth and prevent exposures to them.

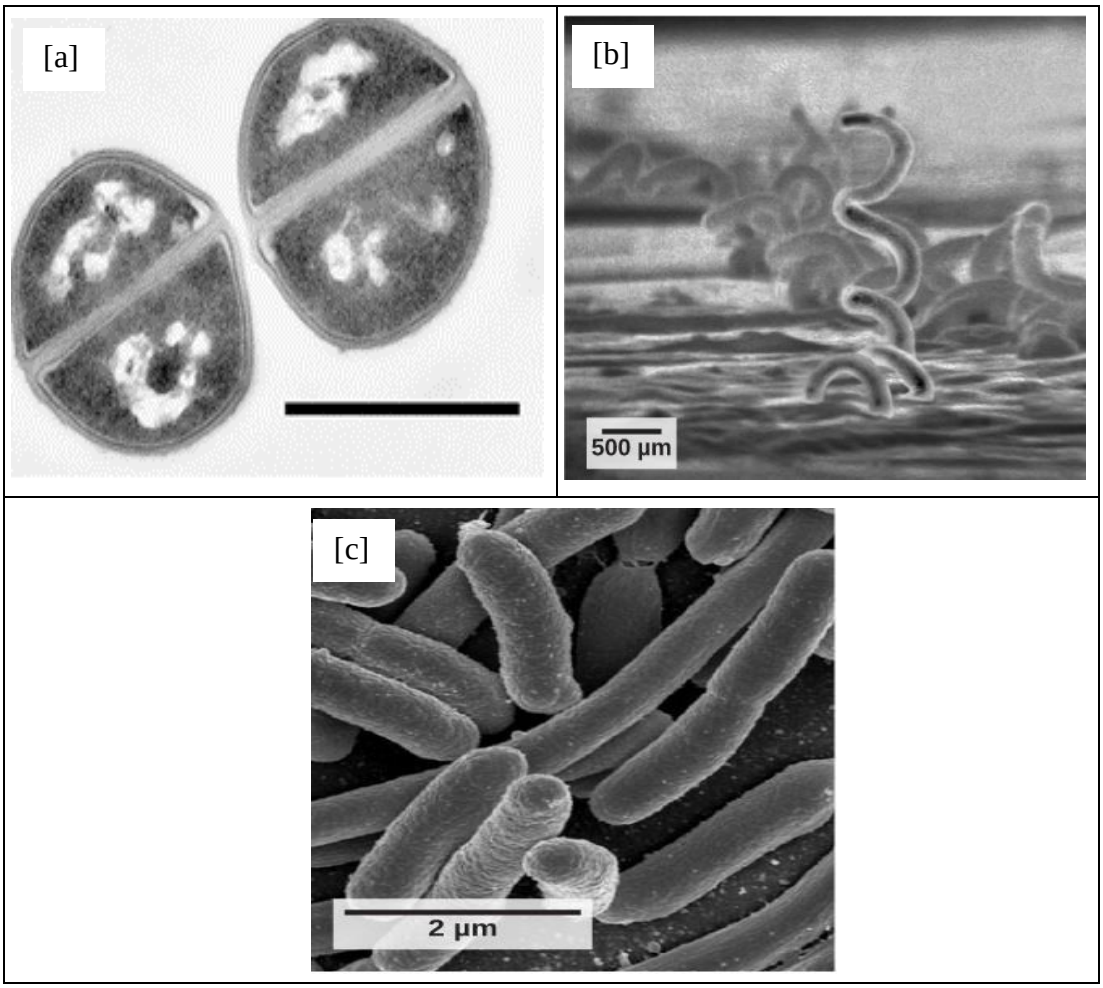

Figure 2.1 Shape of bacteria species in electron micrographs:- [a] Spherical shapes for C*occus* (Zapun et. al, 2008); [b] Spiral shapes for S*pirillum* and [c] Rod-shaped for B*acillus* (Biology, 2018)

2.5.2 Fungal

According to Havlickova *et al*., (2008), more than 25 percent population worldwide have human skin infection by fungal pathogens. Fungal has been classified into two types, which are mold and yeast. Mold is described the visible manifestations of the growth of large number of organisms. While yeast is used to describe of single cell fungal. Fungal only exists as masses of threadlike filaments or hyphae. *Mycelium* was the vegetative part of organisms that infest a substrate and extracts food for the organism that had been describes as the collective mass of hyphal filaments (Godish, 2000).

Fungal can be present in both outdoor and indoor air. Furthermore, over 400 reports regarding pathogenic fungal species are widely distributed in damp location and responsible for several infections (Chabasse et al., 2009). This is because water is a major limiting factor for fungal growth. A fungal can germinate and grow when humidity exceeded 70%. Fungal is a species that had broad tolerance range for its availability. In describing the moisture content, water activity (aw) refere to the humidity of the substrate which expressed as a decimal fraction as 50% = 0.5 aw. Then, approximately 0.55 aw to 1.0 aw is needed for growth activities (Godish, 2000).

*Penicillium, Aspergillus, Cladosporium, Alternaria,*and yeast was the most common fungal genera occurring in indoor space (Nevalainen and Morawaska, 2009). According to World Health Organization, fungal requires carbohydrates, proteins and lipids for germination. All the elements easily found in house dust, construction materials, wood, paper and stored food. Fungal also germinate on inert materials like ceramic tiles.

2.6 Microbial Contaminant in Industry Code of Practice (ICOP)

ICOP (2010) has been established to provide guidance on improving indoor air quality (IAQ) and to set minimum standard for selected parameters in order to avoid discomfort and adverse health effect on human being. These stated parameters had been used as guideline to employees and other occupants while operating or occupying enclosed space or building. In managing any building, the inspection should be conducted regularly, so that the incidence high microbial contamination

that lead to certain diseases can be contained. Table 2.2 below shows the acceptable limits for microbial contaminants of total bacterial counts and total fungal counts as stated in ICOP at 500 cfu/m³ and 1000 cfu/m³, for bacterial and fungal, respectively.

Table 2.2 Acceptable limits for microbial contaminants of total bacterial counts and total fungal counts as stated in ICOP

Indoor Air Contamination	**Acceptable limits (cfu/m³)**
Microbial Contamination	
(a) Total bacterial counts	500
(b) Total fungal counts	1000

(Sources: ICOP, 2010)

2.7 Health Effect on Microbial Contamination

A various types of study has reported on the effect of chronic exposure to microbial contamination within indoor environments especially harmful effect on human respiratory (Amman, 2003; Daisey et al., 2003; Bouillard et al, 2005). The results obtained due to airborne contamination gave incomplete picture of the total exposure assessment of airborne contamination. Hess-Kosa (2011) stated that an effective air quality assessment involves series of steps was needed to prevent poor indoor air quality. Furthermore, poor occupant's management also contributed to increase in the percentage of microbial contamination inside a confined space.

Either during occupational activities or in domestic environments, many individuals are exposed to dust from vegetation, animal or microbial origin. Inhalation of endotoxins, major component of the outer membrane of Gram-negative bacteria (GNB), carried by airborne dust, leads to some adverse effects on human health. Endotoxins initiate a cascade of biochemical and cellular events giving rise to

multiple dysfunction associated to the sick building syndrome (SBS), or to acute chronic lung diseases (Raylander, 2002).

Besides that, Moldoveanu (2015) stated that allergic reactions related to respiratory system could be caused by indoor air contamination. Some of the effects due to the biological contamination of indoor air had caused the inflammation of the airways. This could appear in both allergic and non-allergic respiratory ailments, with differences between the two entities of IgE and IgG antibodies being important cause inflicting asthma and rhinitis conditions.

2.8 Anthropometric Dimension of People

Anthropometry is a human science that measure body size, shape, strength and working capacity (Pheasant, 2014). According to Pheasant (2014), human proportion (measurement) has been calculated since the year 15 BC from classical times of Roman architectural. Most of the measurement regarding well-made man are the fundamental principle in building design. By this stage, human proportion from anthropometry dimension was illustrated to classify workability, achievable and accessibility of building facilities. People started to collect all anthropometric dimension with samples of population suggested to their county or places. Similar to Karmegam et. al. (2011) that implanted their study an anthropometric dimension on Malaysian population either adult or children with various ethnic. With no anthropometric data, it could cause of lack of required information to predict future development or complete model on building design. Figure 2.2 and Table 2.3 show

the anthropometric illustrations with recommended dimension for standing and sitting adult users, respectively, Wentz (1999).

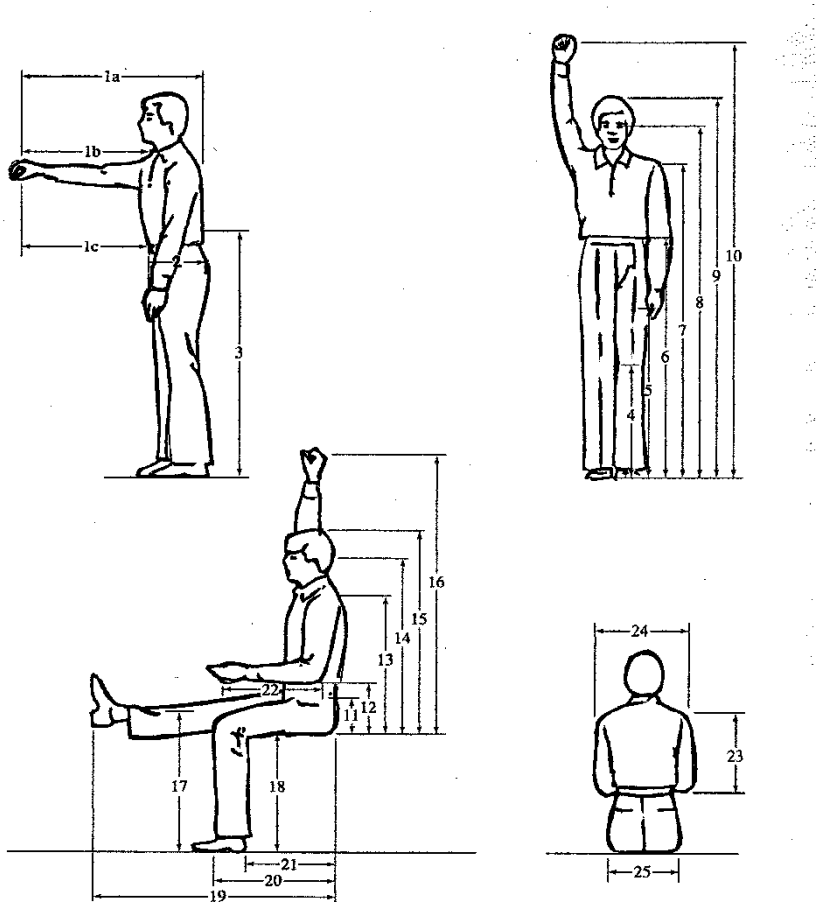

Figure 2.2: The anthropometric illustrations with dimensions of standing and sitting for normal adult

Table 2.3: The anthropometric dimensions for normal adult while standing and sitting

Measurement (inch)		Males		Female	
		Mean	**SD**	**Mean**	**SD**
Standing					
1	Forward functional reach				
	1a Includes body depth at shoulder	32.5	1.9	29.2	1.5
	2a Acromial process to functional pinch	26.9	1.7	24.6	1.3
	3a Abdominal extension to functional pinch	24.4	3.5	23.8	2.6
2	Abdominal extension depth	9.1	0.8	8.2	0.8
3	Waist height	41.9	2.1	40	2
4	Tibial height	17.9	1.1	16.5	0.9
5	Knuckle height	29.7	1.6	28	1.6
6	Elbow height	43.5	1.8	40.4	1.4
7	Shoulder height	56.6	2.4	51.9	2.7
8	Eye height	64.7	2.4	59.6	2.2
9	Stature	68.7	2.6	63.8	2.4
10	Functional overhead reach	82.5	3.3	78.4	3.4
Seated					
11	Thigh clearance height	5.8	0.6	4.9	0.5
12	Elbow rest height	9.5	1.3	9.1	1.2
13	Midshoulder height	24.5	1.2	22.8	1
14	Eye height	31	1.4	29	1.2
15	Sitting height, normal	34.1	1.5	32.2	1.6
16	Functional overhead reach	50.6	3.3	47.2	2.6
17	Knee height	21.3	1.1	20.1	1
18	Popliteal height	17.2	1	16.2	0.7
19	Leg length	41.4	1.9	39.6	1.7
20	Upper-leg length	23.4	1.1	22.6	1
21	Buttocks-to-popliteal leangth	19.2	1	18.9	1.2
22	Elbow-to-fist length	14.2	0.9	12.7	1.1
23	Upper arm length	14.5	0.7	13.4	0.4
24	Shoulder breadth	17.9	0.8	15.4	0.8
25	Hip breadth	14	0.9	15	1

CHAPTER THREE

METHODOLOGY

3.1 Introduction

Figure 3.1 shows all related procedures that were performed to achieve each of the objectives. Percentage of Compliance (PC) and Cleanliness Index (CI) was developed based on evaluation of 7 criteria of water closet in mosque i.e. general facilities (GF), wash hand basin (WHB), water closet cubicle (WCC), shower (SHW), ablution area (AB), water closet for disabled (WCD) and water closet cleanliness. Evaluation was made based on "as-built" water closet facilities and design according to seven (7) national standards, guidelines and legislation. Criteria and elements selections for parameters were made to ensure comprehensive and guided assessment on mosque water closet. Observation and on site 'as built' assessment were performed to identify user satisfaction on the water closet condition in term of their facilities and design. In the last stage, a layout consists of newly recommended design water closet is developed and built based on Cleanliness Index and Percentage of Compliance.

3.2 Study Area

This study was conducted at thirty one (31) Qaryah mosques mosques without taking into serious consideration of locational differences. Hence, equal number of mosques for each state were not crucial. During the study, assessment of water closet facilities and design were carried out, while, the sampling for biological

contamination (bacteria & fungal) was conducted at certain area in selected mosques for incubations.

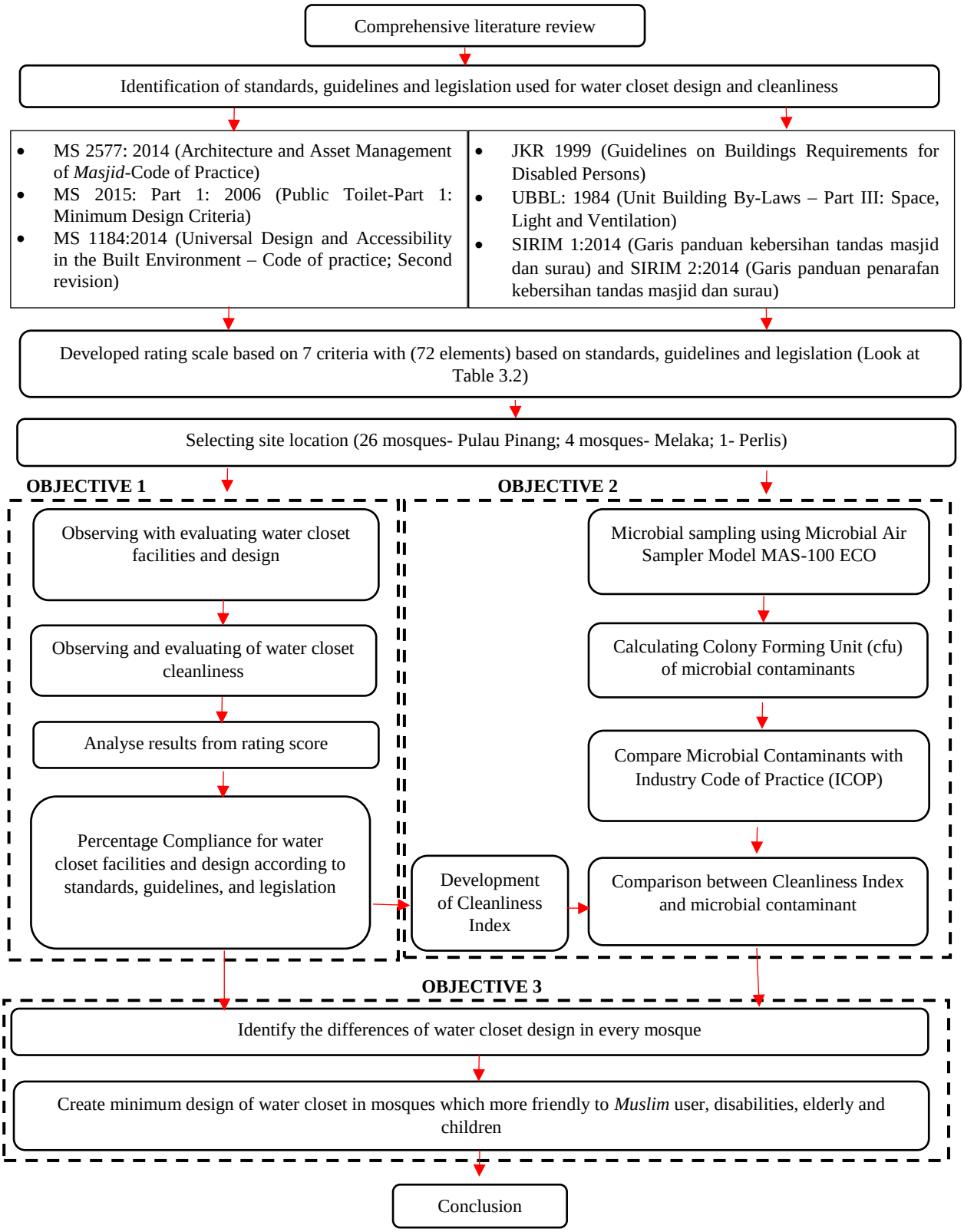

Figure 3.1 Flow of research methodology

3.3 Site Selection

All mosques were categorized as Qariah/Jamek mosque (Malaysian Standard, 2014a) in Malaysia. Qariah/Jamek mosque was classified based on the number or population and ‘mukim’, as well as the second lowest hierarchies in Islamic place of worship in Malaysia. The existing of hierarchies in Islamic building was to classify the importance to distinguish between religious monuments between the imperial capital and the provinces (Asani, 2018). Figure 3.2 dan Table 3.1 shows the location of the thirty-one (31) selected ‘Jamek’ mosques in Pulau Pinang, Melaka and Perlis.

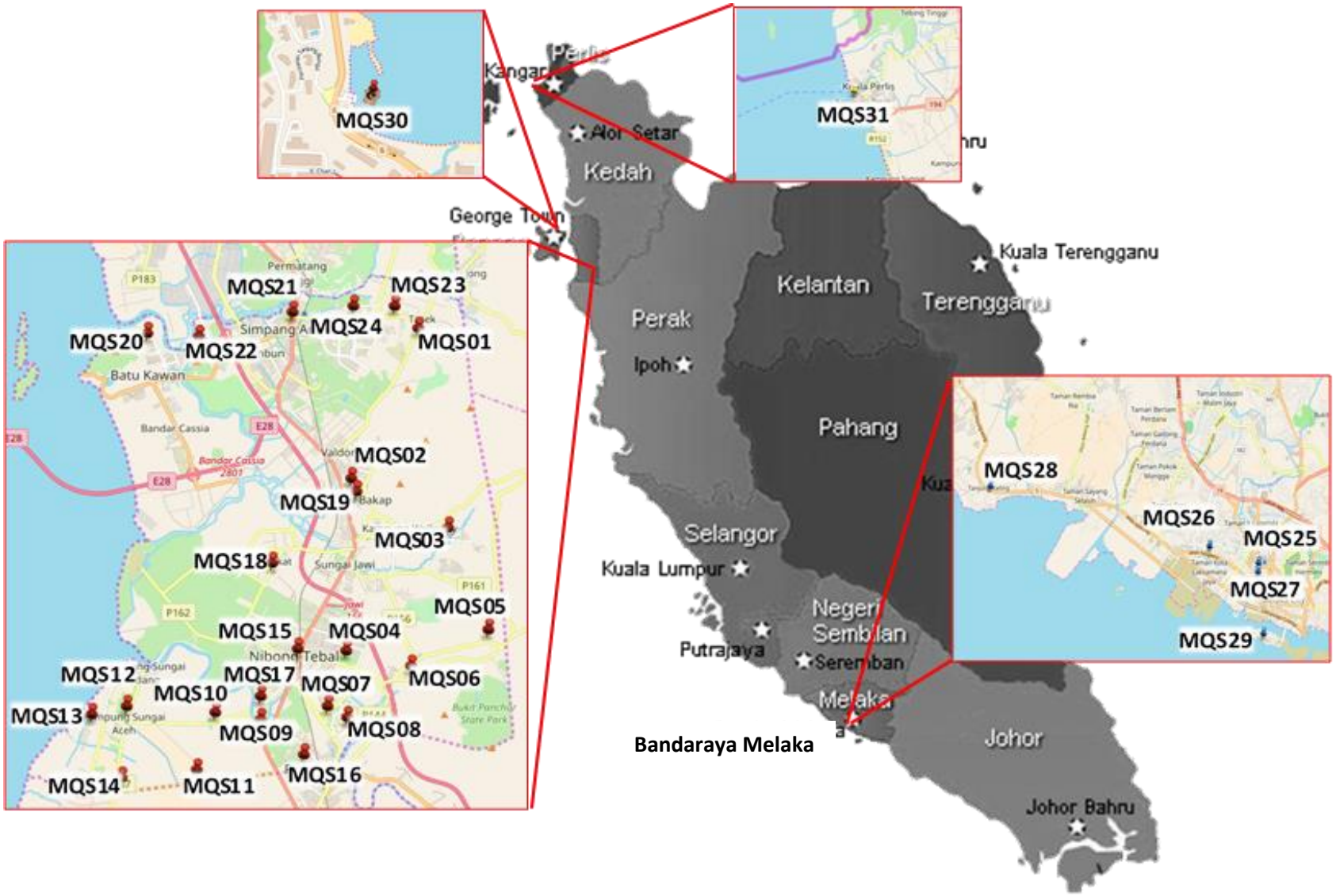

Figure 3.2 Location of selected mosque (Qariah/Jamek mosque) on Semenanjung Malaysia (not drawn to scale)