UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF POROUS CERAMICS WITH HUMIDITY CONTROLLING AND ANTIMICROBIAL CHARACTERISTICS FROM MODIFIED DIATOMACEOUS EARTH (DE): POTENTIAL TO IMPROVE INDOOR AIR QUALITY

NURUL HAFIZAH BINTI AHMAD

Ip
FPSK4 2018 10

KESIHATAN
UNIVERSITI PUTRA MALAYSIA

ACKNOWLEDGEMENTS

In the accomplishment of this project successfully, I would like to dedicate to each person who have helped me with their valuable suggestions and guidance in various phases of the completion of the project. I am grateful to Almighty for giving me the strength to successfully conduct my experiment and for sustaining my efforts which many a times did oscillate.

Firstly, I show my gratitude to my supervisor, Associate Professor Dr Emilia binti Zainal Abidin, who gave me the golden opportunity to do this project. Secondly, bunch of thanks are given to my co-supervisor, Professor Ir Dr Mohd Sapuan Salit and Dr Azmiza Syawani Jasni who has given valuable support cooperation and suggestions from time to time in successfully completing this project.

I wish to express my sincere gratitude to the laboratory staff in Laboratory of Environmental Health, Laboratory of Medical Microbiology and Parasitology of Faculty of Medicine and Health Science and Institute of Tropical Forestry and Forest Products (INTROP) for providing the best of facilities and environment to bring out our innovation, talent and spirit of inquiry through this project. I sincerely thank to my project partner, Miss Huong Pei Zam for guidance and encouragement in carrying put this project work.

A special thankful appreciation is also dedicated to Miss 'Aina Rusydina binti Ahmad Raji and Miss Nur Izzaty Natasha Ismail as groupmates under the same supervisor who had given me the support and helping hands during the research. I would like to extend my thanks to all my friends Nurulain Atikah binti Shaipuzaman, Siti Nur Atika Yap binti Mohd Taufiq Yap, Nurul Farah Nadhirah binti Zainal and Asna Syahirah binti Salihin who helped me and supported me through this journey.

Most of all, I would also like to thank my parents and family members who always listening and giving me words of encouragement. Last but not least, I would like to express my gratitude to everyone that had offered assistance and gave motivation, either directly or indirectly, in term of time and moral support in order to complete this research.

© COPYRIGHT UPM

ABSTRACT

DEVELOPMENT OF POROUS CERAMICS WITH HUMIDITY CONTROLLING AND ANTIMICROBIAL CHARACTERISTICS FROM MODIFIED DIATOMACEOUS EARTH (DE): POTENTIAL TO IMPROVE INDOOR AIR QUALITY

NURUL HAFIZAH BINTI AHMAD

Background: Indoor humidity is one of the indoor comfort issues in indoor environment. Imbalance of indoor humidity would arise when there is an inefficient use of air conditioning system. Most of the buildings in Malaysia would be facing the similarities problem because air-conditioning will not run for 24hours, instead it is usually switch on during working hours only. However, the use of MVAC are energy saving and costly. Overgrowth of fungus and bacteria is related with high relative indoor humidity. Such porous ceramic if able to be developed is hypothesize to help regulate humidity in indoor environment, in which it has an ability to balance indoor humidity. **Objective**: The aim of this study is to determine the extent sick building syndrome (SBS) problems among office workers in a public university and to identify the problems related to humidity and perception on the use of humidity control materials in offices. Additionally, this study further aims to develop porous ceramics with humidity controlling and antimicrobial characteristics from modified Diatomaceous Earth (DE). **Method**: The first part of this study was designed as a cross-sectional study among office workers to selected offices in Malaysia. The experimental part of this study consists of the development of porous ceramics from DE, waste glass and oyster shell in several formula (80%, 70%, 60% and 50% DE). The mixture were prepared in powder form and were then compressed in the form of 15cm x 15cm x 5mm of green molds, then were sintered at 1100° C for 20 minutes. The resultant porous ceramics were subjected to humidity adsorption-desorption analysis, anti-bacterial assay and impact strength test using loads. The best formula ratio for the porous ceramics was then identified from these tests. **Result:** The prevalence of SBS is 73.4%. The humidity adsorption desorption ability of porous ceramics was increased as the DE content increased. The humidity adsorption desorption performance for modified DE within a range of 3-5%. The inhibition zones against *S. aureus* and *P. aeruginosa* depends on the percentage of DE and it increases as the content increases. On the other hand, the inhibition zones for *S. aureus* depends on the percentage of oyster shell and it increases as the content increases. The average of clear zone against bacterial was 15mm. The impact test found that the formula of 50%DE has the greatest impact test compared with three other ceramics. **Conclusion**: This study revealed that there is a need for the development of porous ceramics to help reduce humidity problems and the corresponding sick building syndrome in building offices. This study found that a suitable ratio for porous ceramics with humidity controlling and anti-bacteria characteristics could be developed by using 50% modified DE. The modified DE added with local and low-cost materials have the potential to solve the problem of humidity imbalance and microbial growth in office settings can be solved in order to reduce sick building syndrome and ensure productivity of workers is maintained.

Keywords: anti-bacteria, oyster shells, calcium oxide, respiratory health symptoms, indoor air quality

ABSTRAK

PENGHASILAN SERAMIK BERLIANG DENGAN BERCIRI KAWALAN KELEMBAPAN DAN ANTIMIKROB DARIPADA PENGUBAHSUAIAN TANAH DIATOM (TD): POTENSI MENINGKATKAN KUALITI UDARA DALAM BANGUNAN

NURUL HAFIZAH BINTI AHMAD

Pengenalan: Kelembapan merupakan suatu isu keselesaan di dalam bangunan tertutup. Ketidaksuaian kelembapan akan wujud apabila penggunaan sistem penyaman udara yang tidak cekap. Kebanyakan penghawa dingin tidak beroperasi selama 24 jam, malah biasanya beroperasi pada waktu bekerja sahaja. Peningkatan kulat dan bakteria dikaitkan dengan kelembapan dalaman yang relatif tinggi. Penghasilan seramik dihipotesis untuk membantu mengawal kelembapan dalam persekitaran tertutup, di mana ia mempunyai keupayaan untuk mengimbangi kelembapan dalaman. **Objektif:** Tujuan kajian ini adalah untuk menentukan masalah-masalah sindrom bangunan sakit (SBS) di kalangan pekerja pejabat di universiti awam dan untuk mengenal pasti masalah-masalah yang berkaitan dengan kelembapan serta persepsi tentang penggunaan bahan kawalan kelembapan. Kajian ini juga bertujuan untuk membangunkan seramik berliang dengan berciri mengawal kelembapan dan antimikrob dari Tanah Diatom (DE). **Metodologi:** Bahagian pertama kajian ini direka sebagai kajian rentas di kalangan pekerja pejabat terpilih di Malaysia. Bahagian kajian ini terdiri daripada pengembangan seramik berliang dari DE, sisa kaca dan tiram dalam beberapa formula (80%, 70%, 60% dan 50% DE). Campuran telah disediakan dalam bentuk serbuk dan kemudian dimampatkan dalam bentuk 15cm x 15cm x 5mm, kemudian disinter pada 1100° C selama 20 minit. Seramik poros yang dihasilkan tertumpu kepada analisis adsorpsi-desorpsi kelembapan, ujian anti bakteria dan ujian kekuatan menggunakan beban. **Keputusan:** Kelaziman SBS adalah 73.4%. Keupayaan penyerapan kelembapan seramik berliang meningkat apabila kandungan DE meningkat. Prestasi penyerapan kelembapan untuk DE dalam lingkungan 3-5%. Zon jelas terhadap *S. aureus* dan *P. aeruginosa* bergantung pada peratusan DE dan ia meningkat apabila kandungan meningkat. Sebaliknya, zon pencerobohan untuk *S. aureus* bergantung kepada peratusan tiram. Purata zon jelas terhadap bakteria ialah 15mm. Ujian impak mendapati bahawa formula 50% DE mempunyai ujian impak terbesar. **Kesimpulan:** Kajian ini mendedahkan bahawa terdapat keperluan untuk pembangunan seramik berliang untuk membantu mengurangkan masalah kelembapan dan sindrom bangunan sakit yang bersesuaian di pejabat bangunan. Kajian ini mendapati bahawa nisbah yang sesuai untuk seramik berliang dengan kelembapan mengawal dan ciri-ciri anti-bakteria boleh dibangunkan dengan menggunakan 50% DE yang diubah suai.

Kata kunci: antibakteria, kulit tiram, kalsium oksida, gejala kesihatan pernafasan, udara dalaman

TABLE OF CONTENTS

© COPYRIGHT UPM

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

DE	Diatomaceous Earth
SBS	Sick Building Syndrome
IAQ	Indoor Air Quality
WHO	World Health Organization
JIS	Japanese Industrial Standard
USEPA	United States Environmental Protection Agency
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
EPA	Environmental Protection Agency
DOSH	Department of Occupational Safety and Health
OSHA	Occupational Safety and Health Act
ICOP	Industry Code of Practice
MVAC	Mechanical ventilation and air conditioning
HVAC	Heating, Ventilation and Air Conditioning system
AHU	Air Handling Unit
HCM	Humidity control materials
MRSA	Methicillin-resistant Staphylococcus aureus
CaO	Calcium oxide
MgO	Magnesium oxoide
XRD	X-ray powder diffraction
RH	Relative Humidity
CFU	Colony-forming unit

© COPYRIGHT UPM

CHAPTER 1

INTRODUCTION

1.1 Background

Indoor Air Quality (IAQ) refers to the air quality inside and around the buildings, particularly as it identifies the state of well-being and the occupant's comfort within the buildings. Most people use 90% of their time indoors and in an office environment during their working hours (USEPA, 2017). Zakaria et al., (2016) mentioned that people spend almost 90% of their time doing indoor activities compared to outdoor. The levels of indoor air pollutants sometimes are higher than contaminants from exterior buildings (USEPA, 2017). In Malaysia, most of the workers spent eight hours per day at their workplace. Within the time frame when the workers are at work, they are potentially exposed to indoor air pollutants including particulate matter, chemical contaminants and microbial contaminants such as *Aspergillus flavus*, *Penicillium spp*, *Staphyloccous aureus* and *Bacillus subtilis* (Hussin et al., 2011). These indoor air pollutants may give significant health impact on the inhabitants exposed (Fernández & Bellotti, 2017).

© COPYRIGHT UPM

In certain places especially in buildings located in humid area, high relative humidity is one of the most significant indoor air which has become major concern among building tenants, offices, employees and business owners as well. When relative indoor humidity levels are too high, condensation occurs on walls and windows and start to cause structural damage due to its moisture content. Damage to building materials will increase with the moisture build up, issues such as peeling paints and permanent wood warping can occur.

Indoor environment such as office buildings in Malaysia, mechanical air conditioning and ventilation (MVAC) system will need to run for the duration of office hours. In building offering 24-hour services, the system will run throughout the day and night. The MVAC system is crucial and is responsible in balancing the indoor temperature, indoor relative humidity and reducing the excess moisture that can be found on some building materials and in indoor spaces, in addition to expelling CO_2 and as a source of intake of fresh air from the outside. The excess moisture needs to be expelled in order to inhibit the growth of microorganism. Mold and bacteria has been significantly associated with asthma and allergies to human especially through inhaling of airborne particles that is contained in this microorganism (Orosa & Oliveira, 2012).

In ensuring that the indoor air environment is safe for the building occupants, a few existing standards has been introduced international and nationally. According to The American Society of Heating, Refrigerating and Air-Conditioning Engineers ASHRAE Standard 55-2017: Thermal Environment Conditions for Human Occupancy is a standard that use is for the offices and homes. Thus, this standard specifies condition of allowable thermal environment in buildings and other occupied spaces including temperature, thermal radiation, air speed, humidity and personal factor. ASHRAE (2017) set the acceptable range for relative humidity which is between 20%-70%, 21-23° C for temperature and 0.3 m/s of air velocity (ASHRAE, 2017).

For the Malaysia occupational setting, Department of Occupational Safety and Health (DOSH), has drawn up the Industry Code of Practice (ICOP) on Indoor Air Quality (DOSH, 2010). The ICOP focuses on indoor air recommended acceptable range which is between 23-26° C, 0.15 m/s to 0.50 m/s of air velocity and for 40-70% is relative humidity. The ICOP was introduced by the Minister of Human Resources to help reduce health problems related to unhealthy indoor air quality. It is emphasized under Section 15 of Occupational Safety and Health Act 1994 (OSHA) and Section 17 of OSHA, that is the general duties of employers and self–employed persons to their employees to ensure as far as practicable the employee's safety, health and welfare at their workplace (OSHA, 1994).

© COPYRIGHT UPM

1.2 Health effects from exposure to indoor air pollutants

Health effects on humans can be show up immediately after exposure to the air pollutants. It could also give long-term effects (ASHRAE, 2017). Exposure to variety of pollutants including chemical contaminants, particulate matter and microbial contaminants has been shown to results in asthma-like symptoms, allergy and skin infections (WHO, 2017). Skin aggravation and respiratory issues has been linked with indoor environmental quality especially with regards to living in stuffy building where harmful agents exists (Vu, Wang, Nam, Bac, & Chu, 2011).

General symptoms of unhealthy indoor air quality can also be manifested by several symptoms likes irritation of eyes, nose, mucosal symptoms, headache and dizziness (WHO, 2017). Indoor air problem especially biological contaminants historically have been shown to pose severe risks such as the event of the Legionnaire's Disease. The disease is attributed from the bacteria called *Legionella pneumophila.* This disease is one of the building-related illness in a form of bacterial pneumonia. *Legionella* grows and multiplies in air handling system. This bacteria will spread throughout the building in the form of water droplets and small enough for people to breathe in. Those with Legionnaire's diseases will have fever, muscle aches and coughing symptoms.

© COPYRIGHT UPM

Indoor environment exposure in to microbial contaminations can be allergic asthma, allergic rhinitis, infection (*cryptococcosis* and *histoplasmosis*) and hypersensitivity pneumonitis (OSHA, 2006). Hu et al (2017) revealed that airborne fungi such as *Penicillium, Aspegillus* and *Cladosporium* in indoor environment could result to respiratory disease and allergies. A study by Rios et al., (2009) disclosed that tiredness, headache, ophthalmic and upper airways symptoms were highly prevalent in office with sealed building.

Indoor humidity nearly related with human health problem including respiratory problems and allergies. Indoor humidity needs to be control at convenient level because if the air is too dry, it will affects the building materials and lead to breach, crack and misshape that can cause leads to skin irritation and asthmatic problem (Vu et al., 2011).

© COPYRIGHT UPM

1.3 Diatomaceous Earth as Humidity Control Material

Ideal indoor air quality can be reached by controlling the source and dispersion of pollutants in several ways. For chemical exposures, indoor pollution can be controlled using material and products with low emission of contaminant (Penney et al., 2010) but to control microbial growth, focus needs to be given in moisture control. According to Sullivan et al., (2013), three conditions required to promote microbiological growth on surfaces, (1) the temperature range between 4°C and below 37°C (40°F to 100°F); humidity, greater than 80%; and (3) nutrients for growth (most surfaces contain). Increased growth of fungus and bacteria on building materials has been shown to be associated with relative humidity of more than 60% (EPA, 1997). However, humidity below than 20%, can cause drying of skin and promotes skin irritation (EPA, 1997).

Humidity Control Materials (HCM) is one of the solution to regulate indoor ambient air humidity. The usage of HCM can be used either in passive and active way, in which the active way requires electricity. To control moisture in indoor environment, Diatomaceous Earth (DE) as one of the HCM that has been shown in several studies to be a very good humidity adsorption (Vu et al., 2013; Hu et al., 2017; Sun et al., 2017; Zheng et al., 2017). DE is amorphous silica derived from the deposition of single-celled aquatic algae and is widely used as filter aid, adsorbent, catalyst carrier, porous ceramics and environmental protection (Hu, Zheng, Jia, Dong, & Sun, 2017). It has the ability to be use as potential humidity control materials in any building materials in order to

© COPYRIGHT UPM

improve relative indoor humidity. It also has an ability to adsorb excess moisture and desorb it to ambient air in certain humidity levels.

1. 4 Problem statement

The Occupational Safety and Health Administration (OSHA) reported that 69,000 people complaint of headache meanwhile 105,000 people reported of asthmatic problems at their workplace due to poor Indoor Environmental Quality (Sullivan et al., 2013). The study also reported that a large number of office buildings have problems with high relative humidity.

One local indoor air quality study in Malaysia, (Zakaria et al, 2016) reported that relative humidity in an office building (Academic Management Center) at a university exceeded the allowable range used in the Malaysian framework. Malaysia Industry Code of Practice Indoor Air Quality (DOSH, 2010) showed the acceptable range for relative humidity in indoor setting is 40-70%. The study reported that the relative humidity was 70% to 80% within a week during the working hours of 8.00am to 5.00pm. The monitoring results represented the actual condition in the indoor environment of office setting. Another study by Abidin et al., (2017) reported that animal clinics have high relative humidity in the range of 71-85%. A total of 9 out of 14 animal clinics exceeded the acceptable range of relative humidity. As stated earlier, high relative humidity and moisture can promote the growth of microbial agent.

© COPYRIGHT UPM

In indoor setting, Mechanical Ventilation Air Conditioning (MVAC) system shall be inspected twice a year to ensure no bacterial growth in the accumulation of water in ductwork, dehumidifier and internal building surfaces, cooling coils, filters or any components of MVAC system (Industry Code of Practice on Indoor Air Quality, 2010). Increasing of biological agents in dwelling and buildings can trigger illness and allergies to worker's health (Fernandez & Belotti, 2016).

Penney et al., (2010), it was found that the relative humidity in offices at public university was 69% while the average temperature was 25.1°C and the air velocity was 0.2 m/s. Similarly, another study in an office building in Universiti Teknologi Malaysia reported that the relative humidity measured was 63.1% to 72.1% even though the results of these studies being cited showed that relative humidity in office buildings only exceeded a little from the acceptable range, but majority of respondents in these studies mentioned that they were uncomfortable with the office room's thermal conditions (Rohizan & Abidin, 2015).

Ventilation rates has a vital role in maintaining indoor humidity at the optimal level. Lower performance of ventilation system will increase the moisture levels and they increasing the relative humidity (Rohizan & Abidin, 2015). Rohizan & Abidin (2015) reported that offices at public university in Malaysia showed that the prevalence of SBS is 9.7% and perception of discomfort among respondents was 11%.

© COPYRIGHT UPM

In tropical country like Malaysia, indoor humidity in offices are often characterized by the use of air-conditioning as one of the main method for cooling the indoor air to ensure thermal comfort (ASHRAE, 2017). For example, Mechanical Ventilation Air Conditioning (MVAC) has been used extensively in office building, where it attached with Air Handling Unit (AHU) to balance the humidity inside the building, removing excess moisture and other pollutants. Imbalance of indoor humidity would arise when there is an inefficient use of air conditioning system. Most of the buildings in Malaysia would be facing the similari problem because air-conditioning will not run for 24 hours, instead it is usually switch on during working hours only. MVAC system function as a filter for the outdoor air pollutants from entering the indoor environment (Toyinbo, 2012). However, the problems which relates to the use of MVAC are energy saving and costly by which the ventilation efficiency are require to be reduce to minimal.

As reported by Vu et al., (2012) the use of air-conditioning commonly is one the solutions to control indoor environment humidity but it needs to be used for a prolonged period which is costly. Dehumidifier is often used in temperate countries to remove excess moisture inside buildings and help to minimize symptoms of asthma and allergy, however the cost of running and the price of the equipment is costly and may not be affordable to everyone. Moisture absorbing material depending on size is ideal to be used in small spaces, cupboard or at any area in the home or offices. It can help to reduce dampness, remove unpleasant odor and avoid any growth of mold and mildew. However

© COPYRIGHT UPM

such product available in the market only lasts up to 2 months and needs to be change when it is saturated.

Internationally, ASHRAE (2017) suggested that the ideal relative humidity for office building was 20% - 70% meanwhile the EPA predicted that poor indoor environment quality will lead to lost productivity, higher expenses in medical care and greater number of lost work days (EPA, 1997). This evidence was attributed to the duty by Kang et al. (2017) which reported that reduction of work productivity and symptoms of SBS (lethargy, mental fatigue and headache) were linked by poor indoor environmental quality. Workers' performance can be reduced by improving the indoor air quality (Fadhilah & Juliana, 2012). Goldstein (2012) implied that poor indoor environmental quality and its association with health problem is costly and to solve or to remediate this problem will affects people financial unless they have insurances that are willing to cover the cost.

During the development of a building, the material selection for wall building must be taken into consideration with regards to moisture absorption and the ability to inhibit growth of mold (Vu et al, 2011). Goldstein, (2012) proposed a solution in terms of solving indoor air quality problem where the development of materials with specific properties that could lessen the size of the mold contamination issues needs to be emphasized. The author support that arrangement such as this will enable remediation to be more productive and cost to be diminished or minimized.

Such porous ceramic if able to be developed is hypothesize to help regulate humidity in indoor environment, in which it has an ability to balance indoor humidity by absorbing the humidity from surrounding and desorbing it into the air. This characteristics is expected to reduce the problems related to high moisture content in indoor environment, together with reducing the problems associated with the growth of microbial indoors.

© COPYRIGHT UPM

1. 5 Study Justification

Living in dwelling and airtight sealing buildings without good ventilation system would create problems related to poor indoor humidity. Occupants are not only exposed to hazardous contaminants generated from the outside but inside the buildings as well. In Malaysia, numerous study has been conducted to determine the level of pollutants and health effect associated with sick building syndrome among office workers, school children and home's occupants. Result obtained from previous study were used as a baseline data for IAQ and references in improving indoor environments at workplace. None of this study has come out with a solution to eliminate or reduce the problems related with indoor humidity.

Relative humidity in indoor environment of workplace causing some serious problems to the occupants including comfort, health effects and energy consumption. The needs of materials to control humidity and moisture are advisable. An innovation of building material is a must with "humidity control material" characteristics. It would be one of the solutions to improve indoor humidity and reducing excessive moisture. This product has been promoted for dwelling and air tight seal of buildings (Vu et al., 2013) and replace the use of moisture absorber, air purifier and air conditioning usage in prolonged time. Vu et al., (2013) stated that HCM capable to absorb humidity from ambient air and desorb it into the air. It works in two ways either passive or active way which needs an electricity for it functioning. Recommended by Bo & Qian (2016), humidity control material capable to perform automatically without any power source or equipment due to its sensitivity to difference ambient humidity and temperature.

1.6 Research questions

1. What is the extent of the Sick Building Syndrome (SBS) problem, humidity related problems and perception on the use of porous ceramics with humidity controlling and antimicrobial characteristics among workers in selected offices in Malaysia?
2. What is the potential materials that can be used for moisture adsorption desorption performance, antibacterial characteristics?
3. What is the ability of humidity absorption – desorption performance of the potential materials?
4. What is the ability for antibacterial performance of the potential materials?

© COPYRIGHT UPM

1.7 Research Objective

1.7.1 General Objective

1. To develop humidity-controlling and antimicrobial of porous ceramics from modified DE

1.7.2 Specific Objective

1. To determine the extent of the Sick Building Syndrome (SBS) problem, humidity related problems and perception on the use of porous ceramics with humidity controlling and antimicrobial characteristics among workers in selected offices in Malaysia.
2. To identify potential materials for humidity adsorption desorption performance, antibacterial characteristics.
3. To develop porous ceramics with humidity adsorption desorption performance of antimicrobial characteristics.
4. To determine the ability of humidity adsorption-desorption performance of the potential materials
5. To determine the ability of antimicrobial performance of the potential materials

1.8 Hypothesis

HCM products has an ability of humidity absorption-desorption. Other than that, produced HCM from potential materials will have anti-bacterial properties. Thus with these characteristics, this porous ceramics can eradicate the indoor humidity problems in office setting.

© COPYRIGHT UPM

1.9 Conceptual Framework

Figure 1.9 shows the needs of humidity-controlling, antimicrobial characteristics of porous ceramics from modified DE. Biological contaminants are as a mixture of microorganisms including bacteria, fungi, spores, hyphal elements, virus and others. However, fungi and bacteria are the most problems can be found indoor environment. Excessive moisture leads to breeding of mold. Combination of excessive moisture, temperature and humidity can promotes the growth of molds on building material surfaces. Concern issues about biological contaminants has rising when people potentially exposed with these contaminants through inhalation and dermal contacts. Exposure to mold giving many symptoms such as coughing, eye irritation, sneezing, runny nose, congestion, skin rash and asthma aggravation. Indoor dampness and mold growth contribute to severe health effects including infections, allergy and toxin mediated conditions. Porous ceramics is one of building materials that should be considered during residential construction in order to prevent growth of mold and preserve the moisture.

© COPYRIGHT UPM

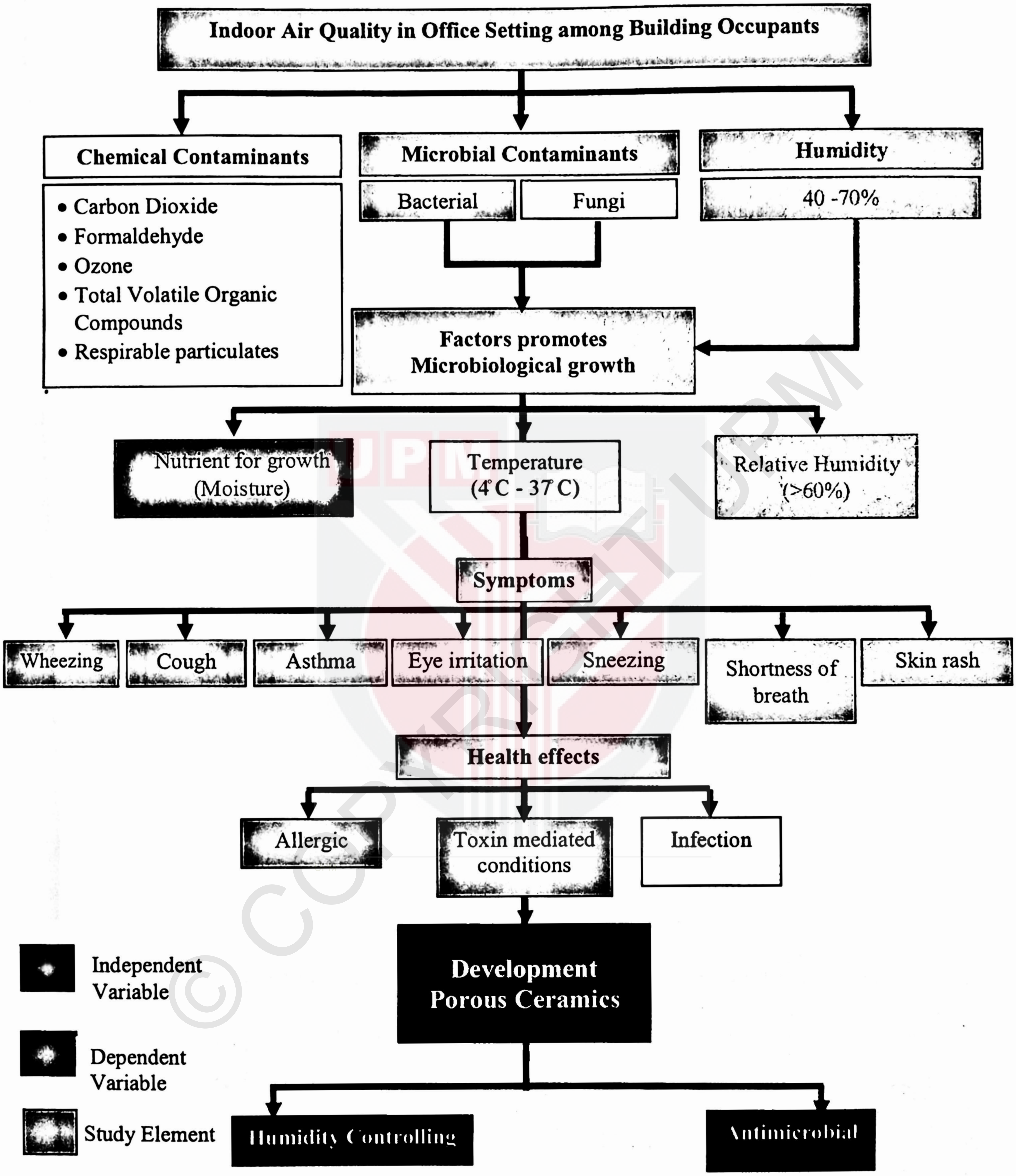


Figure 1.1 The Conceptual Framework of Study

© COPYRIGHT UPM

1.10 Definition of Term

1.10.1 Sick Building Syndrome (SBS)

Conceptual definition: "Sick Building Syndrome generally known as unidentified illness where office workers suffered with acute health including daytime fatigue, eyes and nose irritation and allergies. This is causes of poor indoor humidity setting in a close buildings. In other part, office workers affected with imbalance of humidity where reducing their comfort at the workplace.

Operational definition: It used to describe the illness that suffered by building's tenant due to poor indoor air quality. Generally, this building's tenants have an experience including flu, wheezing, nose and eyes irritation, daytime fatigue, headache or combination of these. In addition, they will feel uncomfortable in this particular buildings. (Industry Code of Practice of Indoor Air Quality, 2010).

1.10.2 Indoor humidity

Conceptual definition: Indoor humidity is one of the indoor comfort issues in indoor environment. Overgrowth of fungus and bacteria is related with high relative indoor humidity and if it is too low, people will suffer from dry skin, lips, hair and mucous membrane in noses and throat dry out, leads to irritation and respiratory illness.

© COPYRIGHT UPM

Operational definition: American Society of Heating, Refrigerating and Air-Conditioning Engineers or ASHRAE (2017) has set the ideal relative humidity to be between 20-70% meanwhile acceptable range set by the Malaysian Industrial Code of Practice of Indoor Air Quality (2010) is 40-70%.

1.10.3 Diatomaceous earth (DE)

Conceptual definition: The diatomaceous earth is potential material that can be used in reducing moisture and inhibit the growth of microbial in indoor setting.

Operational definition: Diatomaceous earth is originated from fossilized remains of tiny, aquatic organism called diatoms. Silica is natural substance that can be found in their skeletons. Diatoms deposited in the sediments of rivers, streams, oceans and lakes over a period of time. (National Pesticide Information Center, 2013)

1.10.4 Humidity Control Material

Conceptual definition: Humidity control material has an ability to control indoor humidity environment and act as moisture absorber.

Operational definition: Materials that can be applied to any surface on building materials and have capability to adjust the indoor humidity during the time by retaining humidity from surrounding air and desorbing it into the air (Zu et, al., 2013).

© COPYRIGHT UPM

1.10.5 Anti-microbial characteristics

Conceptual definition: Medium that can has an ability to inhibit or kill the growth of fungi and bacteria that rest on it.

Operational definition: Antimicrobial resistance is a broader term for resistance in variety kinds of microorganisms and encompasses resistance to antibacterial, antiviral, antiparasitic and antifungal. This is works when the materials that used can inhibit the growth of microbial that rely on this medium *(World Health Organization, 2017)

© COPYRIGHT UPM

CHAPTER 2

LITERATURE REVIEW

2.1 Occupants building in office setting

Building owner or building management has the duty to control the exposure to contaminants and should keep up the workplace fitting with acceptable range. This is in line with the legislation of the Occupational Safety and Health Act 1994 and the Malaysian Industry Code of Practice of Indoor Air Quality (DOSH, 2010).

According to Ahmad & Hassim., (2015), workers in administration office works in the same environment more than 6-hours a day when compared to other types of occupation which involves a more mobile daily tasks. Office workers are exposed to various types of indoor environment which is sometimes can be more contaminated than outside (Ahmad & Hassim, 2015). The previous findings from a study by Fadilah & Juliana., (2012), found that health of the workers in office settings should be taken care by the management of the workplace to ensure that sick building syndrome (SBS) does not arise. In another study by Zuliza et al, (2016) the authors stated that in wet laboratories, almost half of the occupants suffered from SBS and this issue requires attention to ensure it is resolved.

2.2 Prevalence of Sick Building Syndrome (SBS) and SBS Symptoms

Sick Building Syndrome (SBS) is a well-known health effects resulting from of poor indoor air quality. It is one of the major health concerns where building occupants having acute health effect or thermal comfort problems but where no specific illness or cause can be recognized. This health effects showed a significant relationship with the time spent in a buildings (DOSH, 2010). Lethargy, eye, nose and throat irritation, headache, skin irritation and breathing problems are a range of symptom of SBS (Rohizan & Abidin., 2015). World Health Organization (2009), stated that building dampness and indoor mold growth can be related with SBS symptoms. Mold and bacteria compound can be detected in form of dust. Endotoxin that found in dust has pro-inflammatory effects like asthmatic problems.

A study that was conducted by Ahmad & Hassim (2015), found that new buildings (less than 10 years established) had worse air quality compared to old buildings (more than 10 years established). The study went on and found that there was a clear significant association ($p<0.005$) between physical parameters of indoor air quality and ages of buildings (Ahmad & Hassim, 2015). Based on the findings from the survey done, most of the occupants (52.8%) categorized their workplace had very high pollutant presence (Ahmad & Hassim, 2015). The result is supported study done by Fadilah & Juliana., (2012), where occupants in new building showed higher prevalence of SBS (47.4%) when compared to the prevalence of SBS among occupants in old buildings (33.8%). In new buildings, the highest percentage of reported symptoms include dizziness or light

© COPYRIGHT UPM

headedness (36.3%), followed by headache (31.3%), last but not least was tired and strained eyes (30%).

However, these finding contradict with the findings by Zamani et al., (2013) which claimed that prevalence of SBS in new buildings was lower (25.9%) compared to old buildings (68.2%). When statistical analysis was performed, nevertheless According to Zamani et al., (2013) found that the prevalence of sick building syndrome had no significant association with high levels of indoor air quality.

Another comparative study conducted by (Norhidayah et al., 2013) showed that workers in a public library in Pahang had higher prevalence of SBS (35.15%) compared to workers in a public museum building (20%). Most of the workers in the public library reported to have SBS symptoms including dizziness or lightheadedness (27%), strained eyes, tired eyes (24%), sneeze (22%), stuffy nose, runny nose, sinus (16%), itchy, dry, irritation to eyes (16%) and headache (16%). The public library is a relatively newer building although has been built 53 years ago meanwhile the museum was built during the British colonial time of about 100 years ago (Norhidayah et al., 2013).

In terms of possible indoor chemical pollutions, previous study conducted by Zuliza et al., (2016) stated that the prevalence of SBS among workers working in wet laboratories indicated as higher prevalence with irritated stuffy or runny nose (13.4%), headache (10.9%), drowsiness (18.5%) and fatigue (10.1%) compared to dry laboratories where the highest symptoms were irritated stuffy or runny nose (4.1%), headache (1.4%),

© COPYRIGHT UPM

drowsiness (6.9%) and followed by fatigue (5.5%). Both groups of laboratories were housed in the same buildings as such the age of building is not a factor here but the SBS is more likely to be contributed to the presence of chemicals.

2.3 Indoor Relative Humidity

Study done by Zakaria et al (2016), showed that there are a higher relative humidity in a management office which exceeded the acceptable range of 40% to 70%. Monitoring for relative humidity was conducted for seven days and reading obtained were in the range of 70% to 85%. A study by Ahmad & Hassim (2015) revealed the relative humidity in office buildings of Universiti Teknologi Malaysia (UTM) which are slightly higher than the allowable range of 40% - 70%. The environment which had higher level of RH was the Faculty of Petroleum and Renewable Energy Engineering (72.1%), followed by Faculty of Islamic Civilization (68.7%), Faculty of Civil Engineering (66.9%), Faculty of Chemical Engineering (66.7%), Faculty of Management (63.8%) and Faculty of Geoinformation and Real Estate (63.1%). The temperature is inversely proportional with relative humidity.

Rohizan & Abidin (2015) reported that RH in offices at a public university in Malaysia ranged from (67.7-71.3%) which was slightly higher from the acceptable range. It was found that high relative humidity were significantly associated to the reporting of SBS and higher level of relative humidity were found as contributors in the perception of comfort in university laboratories (Rohizan & Abidin, 2015). The study by Fadhilah and Juliana (2012), showed that the relative humidity in new buildings in a public university

© COPYRIGHT UPM

was slightly higher which was 60.80% compared to old buildings 59.10%. One of the offices in the public university revealed that the average relative humidity was 67.05% within seven days of monitoring. However, some of days showed that the relative humidity reading exceeded the allowable range (Ariffin et al., 2013). To reiterate an earlier point, ASHRAE (2017) suggested that the ideal relative humidity for office building is 20-70%, while the acceptable range of RH that were introduced by DOSH is 40-70%. Hu et al., (2017) suggested that ideal relative humidity for resident buildings is 40% to 60%. Having an indoor environment being very dry or very damp will potentially give adverse health effects and impacts the livelihood of the occupants (Hu et al., 2017).

© COPYRIGHT UPM

2.4 Microbial contaminants

According to Hu et al., (2017), large relative humidity can promote the microbial breeding of microbial fast. A study by Orosa & Oliveira (2012) showed that wall problems has a clear relationship with humidity and growth of fungi. Another study also stated that high relative humidity has significant association with mold presence (Rohizan & Abidin 2015). According to Orosa & Oliveira, (2012) in promoting the growth of microbial, there are two primary condition; (1) construction failure of wall of buildings that allow moisture to seep into it and (2) excessive humidity due to poor ventilation, resulting mold dampness. The study went further to report that relative humidity, temperature in indoor conditions was associated with the presence of mesophiles and fungi.

Temperature and moisture levels as basic indoor environmental characteristics could promote the formation and dispersion of microbial contaminants (Kim et al., 2017). It was reported that the formation of bio aerosols were contributed from dead or living microorganisms including bacteria and fungi and bio aerosols can potentially be present in an to indoor environment due to its light weight and small size. In addition, human are also capable of producing bio aerosols from activities such as washing, toilet flushing, talking, walking, coughing and sweeping floors.

OSHA (2009) reported that dampness could cause bacterial growth and allow viruses to survive. Furthermore, it could be an indicator of poor ventilation. Water leakage or damage, discoloration of floor coverings, bubbles, and visible mold on ceilings, walls and floors is defined of the problems related to dampness. Inadequate ventilation and building dampness are both the main factors linked with the presence of microbial contaminants in indoor environment (WHO, 2009). According to ASHRAE, the Standard 62 for Natural and Mechanical Ventilation states that the minimum acceptable range for office building is 20cfm/person (ASHRAE, 2005).

Lower ventilation rates have an ability to influence indoor humidity by increasing moisture levels. Therefore, poor ventilation can be a medium for pathogenic microorganism to be transported and circulated inside the dwellings (OSHA, 2009). The significance of good ventilation in homes is crucial. In order to solve indoor dampness problems, home ventilation performance must be efficient (Sun et al., 2017). Reported by OSHA (2009), the prevalence of airborne infectious disease can be reduced by higher ventilation rates. Hence, ventilation can control the dispersion of airborne viruses or bacteria that cause infectious disease.

Figure 1.2 Mold problems on ceiling

© COPYRIGHT UPM

Water content on or in building materials is the important factors that trigger the growth of microorganism including antinomycetes, fungi and other bacteria. It does not only promote growth of microbes but also emit spores, cells, fragments and volatile organic compounds into indoor air. The presence of these microbes is attributable to dampness on almost all indoor materials (OSHA, 2009). According to (OSHA, 2006), damp or wet building materials and furnishing can promote growth of mold. Dust and dirt, the source of nutrients for microorganisms rely on all materials support the extensive problem of microbial growth (OSHA, 2009)

2.4.1 Health-related Symptoms

The exposure of microbial contaminants to the workers has been reported in literature with the presence of various symptoms including allergic, rhinitis and airway inflammation (Kim et al., 2017). House-dust mites and pets are another factors that can cause allergies (WHO, 2009). It was reported that a variety of infections including ear, nose and lungs has been associated with *Streptococcus* pneumoniae bacteria. Globally, this bacteria attacks susceptible person including children, people with weaken immune systems and the elderly (Kim et al., 2017). A research by (Sun et al., 2017), from all the viruses found, coronavirus accounts for 10-20%, rhinovirus accounts for 15-40% and *S. aureus* were the causes of common cold and causing respiratory infections. Endotoxin is one of the components in bio aerosols. Study conducted by Kim et al, (2009) reported that, endotoxin can be characterized as lipopolysaccharides (LPS) in Gram-negative bacteria with high pro-inflammatory properties. Human are potentially able to inhale to endotoxins wherever they are as it easily binds to dust. Exposure to endotoxins can reduce

© COPYRIGHT UPM

lung diffusion capacity and it is a main factor contributing to occupational lung disease and organic dust toxic syndrome (Kim et al., 2009).

Reported by OSHA (2009), several types of fungi and dust mites are able to produce allergens and can cause allergies and asthma. Toxins and irritants with suspected effects on human respiratory system are attribute by fungi produced. Study conducted by Hussin et al (2011), found that the most common fungal found in indoor were *Aspergillus, Penicillium, Rhizopus, Zygomycetes* and *Fusarium*. *Aspergillus* was the predominant genus found in indoor air samples. Some species of Aspergillus such as *A.flavus, A.versicolor and A.fumigatus* have allergenic, toxigenic and infectious effects (Hussin et al, 2011).

2.4.2 Potential microbial in hospitals

Both exposure of microbial contaminants in occupational and residential environments potentially impacts human health including respiratory disease and asthmatic problems (Kim et al., 2017). *S. aureus* is a common bacterium that can be found in human body including nose and skin. . According to the Rao et al, (2015) *S. aureus* is a leading cause of bacterial infections in hospitals and communities worldwide. Hussin et al (2011) reported that *S. aureus* showed the highest percentage of bacterial found in indoor setting which was 12.73%, followed by *B. subtilis* (6.06%) and *P. stutzeri* (5.45%).

© COPYRIGHT UPM

Methicillin-resistant Staphylococcus aureus (MRSA) is a strain that are resistant to methicillin antibiotic and Sit et al (2017) found that the prevalence rate of MRSA infections were reported to be the highest in Asia (>50%) . MRSA is widely known as pathogen causing hospital and community-acquired infections. According to Sit et al (2017), nosocomial bacteremia has been reported to be norm in public health sector worldwide including hospitals, clinics and thus lead to high mortality. In Malaysia, 21% cases reported to caused by MRSA (Sit et al., 2017).

MRSA spreading by direct contact by touching objects or person that have this bacteria on them. This bacteria is infected to skin through wound cut, bruises or exposed skin. In worst cases, this bacteria can cause severe diseases and life-threatening such as pneumonia.

2.5 Construction and Building Materials

Ahmad & Hassim (2015) reported in their study expert building designers should consider designers of buildings and lifecycle stage from the start. "*Cradle to the Grave*" concept has been suggested in order to achieve ideal IAQ level. Design stage, selection of building materials, construction progression, land operational and building maintenance, all of these stages must be planned in details (Ahmad & Hassim, 2015). Goldstein (2012) proposed a solution of development materials with wanted properties that could lessen the size of the mold contamination issues. The author also added that this arrangement would enable remediation to be more productive and diminish the cost.

© COPYRIGHT UPM

2.6 Product Specification

The stability of indoor relative humidity in rooms can be achieved by using hygroscopic walls and ceilings. A few centimeters of these building materials are enough to buffer the daily relative humidity cycle. For annual cycle of relative humidity, 40 cm of porous ceramics are sufficient to buffer about 0.1 air change per hour in a room ("Humidity buffering by absorbent materials in walls," 2017). The use of porous materials as building materials proved an excellent performance to regulate indoor humidity where this material can ventilate away the moisture generated by human, resulting in even better buffering and less use of energy.

Consideration of materials selection in the development of humidity control materials include good physicochemical characteristics including small size, light weight, better absorption capacity, low price and non-toxic (Hu et al., 2017). In addition, materials supporting healthy living environment and has properties for demand for energy saving is also promoted in the preparation of selection materials. Materials must be capable in improving human health and exhibit excellent moisture adsorption-desorption performance and including being of safe materials origins is advisable (Vu et al., 2011). Materials selection must have an ability to replace the use of air conditioning to control indoor humidity environment by resembling the similar functions and reduce the demands of energy consumption and cost (Vu et al., 2013).

2.6.1 Diatomaceous Earth as Humidity Control Material

Example of good humidity control material reported in literature is diatomaceous earth or DE. DE are unicellular algae, one of the highest classes of the phytoplankton that comprises the bottom of the food chain in oceans and freshwater. DE, mainly contains of siliceous sedimentary rock, widely used as one of building materials that have humidity-controllability. The use of DE when mixed with other materials such as volcanic ash, bentonite, and waste glass has been shown to be used as porous ceramics. Porous ceramics which have absorption and desorption characteristics can also ensure that the relative humidity is maintained at optimum level.

The development processes of HCM by using DE as main materials is as presented in Table 2.1 The factors being considered are process requirements, mixing ratio, dimension of mold, molding pressure, molding time, sintering temperature, sintering time, surface area, building strength and adsorption-desorption performance.

© COPYRIGHT UPM

Table 2.1: Development process of Humidity Control Materials

1.Process requirements and product's criteria	Cement Technology (Vu et al, 2013)	Construction and Building Materials (Vu et al, 2011)	Advanced Powder Technology (Hu et al, 2017)
2. Mixing ratio	Diatomite and powdered waste glass	Diatomite and volcanic ash	Diatomite/ground calcium carbonate
3. Dimension of mold	15cm x 15cm x 0.5cm	50mm x 6mm	Not available
4. Molding pressure	60 tons	32Mpa	414Mpa
5. Molding time	20 minutes	Not available	Not available
6.Sintering temperature	900-950°C	1000 - 1000°C	Not available
7. Sintering time	20 minutes	30 mins	Not available
8. Surface area	5.74-12.76 m^2/g	14.1±1 - 65±376 m^2/g	Not available
9. Bending strength	112±17-232±20kg/cm^2	460±21 – 487±20 kg/cm^2	Not available
10.Adsorption-desorption performance	8.61-9.83%	Not available	8.00-11.66%

© COPYRIGHT UPM

2.6.2 Antimicrobial Filler Materials

To add to the ability of HCM for antimicrobial activities, the use of several filler materials has been reported in literature. Table 2.2 presents potential materials that have an ability as antimicrobial characteristics that can be mixed with DE as porous ceramics In considering materials being of local origins, oyster shell are primarily found in Malaysia and is considered as waste products. Large amount of shells piled up near the seaside making problems including unpleasant smell and thus, source of pollution can be reduced and the waste exploited as a resource (Xing et al, 2013).

According to Mohammad et al, (2017), oyster shell ash can be alternative materials replacing limestone that used in cement production. The author added that percentage of calcium carbonate in oyster shell is similar with percentage of calcium carbonate in limestone. This study supported by Espinosa, oyster shell contain 97.5% of calcium carbonate, which can be an ultimate source of calcium oxide after applied with heat treatment.

Xing et al, (2013) reported that oyster shell have anti-fungal characteristics at high concentration. In addition, heat-treated oyster shell powder exhibited anti-fungal activity at 500 ppm. The author reported that CaO that can be found in oyster shell against pathogenic fungi including *R. solany*, *P. piricola*, *P. asparagi* and *A. solany*. Sawai & Yoshikawa (2003) claimed that magnesium oxide (MgO) and calcium oxide (CaO) against gram-positive and gram-negative bacteria. The author reported that these components can be used in controlling microbial in the environment.

Table 2.2: Materials with antimicrobial characteristics

No	Formula		Characteristics	Microorganisms detected	References
1	Modified DE		Antimicrobial	Fungal *A. alternata* *C. globosum* Bacterial *E. coli* *S. aureus*	(Fernández & Bellotti, 2017)
2	Types of seashell	Cockle shell	Anti-bacterial	Not available	(Hamidi & Zulkifle, 2013)
		Oyster shell	Anti-fungal	*R. solani* *P. piricole* *A. solany* *P. asparegi*	(Xing et al., 2013)
3	Date palm powder		Anti-bacterial	Not available	(El Hassni, El Hadrami, Daayf, Barka, & El Hadrami, 2004)
4	Husk fiber of coconut		Anti-bacterial	S. aureus	(Esquenazi et al., 2002)
5	Arabic Gum		Anti-microbial	Not available	(A., L., Valle, & D., 2012)
			Anti-fungal	Not available	(Maqbool, Ali, Ramachandran, Smith, & Alderson, 2010)

© COPYRIGHT UPM

2.6.3 Waste glass as filler materials

Recycled glass can be obtained from several sources such as flat glass, glass bottle, lamps and television screens. Few research has been conducted in using recycled glass to develop ceramic raw materials (Fraga et al, 2011; Lodins et al, 2011). Main components in waste glass including silicon, sodium and calcium oxide are the best composition that can be used in the ceramic industry either as flux agent or glazes (Fraga et al., 2011). As flux agent, it will helps to interact the particles during the sintering. The fluxing agent melts and binds particles to each other. A thin layer of glass can created a ceramic glaze on the ceramic surface to enhance the aesthetic appearance and also to waterproof the artifact (Hotza & Oliveira, 2014)

According to Lodins et al., (2011) mineralogical composition of glass-ceramics in crystalline phases were identified by XRD analysis which are quartz (SiO_2), anorthite ($CaAl_2Si_2O_8$) and hematite (Fe_2O_3) could ensure the high density of materials and improve the mechanical properties of material. Another study by Chinnam et al., (2015) , waste derived glass ceramics made from waste residues are found to be chemically stable and exhibit improved mechanical and functional properties in comparison with the parent glass. In addition, this porous glass ceramics are suitable use in sound insulation, thermal insulation and as lightweight aggregates in concrete(Chinnam et al., 2015).

CHAPTER 3

METHODOLOGY

3.0 Study Design

This study is categorized as a cross-sectional study with an addition of a part of experimental study. The cross-sectional study recruited study participants of office workers to determine the extent of Sick Building Syndrome (SBS) problems and humidity related problems among workers in selected offices in Malaysia.

The experimental study consists of the development of porous ceramics. Porous ceramics is one of the building materials that were suggested in previous studies in order to diminish problem related with poor indoor air quality. As have been mentioned earlier, it is hypothesized that porous ceramics can be used to reduce humidity and with this potential it can reduce the problem of high relative humidity in office setting. Due to these characteristics, porous ceramics was ensure that the high relative humidity is maintained because of its desorption abilities.

In addition, mold problem which are attributable to the accumulation of bacteria and fungi in some building materials including walls, furniture and tiles can be solved by using this porous ceramics. It has an ability to kill any fungi and bacteria that lay on this ceramics and in turns reducing mold problem in office setting. Thus, the resulting products will have humidity-controlling and anti-bacterial characteristics which will improve indoor environmental quality.

3.1 Study Location

As for the first part of the study, the administration offices in the Faculty Medicine and Health Sciences, Universiti Putra Malaysia (UPM) were selected for the cross-sectional study where a survey related to indoor humidity problem including mold contamination were performed. The administration offices were categorized as new buildings where it is aged about 20 years. Previous study showed that there were issues with high relative humidity related with improper performance of ventilation system in new buildings (Ahmad & Hassim, 2015). The use of MVAC has been practiced to regulate humidity, in addition to cooling the building of thermal comfort. However, for the best performance, it needs to be run throughout the year and this is not an option because it is costly. This problems leads to imbalance of indoor humidity inside the buildings. In order to determine the extent of the relative humidity problems, the survey need to be done in the office setting

For the second part of the study, porous ceramics were developed at the in Institute of Tropical Forestry and Forest Products (INTROP) at UPM and the performance of anti-bacterial was tested in Medical Microbiology and Parasitology Laboratory located at Faculty Medicine and Health Sciences of UPM.

© COPYRIGHT UPM

3.2 Study Population

The target population survey to identify the extent of the problem of relative humidity were male and female workers in administration office in each department of Faculty of Medicine and Health Sciences, UPM. The selection of employees in the administration office were relevant because the employees spend their time during working days for at least 8 hours in similar workplace environment. The participants were selected when being considered to lecturers and students. Lecturer and students needs to move from one place to another every day while workers in administration offices commonly works in a similar environment.

3.3 Study sample

3.3.1 Inclusion criteria

- Male & female workers in administration office, Faculty of Medicine and Health Sciences
- Works more than a year
- Age: 18-56 years

© COPYRIGHT UPM

3.4 Sampling

3.4.1 Sampling Method

The sampling method for respondent selection was purposive sampling. The respondents were selected based on their availability during the sampling. Those respondents who fulfilled with the inclusion criteria will be initiated to be invited to participate in the questionnaires survey.

© COPYRIGHT UPM

3.4.2 Sampling Size

The sample size of this study was based on Lemeshow & Lwanga (1990). The formula used is below:

$$n = \frac{z^2_{1-\alpha/2}\, P(1-P)}{d^2}$$

n	= sample size
$z^2_{1-\alpha/2}$	= standard errors associated with confidence intervals, 90% (1.645)
P	= highest prevalence
d	= decision precision (0.1)

According to the previous study, the prevalence of SBS in the office setting is 0.47 (Fadilah & Juliana, 2012).

Therefore, the sample size is,

$$n = \frac{(1.645)^2 \times (0.47)(1-0.47)}{(0.10)^2}$$

n = 67.4

An additional 10% of study population will be included to reduce low response rate.

n = 67 + 10% (67)

n = 74 workers

© COPYRIGHT UPM

3.5 Study Instrumentation

3.5.1 Questionnaire

A self-administered questionnaires was designed to determine the extent of Sick Building Syndrome (SBS) and humidity related problems among workers in selected offices in Malaysia. Input gathered from the surveys was used to determine the potential humidity materials to be used to develop porous ceramics with characteristics of humidity absorption-desorption performance and anti-bacterial properties. The link between humidity problems gathered in the questionnaire will strengthen the justification for the development of the porous ceramics. From evidence found in several literatures (Zuliza et al., 2016; Fadilah & Juliana., 2012; Ahmad & Hassim., 2015) humidity problem faced by the occupants in a tropical country setting is different from what is found in a temperate countries. This is linked with the system of air ventilation that is used in Malaysia, which is mainly the MVAC system while in temperate countries, the system typically used is the Heating, Ventilating and Air-Conditioning system (HVAC).

The MVAC system is a central cooling system attached to the AHU and does not involve conditioning that can be found in certain small offices and most often found in homes. Both systems operates differently as such problems with regards to indoor air pollution is different. For instance, the cooling process that takes place in an office such as in the faculty runs at selected times throughout the day. During this time, the humidity (measured in relative humidity with the unit of %) differs and fluctuate (reduces from 90 to 75%) when the air-conditioning is switched on. As such, the humidity builds up during the night causes impact on the indoor air, which by hypothesis will propel the growth of microbial. This problem will intensify when the AHU is not maintained regularly. On the other hand, when the air-conditioning is switched off, the humidity may rise up to 90% and high humidity for a lengthy period of time will in fact contribute to increased development of fungi and proliferation of bacteria when there are sources that contribute to this.

Identifying the problems affecting participants in the study, using the said questionnaire will give inkling to what may be the problem with the indoor air. The problem may be not restricted to just humidity, but may be related to fungi (or mold growth). Having identified the problems with regards to the indoor air will help in the development of the porous ceramics in two ways such as the following.

The first is, the formula or ratio of the materials used. The formula or ratio used in several combinations affects the ability of humidity adsorption and desorption and its physical properties as well such as the impact strength test. Having much more percentage of diatomaceous earth in the formula or porous ceramics will cause increased ability in the percentage of humidity adsorption. The humidity adsorption will be tested using humidity adsorption-desorption method in this study. Thus, this study will need to identify the best formula that absorbs suitable humidity percentage for a specified type of environment such as found in this study.

© COPYRIGHT UPM

Secondly, information from the survey will proceed with anti-microbial performance of the porous ceramics. DE and other raw materials being used have the added ability of anti-microbial property. According to the Fernandez & Bellotti (2017), modified DE has some antimicrobial ability. Evidence showed that there clear inhibition zones around the samples by agar diffusion test against fungal and bacteria. *Alternaria alternata* was the most susceptible fungi from the results of the larger diameter of inhibition zones compared to others. To add to the microbial properties, other raw materials such as oyster shell can be added because it has been used as a material to eliminate gram-negative bacteria in dust (Zulkifle, 2013). Dusts are commonly associated with airborne endotoxins in the environment. Endotoxins are toxins that can be found on the bacterial cell wall that composed of proteins, lipids and lipopolysaccharides (OSHA, 2009)

Affirmative answers from the questionnaire with regards to the mold problems will enable this study to factor the anti-microbial ability in the development of this porous ceramics. The anti-microbial ability of the porous ceramics developed will be tested in the laboratory setting, as opposed to testing it in a field setting considering the limitation in time for such a short project.

This questionnaire was modified from the survey form of Bio aerosol Exposure among Veterinary Doctor and Respiratory Related Symptoms (Abidin et al, 2017), "Industry Code of Practice on Indoor Air Quality (DOSH, 2010)", "International Union against Tuberculosis and Lung Disease Questionnaire (1984) (Burney et al, 1989)" and

© COPYRIGHT UPM

"Questionnaires in Building-related Illness and Sick Building Syndrome Surveys (Andersson & Stridh, 1991)". This questionnaire was used to obtain health problems and respiratory related symptoms from the respondents. The occupant's perception about the working environment was determined to describe the indoor climate in terms of odor, perception of humidity and microbial problems. Modified questionnaires consists of six sections as below:

- **Section A: Socio-demographic Information**
- **Section B: Employment Information**
- **Section C : Sick Building Syndrome (SBS) Symptoms**
- **Section D: Work Environment**
- **Section E: Extension humidity problems in offices**
- **Section F: Intervention to improve indoor air quality in offices**

The pre-test questionnaire was conducted among workers in administration office, UPM but in different places to determine the validity in term of clarity of the questionnaires. This questionnaire was validated by the expert within in the field of Environmental health. This pre-test questionnaires was distributed to at least 10% from the total of sample size of the respondents but they were not included in the study as respondents.

© COPYRIGHT UPM

3.5.2 Experimental Part of the Study

Development of porous ceramics using mixture of DE method was referred to the method in previous a study entitled "Humidity control materials prepared from diatomite and volcanic ash", conducted by Vu et al, (2013). The method used to determine the moisture adsorption desorption performance was referred to the method reported by Japanese Industrial Standard (JIS) A 1475-2004. For the agar-diffusion method, a previous study conducted by Fernandez & Bellotti (2013) and Xing et al (2013) were used to test the anti-bacterial and anti-fungal performance. Both of these method has been modified due to materials suitability.

3.5.2.1 Preparation of Samples

i. Preparation of Diatomaceous Earth

The main porous material, DE was bought from Green Integrity Trading (GIT Sdn Bhd, Malaysia), Diatomaceous Earth Food Grade supplier in Kuala Lumpur. This sample was stored in room temperature to preserve the products from interacting with humidity

ii. Preparation of Waste Glass

Waste glass was collected from a recycling company at Machap, Johor. The waste glass was dried at 105°C for 24 hours and was grinded using wet-ball mill machine. The waste glass was then dried again at 105° C. The powdered waste glass were then sieved

© COPYRIGHT UPM

using a sieve with mesh of 300μm and were then stored in polyethylene plastic bag for the next process in the development of porous ceramics.

iii. Preparation of Oyster Powder

Figure 3.1: Oyster shells after being cleaned with tap water

Oyster shells were collected from a wet market at Putatan, Sabah. The method for preparation of oyster shell powder was adopted from (Mohamad et al, 2016). The raw oyster shells were washed thoroughly with tap water. The shells were then brushed to clean up the impurities found on the shells and ensure there were not mud left. Next, the cleaned oyster shells were boiled for 15 minutes at 100°C and cooled at room temperature. The contents of the shells were then removed and cleaned with distilled water. The shells were then exposed and dried under the sun for a day. Drying is important to avoid agglomeration during grinding process. After that, pestle and mortar was used to crush the oyster shell into small pieces. The powder obtained was then sieved with 106μm stainless steel sieve shaker. The oyster shells powder was then kept in the polyethylene plastic bag for development of porous ceramics.

© COPYRIGHT UPM

3.5.2.2 Development of Porous Ceramics

Figure 3 showed the modified DE products mixed with waste glass and oyster powder in different ration. By using compression molding presses, model CMV100H-20-BCLPX serial #10967, the mixed samples were pressed at 60mPA for 5 minutes. The pressing allows the initial powder form of humidity control materials to sustain its molded shape.

Table 3.1: The percentage ratio of the mixed samples

Materials	DE	Waste Glass Powder	Oyster Shells Powder
50-30-20	50	30	20
60-30-10	60	30	10
70-20-10	70	20	10
80-10-10	80	10	10

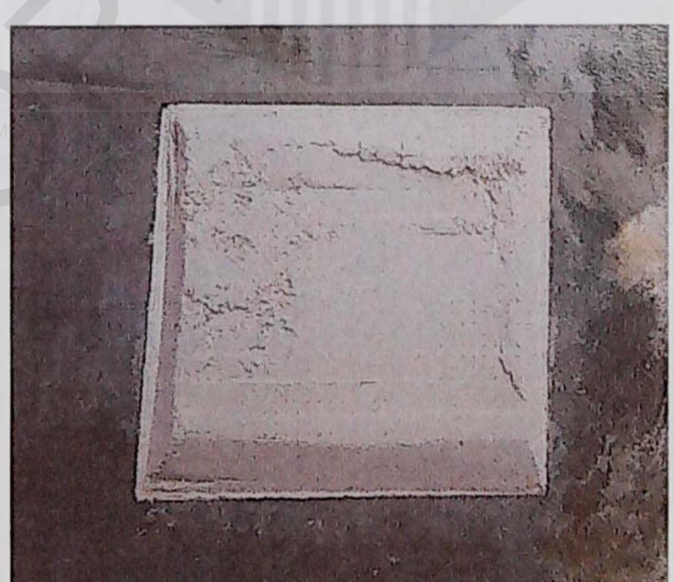


Figure 3.2: Modified DE in a mold

© COPYRIGHT UPM

Figure 3.3: Green compact product

As shown in figure 3.3, green compacts with dimension area of 15cm x 15 cm and 5mm in height were produced from the molding process. The green compacts pieces were the placed on aluminum foil and the weight before sintering were measured and recorded.

Figure 3.4: Green compact in furnace

The green compacts were sintered as shown in figure 3.4, in "DAIHAN" Wise Therm (R) digital muffle furnace, manufactured by Daihan Scientific, Korea, at 1100°C

© COPYRIGHT UPM

for 20 minutes. All the green compacts that have been sintered are dried at 105℃ for 24 hours before being analyzed and kept in desiccators. The sintered samples are now sturdy pieces of samples that have a tile-like shape

© COPYRIGHT UPM

3.5.2.3 Humidity adsorption-desorption test

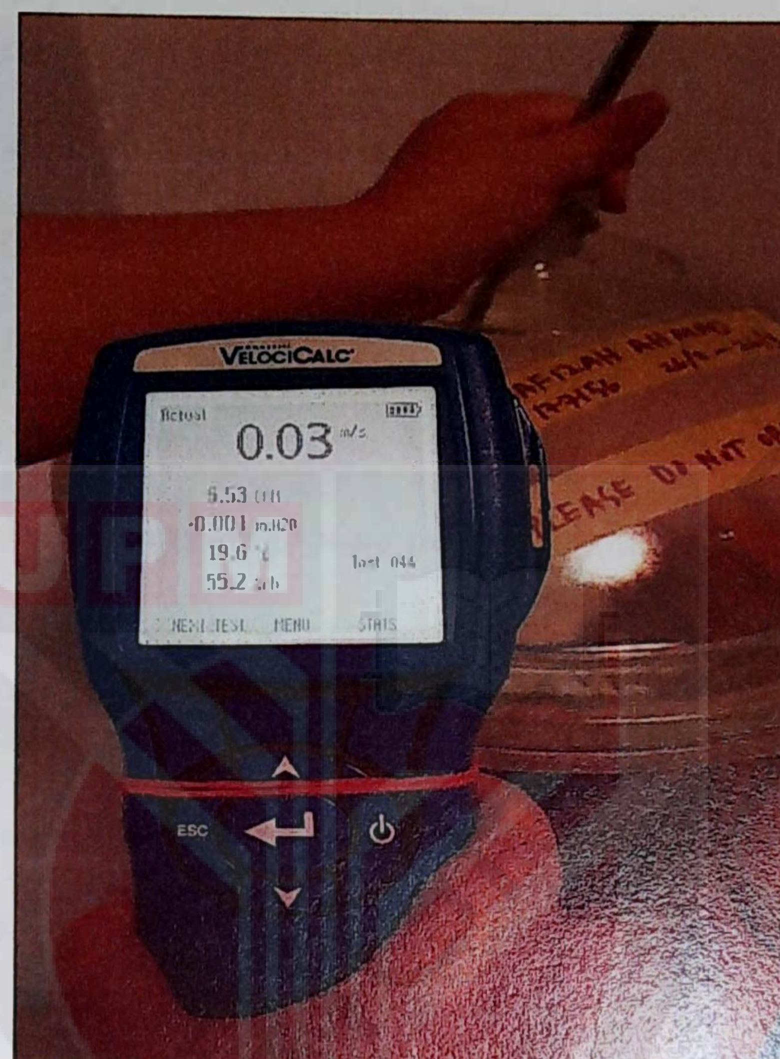


Figure 3.5: Relative humidity reading

The humidity control testing of sintered samples were tested in a desiccator and placed in a room, located at the Environmental Laboratory at Faculty of Medicine and Health Sciences. The test were performed using TSI VelociCalc® Air Velocity Meter to measure the relative humidity inside the desiccator. The specific relative humidity was generated in the form of water vapor from saturated salt solution using a Japanese standard method (JIS, 2017). Two different relative humidity generated were from saturated salt solution with magnesium nitrate for 53% RH and sodium chloride for 75% RH. Weight difference of sintered samples was monitored to examine the moisture absorption-desorption abilities. The temperature was constant at 25℃ in the desiccator. The process is as follows: firstly, the sintered samples were kept with magnesium nitrate (53% RH) and the relative humidity was recorded as shown in figure 3.5. The RH for desorption was 53% while for adsorption process was 75%. Sodium chloride was used to generate 75% of relative humidity. These relative humidity is to realize the condensation process occurred in the desiccator, thus allowed the water vapor generated by the salt solution adsorbed by the sintered samples. Meanwhile, magnesium nitrate was used in desorption to allow the evaporation process occurred in the desiccator. The water vapor that trapped in pore of sintered samples was escaped and evaporated to the top of desiccator. This process takes place for a duration of approximately three days.

The sintered samples were wrapped on the sides with aluminum foil and tape, except on the top surface, to allow water vapor to adsorb and desorb through it. When the relative humidity was constant at needed value, the weight of sintered samples will be measured. Next, the relative humidity was then changed. Figure 3.6 shows the measuring of relative humidity in the desiccator after the salt solution has been replaced. This humidity was maintained for 24 hours to stabilize in this condition.

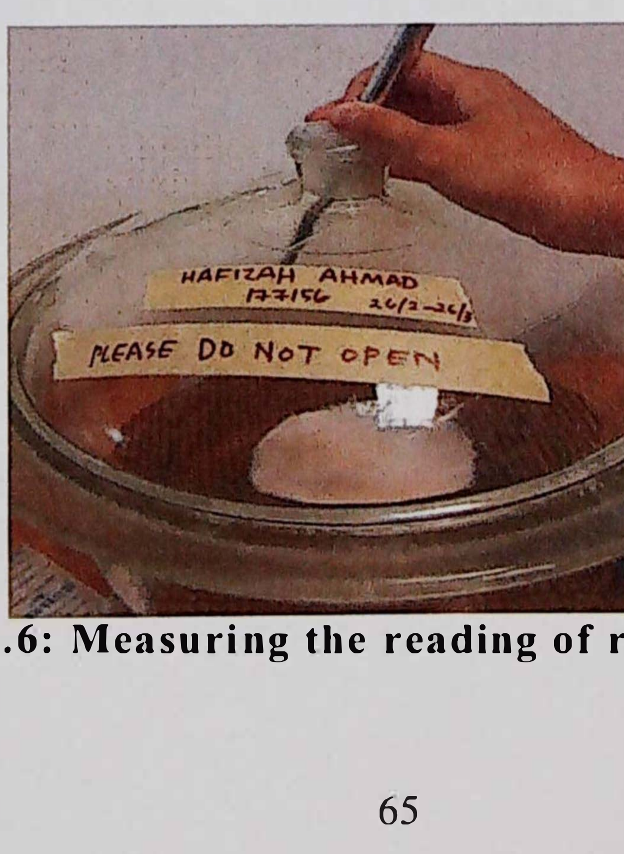


Figure 3.6: Measuring the reading of relative humidity

© COPYRIGHT UPM

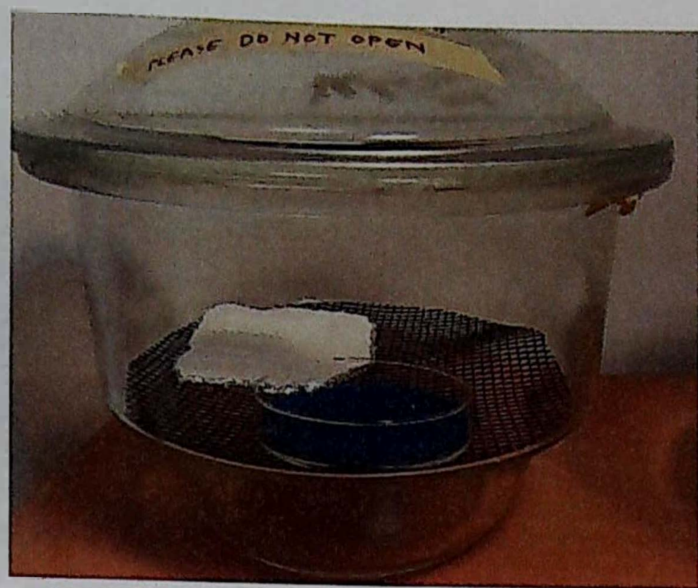


Figure 3.7: Silica gel was placed in desiccator with a sample

After completing the adsorption process using sodium chloride 75%RH, the humidity was changed with magnesium nitrate salts (53% RH). The reading was immediately recorded 2 hour after the salt solution was changed. Silica gel was placed in a similar desiccator to keep the relative humidity which is 53% RH constant. The salt solution (magnesium nitrate) inside the desiccator cannot retain the relative humidity for the expected duration of time as sodium chloride. This problems affects the will desorption process and the reading of the samples as well. In order to solve this problem, the salt solution from magnesium nitrate needed to be changed every four hours. However, due to budget constraint, silica gel was used to replace the magnesium nitrate.

The percentage of adsorption or desorption moisture content was calculated as below:

$$C = \frac{W - W_0}{w_0} x\, 100\%$$

W = adsorption/ desorption moisture weight

W_0 = initial weight

© COPYRIGHT UPM

3.5.2.4 Agar Diffusion Test

Optimization of the method

Few methods has been tried and repeated within eight weeks to get the optimization methods. These methods needs to be conducted in order to identify the best method that can be applied and is suitable with ceramics samples used. All the trials methods that has been used within these eight weeks were as followed;

i. Placed the ceramic samples directly into the wells provided in powder form, this method was not effective for the ceramic samples, as it cannot diffuse well into the red blood agar.
ii. Placed 20mg of ceramic samples and 20μl of distilled water directly into the wells provided. The plates were then intubated however the results did not show any inhibition zones present. It was later concluded that this method was not practicable for the said reason and that the concentration of ceramic samples used was unable to be determined.
iii. By referring few methods from (Fernandez & Bellotti, 2017; Saniayasiaya et al, 2017; Xing et al, 2013 and Maqbool et al, 2010) which has been modified. 1g of ceramic samples in powder form was dissolved in 20ml of distilled water. These mixed solution was heated at 100° C for 30 minutes to allow the homogenization process occurred. This mix solution was prepared a day (16 – 24 hours) before it can be used in antimicrobial testing. These methods was characterized as the best method and can be applied for ceramic samples.

© COPYRIGHT UPM

iv. Red blood agar and Trypticase Soy Agar (TSA) has been used in order to determine the best agar that suits with ceramic samples. Blood agar that contains general nutrients and 5% sheep blood is useful in determining the hemolytic capabilities of an organism. Bacteria produce hemolysins, which is exoenzymes that lyse the red blood cells and degrade the hemoglobin completely. As such results, the reaction will leaves a clear zone around the bacterial growth. Meanwhile, TSA is only suggested for growth medium for the isolation and cultivation of microorganism. Despite of that, blood agar has been selected to determine the antimicrobial performance as it was concluded as the best type of agar for this study.

Sample preparation

For the agar diffusion tests, the sintered samples have to be prepared in the form of powder. Pestle and mortar was used to crush and grind the ceramics samples into fine powder form. About 1g of each sample was diluted in distilled water and heat up at 100° C for 30 minutes. This step was done to ensure the mixture of powder and distilled water was homogenized. All the samples were kept in universal sterile container for next process. The powder mixture took about 16- 24 hours to allow the adsorption of distilled water into it. This will enhance the diffusion of mixture powder towards the agar during agar diffusion process.

© COPYRIGHT UPM

Bacterial culture

For culturing of bacteria, blood agar plates were used. Red blood agar plates were purchased from ISOLAB Sdn Bhd at Kota Kemuning, Shah Alam. This method was used to grow and store the stock of bacteria for antimicrobial testing. *Staphylococcus aureus* ATCC -positive 12228, which are Gram positive bacteria and *Pseudomonas aeruginosa* which are gram-negative bacteria were used to testing. *S. aureus* bacteria is the gram-positive bacteria with the highest colony numbers and percentage in indoor air found inside building environment that found inside the building (Hussin et al, 2011). While for the *P. aeruginosa* is gram-negative bacteria has been characterized and identified bacteria exist in the building (Hussin et al, 2011).

To ensure the sterility of medium, all the steps of microbial assay must be conducted in the laminar flow hood using good sterile technique. The method for the culturing of bacteria are as follows: first, sterilize the laminar air flow with alcohol; second, *S. aureus* was obtained from the Laboratory of Medical Microbiology and Parasitology and was placed in refrigerator inside the ice box to preserve its shelf life; third: before streaking the bacteria onto blood plate ager, thaw it first; forth: pipette tip was used to scrape the bacteria and put in on the blood agar plate; fifth: then, use a sterile loop to streak the bacteria. After completing the five successive steps, grow the bacteria in incubator in an upside down position at 37° C for 24 hours.

Antibacterial assay

Plate from the bacterial culture was taken out from incubator. Scrape the bacterial colonies of *S. aureus* with a sterile loop, inoculate the bacteria in sterile normal saline, and incubate it until 0.5 Mac Farland standard turbidity were obtained, then used for assay. The concentration was adjusted to 10^8 CFU/mL to bacterial strains.

The test tube with microbial suspension was then prepared by removing the cap and sterilized on a gentle flame. Pipette the bacterial broth from the tube with pipette tips to inoculate on the blood agar and repeat the flame sterilization to avoid contamination. Swabbed the blood plate agar from side to side motion with sterile cotton swab. This is to ensure bacteria growth is uniformly. Slightly rotate the plate and use in different motions. After the entire surfaces of the plate has been covered, dispose the cotton swab in the bio-hazard container.

The blood plate agar were then divided into five equal quadrants using a marker. Well of 8mm were made with the help of blue pipette tips. Well sizes was measured and labelled from 1-5 for each type of the samples of porous ceramics prepared at the back of the red blood agar plate.

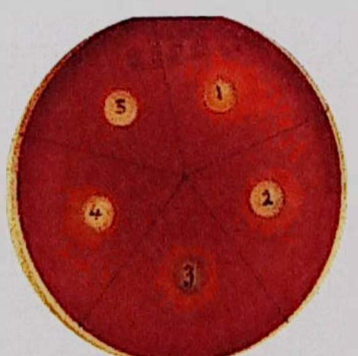


Figure 3.8: Label of ceramic sample on red blood agar

© COPYRIGHT UPM

The label of ceramics sample as figure 9;

1: 1g of raw DE

2: 1g of raw oyster shells

3: 1g of raw oyster shells and 1g of DE

4: 1g of formula sample without undergo heat treatment

5: 1g of formula sample after undergo heat treatment (1100°C)

Approximately 100 µl of ceramics samples homogenized in distilled water were transferred into the wells provided. All the ceramics samples were using Eppendorf® MixMate® Vortex Mixer for 5 seconds before it will transferred to wells. All the plates with ceramics sample were kept in the incubator for 24 hours at 37°C with a lid side up position. Three replicates were made to get the mean clear zone diameter. Finally the inhibition zones diameters were measured.

© COPYRIGHT UPM

3.5.2.5 Impact Strength Test

This method was adopted from Agbayani & Espinosa (2006). Impact strength test was done to gauge the limit of porous ceramics to withstand the different loads. Load (100g, 200g, and 500g) will be dropped on porous ceramics in increasing weight with similar height (0.68cm) and marks will be given based on rating scale below.

Rating scale;

10 – Extensive damage, crushed

20 – Broke into fragment

30 – More cracks but did not break into fragments

40 – Chipped; few cracks

50 – No cracks, no damage

© COPYRIGHT UPM

3.6 Procedure Data Collection

Approval from the ethical board committee of Universiti Putra Malaysia.

The methodology was based on the objectives.

For objectives to determine the extent of Sick Building Syndrome (SBS) problems and humidity related problems among workers in selected offices in Malaysia. The questionnaire was distributed to the administration office in FMHS

For objective to identify potential materials with characteristics of moisture absorption-desorption performance, anti-microbial characteristics, DE and oyster has been selected in developing of porous ceramics.

To develop humidity-controlling, antimicrobial of porous ceramics, cheap, low-cost and environmental friendly materials were used as the material for the porous ceramics.

To determine the ability humidity absorption-desorption performance of the potential materials, the method of Japanese Industrial Standard (JIS) A 1475-2004 was used.

Agar-diffusion method by Fernandez & Bellotti (2017) was used to determine the antimicrobial performance of the potential materials

Data obtained were entered in statistical software and was analyzed according to the objectives

© COPYRIGHT UPM

3.6 Data Analysis

IBM SPSS (Statistical Package for the Social Sciences) version 22 was used to analyze the data obtained. As shown in table 3.2, descriptive analysis was performed to analyze socio-demographic information of respondents and the extent problems of relative humidity.

Table 3.2: Data Analysis Methods Based on Study Objectives

Objectives	Data Analysis Methods
To determine the extent of Sick Building Syndrome (SBS) problems and humidity related problems among workers in selected offices in Malaysia.	Descriptive statistics
To identify potential materials with characteristics of humidity absorption-desorption performance and antimicrobial	Not applicable
To develop humidity-controlling, antimicrobial of porous ceramics from modified DE	Not applicable
To determine the ability of humidity absorption-desorption performance of the potential materials	Descriptive analysis
To determine the ability of antimicrobial performance of the potential materials	Descriptive analysis

© COPYRIGHT UPM

3.7 Quality Control

Pre-test questionnaires were distributed to 10% of total sample size from same population with similar inclusion criteria and background to ensure the quality of data. The questionnaire were re-check before leaving the fieldwork to ensure no missing information or incomplete answered by the respondents. The reliability test was conducted and found that the reliability of the questionnaire was 0.84.

During handling of desiccator, ensure the reading in a constant of temperature and relative humidity, hence comply with the standard use. Properly remove the sample from desiccator and cover on top of the sample before measure the weight change. After reaching the constant weight, subtract with the mass that used to cover the sample. Similar weigh balance was used for weighing the test specimen and soft burh or damp towel was used to clean the balance pan after and before use. Weigh balance was inspected, cleaned and calibrated annually by an ISO 17025 by accredited vendor.

For antimicrobial test, measure the diameter from the back of the plate. Maintain particular density of the organism needs. If the density is low, it would not lead the formation of lawn growth of agar meanwhile if the density is too high, it would not allow the proper development of zone of .inhibition. Make sure no excess moisture present on the surface of medium.

3.8 Ethical Consideration

The gathered information about the respondents was confidential. Written consent was obtained from the respondents prior to data collection.

© COPYRIGHT UPM

CHAPTER 4

RESULT

4.1 Distribution of sociodemographic of respondents

A total of 69 respondents agreed to participate in the questionnaire part of the study however only 64 of respondents were selected. After considering the inclusion criteria, the rest of them need to be dropped from this study. The respond rate was 86.49%, (n=64). Approximately 62.5% (n=40) of them was female. About half of the respondents were within the average age of 35-44. Almost all of the respondents were Malay 95.3% (n=61) and more than two-third of them were married (76.6%). Only eight respondents reported to be current smoker while 14 of them had a history as former smoking.

About 14.1% of respondents revealed that they have a history of asthma meanwhile 21.9% (n=14) of them have sinusitis. A small number if the respondents have a history of eczema 6.3% have history of eczema. One-tenth of the respondents 10.9% (n=7) stated that their siblings suffer from asthma and allergies (asthma, sinusitis or eczema), while 4% were reported for their mothers and only 1.0% for their fathers. Table 4.1 explains the distribution of socio-demographic characteristics of respondents in this study.

Table 4.1: The distribution of socio-demographic characteristics of respondents among office workers in a public university (n=64).

Variables	*F*	*%*
Age		
25-34	27	42.2
35-44	32	50.0
45-60	5	7.8
Gender		
Male	24	37.5
Female	40	62.5
Ethnicity		
Malay	61	95.3
Chinese	2	3.1
Indian	1	1.6
Marital Status		
Single	15	23.4
Married	49	76.6
Smoking status		
Never smoked	42	65.6
Former smoker	14	21.9
Current smoker	8	12.5
History of asthma	9	14.1
History of sinusitis	14	21.9
History of eczema	4	6.3
Family history with asthma, sinusitis, or eczema		
Mother	4	6.3
Father	1	1.6
Siblings	7	10.9
Others	16	25.0

© COPYRIGHT UPM

4.2 Distribution of employment information of respondents

About 40.6% of the respondents worked in a range of 5 to 10 years. More than half of the respondents worked 8 hours in a day and almost 90% had worked five days a week. Almost 70% claimed that they worked in open space with partner while the rest of them worked in private office (6.3%), shared private office (17.2%), and open space without partner (6.3%).

A total of 67.2% (n=47) of respondents disclosed that the ventilation systems that occupied in their office room was MVAC while 32.8% (n=21) was split unit air conditioning. Both of ventilation systems were operated between 1 to 8 hours in a day and the rest of them reported that the ventilation system was run more than 9 hours in a day. The distribution of employment information tabulated in table 4.2.

© COPYRIGHT UPM

Table 4.2: Distribution of employment information of respondents among office workers in a public university (n=64)

Variables	*F*	*%*
Employment duration		
5 years and less	22	34.4
5 to 10 years	26	40.6
10 years and above	16	25.0
Duration of work in a week (days)		
1- 5 days	58	90.6
6 – 7 days	6	9.4
Duration of work in a day (hours)		
1 – 8 hours	38	59.4
9 hours and above	26	40.6
Type of room		
Private office	4	6.3
Shared private office	11	17.2
Open space with partner	44	68.8
Open space without partner	4	6.3
Others	1	1.6
Type of ventilation systems available in office		
Split Unit Air Conditioning	21	32.8
Mechanical Ventilation Air Conditioning	43	67.2
Split Unit Air Conditioning run in a day (hours)		
1 – 8	15	23.4
9 and above	7	10.9
MVAC run in a day (hours)		
1 – 8 hours	24	37.5
9 hours and above	18	28.1

© COPYRIGHT UPM

4.3 Prevalence of Sick Building Symptoms (SBS)

The highest prevalence of SBS symptoms reported among the respondents in this study was headache (59.4%), followed by coughing (42.2%), heavy headed and hoarse, dry throat (40.6%). The least percentage of SBS symptoms among respondents were asthma attack (9.4%), chest tightness (12.5%) and wheezing or whistling (17.2%). The prevalence of SBS symptoms in a range of 9.4% to 59.4%. Overall, the prevalence of SBS was 73.4%. The results of SBS symptoms are presented in Table 4.3.

© COPYRIGHT UPM

Table 4.3: Prevalence of Sick Building Syndrome (SBS) symptoms among office workers in a public university (n=64).

SBS symptoms	*F*	*%*
Wheezing or whistling	11	17.2
Chest tightness	8	12.5
Shortness of breath	14	21.9
Asthma attack	6	9.4
Coughing	27	42.2*
Phlegm	24	37.5
Nausea / Dizziness	18	28.1
Difficulties in concentrating	13	20.3
Itching, burning or irritation of eyes	17	26.6
Fatigue	23	35.9
Heavy-headed	26	40.6*
Headache	38	59.4*
Irritated, stuffy or runny nose	21	32.8
Hoarse, dry throat	26	40.6*
Hands dry, itching, red skin	18	28.1
Dry or flushed skin	14	21.9
Calculated SBS	**47**	**73.4**

*SBS is interpreted as "yes" if the respondents suffered two or more symptoms

© COPYRIGHT UPM

4.4 Working environment

Referring to table 4.4 of the work environment, the respondents reported to suffer from environment with low temperature in their room office. Almost 30% of the respondents agreed that they experience low temperature problem. For all the other factors excluding low temperature that bothers the respondents were below than 10%.

Table 4.4: Work Environment at workplace among office workers in a public university (n=64).

Variables	*n = 64*		
	No (Never)	*Yes, often (Sometimes)*	*Yes, often (Every week))*
		F (%)	
Visible fungal growth	42(65.6%)	18 (28.1%)	3 (4.7%)
Moldy odor	47 (73.4%)	15 (23.4%)	2 (3.1%)
Stain/ discoloration	17 (73.4%)	14 (21.9%)	3 (4.7%)
High temperature	32 (50.0%)	26 (40.6%)	5 (7.8%)
Low temperature	24 (37.5%)	28 (43.8%)	11 (17.2%)
Inadequate ventilation	35 (54.7%)	26 (40.6%)	3 (4.7%)
Dry air	36 (56.3%)	27 (42.2%)	1 (1.6%)
Passive smoking	52 (81.3%)	11 (17.2%)	1 (1.6%)

© COPYRIGHT UPM

4.5 Extension of humidity problems at workplace

In terms of humidity problems at workplace, 47% of the respondents were aware with the excessive moisture problems in office rooms. The respondents reported the mold were often found on the walls (59.6%) and ceiling (48.4%). Meanwhile, wallboard, split-unit air conditioning and MVAC system only showed the least mold problems that were reported by respondents. From 64 of the respondents, only 6 of them were identified as using dehumidifier at their work area. A total of 4 of respondents used dehumidifier as in figure 4.1 and the rest of two respondents used silica gel or charcoal dehumidifier which as passive dehumidifier. Most of the respondents recognized the importance of dehumidifier at their workplace. A total of 71.9% (n=46) of the respondents revealed that they had problems with low temperature at the morning from 8.00 am to 11.00 am and 33% (n=33) of them suffered with high temperature at the afternoon from 12.00 pm to 2.00 pm. The results are as presented in Table 4.5.

Figure 4.1: Compressor dehumidifier

© COPYRIGHT UPM

Table 4.5: Extension of humidity problems at workplace among office workers in a public university (n=64).

Variables	*F*	*(%)*
Aware with excessive moisture problems		
Yes	47	73.4
Location of mold problems		
Ceilings	31	48.4
Wall	38	59.6
Tiles	4	6.3
Desk	9	14.1
Wallboard	1	1.6
Split Unit Air Conditioning	1	1.6
Mechanical Ventilation Air Conditioning (MVAC)	1	1.6
Using dehumidifier at work area		
Yes	6	9.4
Type of dehumidifier		
Charcoal dehumidifier	1	1.6
Silica gel	1	1.6
Compressor dehumidifier	4	6.3
Awareness of the importance of dehumidifier at work area	45	70.3
Room temperature too low		
Morning (8.00am to 11.00 am)	46	71.9
Afternoon (11.00am to 2.00pm)	9	14.1
Evening (2.00pm to 5.00pm)	9	14.1
Room temperature too high		
Morning (8.00am to 11.00 am)	14	21.9
Afternoon (11.00am to 2.00pm)	33	51.6
Evening (2.00pm to 5.00pm)	17	26.6

© COPYRIGHT UPM

4.6 Perception on the need of intervention to improve indoor air quality in the offices

Almost half of the respondents 45.3% (n=29) strongly agree that if new products of humidity control material in the form of ceramic tiles can be developed, the current indoor air quality in their offices can be improved. This statement was supported by 20.3% of them that think ceramics tiles can be installed in office rooms if the ceramic tiles were chemical-free, adsorb excessive humidity, reduce microbial problems and remove unpleasant odor. A total of 39.1% (n=25) of the respondents strongly agreed if building administrator would like to install new tiles which can prevent respiratory health problems in their workplace. Similarly, at the total of 39.1% (n=25) of the respondents agree to install new tiles in their home with the characteristics explained. A total of 45.3% (n=29) of the respondents believes that this new tiles will enhance workers to be more productive by eradicating all the problems related with excessive humidity and mold problems. The results are presented in Table 4.6.

© COPYRIGHT UPM

Table 4.6 Perception on the need of intervention to improve indoor air quality in the offices among office workers in a public university (n=64).

Variables	*Strongly agree*	*Agree*	*Undecided*	*Disagree*	*Strongly disagree*
			F (%)		
If new products in form of ceramic, will the current IAQ in office can be improve?	29 (45.3%)	13 (20.3%)	10 (15.6%)	8 (12.5%)	4 (6.3%)
If ceramic can prevent respiratory health problems that caused by bad indoor air, would agree if the building administrator install new tiles in office room?	25 (39.1%)	25 (39.1%)	4 (6.3%)	4 (6.3%)	6 (9.4%)
If ceramic are cheap and non-toxic, would they install	25 (39.1%)	18 (28.1%)	7 (10.9%)	10 (15.6%)	4 (6.3%)
If ceramic can improve IAQ, will the worker be more productive	29 (45.3%)	18 (28.1%)	6 (9.4%)	6 (9.4%)	5 (7.8%)

© COPYRIGHT UPM

4.7 Humidity adsorption desorption performances of ceramic samples from modified DE

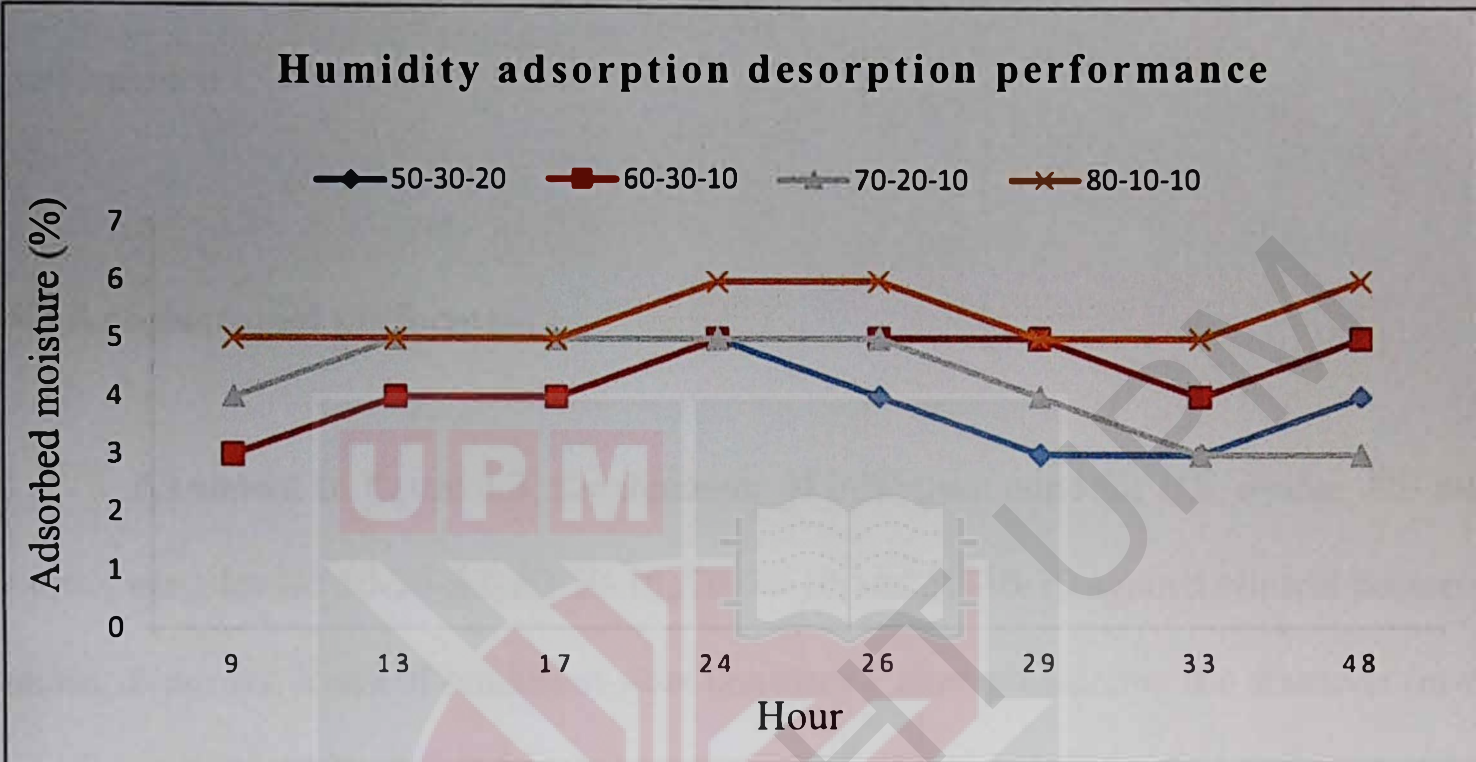


Figure 4.2: Humidity adsorption desorption performance of porous ceramics from modified DE sintered at 1100° C for 20minutes

Figure 4.2 illustrates the humidity adsorption desorption performance of porous ceramic samples from modified DE. Four ceramic with different formula were used for test humidity adsorption desorption test. The adsorption process was analyzed 24 hours after the salt solution of magnesium nitrate (53% RH) changes to sodium chloride (73% RH). The result shows that the adsorbed moisture measured in weight increase slightly with increasing time. Ceramic with formula 80-10-10 stabilized at the same percentage before gradually increasing. The percentage of adsorbed moisture for 80-10-10 was higher compared to others. Meanwhile ceramic with 50-30-20 showed least amount of adsorbed moisture.

For desorption process which is at 53% RH condition, 50-30-20 of ceramic drastically dropped after the salt solution was changed and increased with increasing times up to 48 hours. Figure 4.2 presents the result of humidity adsorption-desorption performance.

4.8 Antimicrobial performance

As shown in figure 4.3, the diameter of inhibition zone for DE, oyster, DE and oyster, samples for 50-30-20, 60-30-10, 70-20-10 and 80-10-10 against clinical bacterial strain, *S. aureus.* Zone of inhibition were confirmed after considering the diameter (mm) of each sample that exceeded 8 mm (the size of the wells in sample with formula). 60-30-10 showed no antimicrobial activity while 70-20-10 and 80-10-10 samples not clearly significant against the bacterial strains.

All the raw sample before heat treatment showed antimicrobial activity exceed the samples after undergo with heat treatment at 1100° C.

Diameter of inhibition zone of raw oyster was higher compared to raw DE and DE with oyster. Samples of 50-30-20 undergo heat treatment at 1100° C exhibit good bactericidal activity towards *S. aureus.* By referring to the Figure 4.4, all the samples after applied with heat treatment were applied showed presence of inhibition zones against *P. aeruginosa*. 50-30-20 exhibited strong antibacterial activity compared to other samples. Comparing the assay tests between raw DE against Gram-positive and Gram-negative bacteria, there is a reduction of clear zone.

© COPYRIGHT UPM

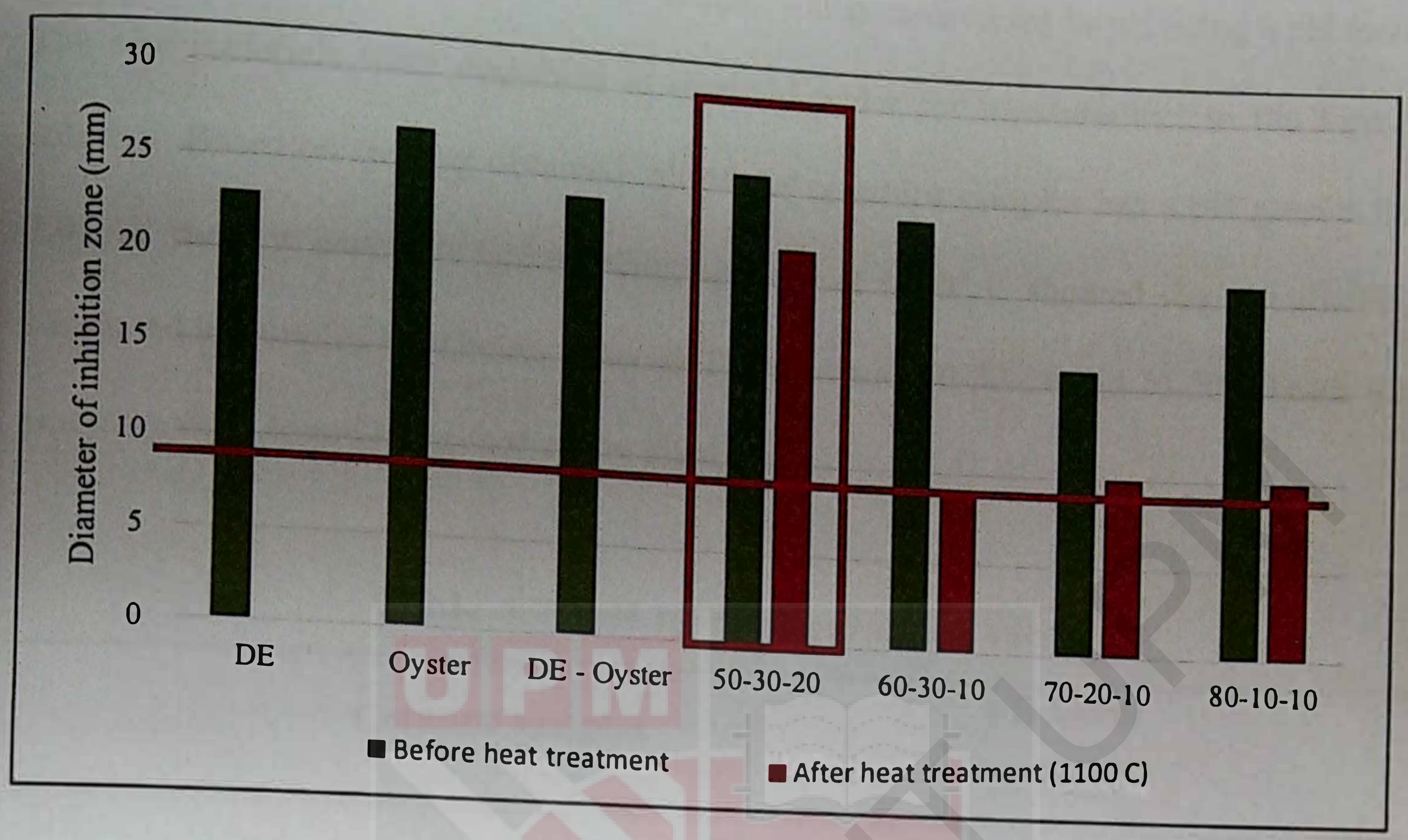


Figure 4.3: Diameter of inhibition zone across raw materials and samples (non-sintered in green and sintered in red) against *Staphylococcus aureus* (Gram-positive bacteria)

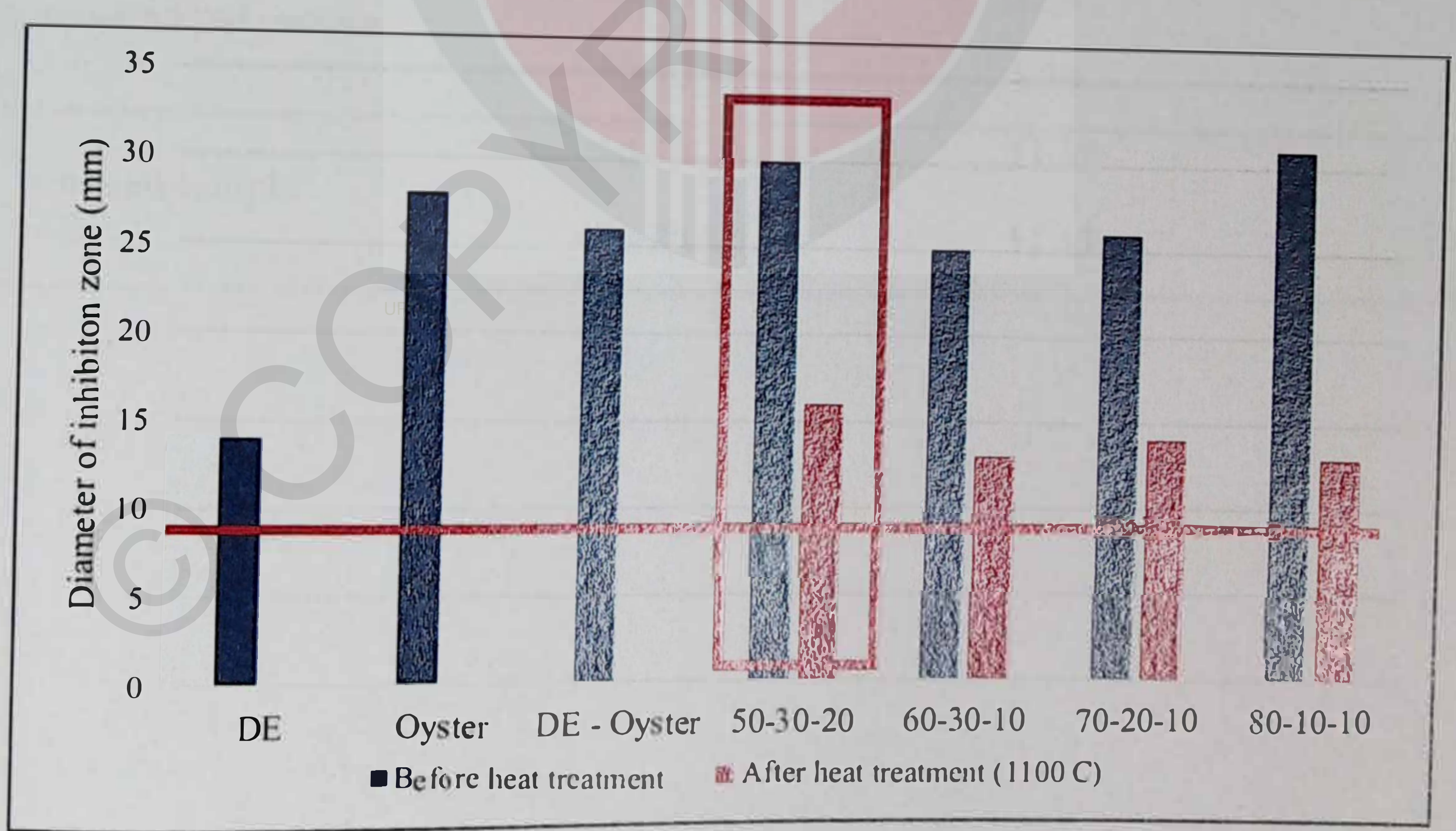


Figure 4.4: Diameter of inhibition zone across raw materials and samples (non-sintered in blue and sintered in red) against *Pseudomonas aeruginosa* (Gram-negative bacteria)

By referring in table 4.7, the ceramics sample was measured for its pH using a pH meter. The raw materials were dissolved in distilled water for measurement in the form of solution. Based on reading obtained, all of the ceramics samples has a pH greater than 7.0. All the raw materials before being sintered at 1100° C showed slightly alkalinity compared to samples after being sintered. The tiles with 50-30-20 and 70-20-10 ratio after sintering were found to have strongly alkalinity.

Table 4.7: pH level of ceramics sample

Ceramic samples		**pH Level (mean)**
DE		6.94
Oyster		8.24
DE + Oyster		8.13
non-sintered sample	50-30-20	8.39
	70-20-10	8.38
sintered sample	50-30-20	11.39
	70-20-10	11.13

© COPYRIGHT UPM

4.9 Impact strength test

Each of ceramics was tested with three different loads at same height. Referring in figure 4.8 the total mean after the impact test was done and it indicates that ceramics 50-30-20 has the greatest impact test compared with the other three ceramics. In contrast, 80-10-10 has the least of mean value, illustrated that this ceramics was the weakest one. This result disclosed that 80-10-10 was not feasible to form a ceramics.

Table 4.8: Impact strentgh test with different loads

Ceramics	1 (100g)	2 (200g)	3 (500g)	Mean
50-30-20	40	30	20	30.00
60-30-10	30	20	20	23.33
70-20-10	30	20	10	20.00
80-10-10	20	10	10	13.33

© COPYRIGHT UPM

CHAPTER 5

DISCUSSION

5.1 The extent of Sick Building Syndrome (SBS) and humidity related problem among workers in selected offices in Malaysia.

The prevalence of SBS in this study was 73.4%. By comparing with a study that was conducted by Fadhilah & Juliana (2012), the prevalence of SBS in a new building was only 47.5%. According to the author, the respondents will be concluded suffering with SBS if the percentage were more than 20%. This reading was two times lower than the current prevalence of SBS in office setting in this study. In addition, Zuliza et al., (2016) found out that the SBS prevalence in wet laboratory was 45.4%, which was higher than in dry laboratory that only recorded 20%.

The finding revealed that respondents suffered with SBS symptoms. The highest prevalence of SBS symptoms in office setting was headache (59.4%). Similar with the finding previously by Rohizan & Abidin (2015), headache was reported as the highest prevalence of SBS symptoms among the respondents, which was 21.1%. This study was equivalent with Fadilah & Juliana (2012), headache (37.3%) was determined as most symptoms that experienced by the respondents.

Considering the working environment with different room office partition, the respondents were exposed to several conditions that might cause discomfort including

© COPYRIGHT UPM

temperature, dry air and dust. From the study by Zuliza et al (2016), evidence was shown that temperature is significantly associated with higher prevalence of SBS symptoms. Based on a study done by Rohizan & Abidin (2015), temperature and relative humidity were significantly associated with the perception of comfort. In addition, further investigation was done by them and disclosed that MVAC issues was likely a reasons the imbalance of relative humidity and temperature in offices.

In the survey questionnaire distributed to the respondents in the office setting, it was found that about 67.2% of the participants occupied offices with MVAC system. The MVAC system was operated for almost 8 hours per day. Moreover, improper of the MVAC system leads to poor distribution of fresh air to all the areas in the office setting. This study reported that the respondents experienced with stuffy nose (32.8%) due to lacking fresh air in their room offices. It was shown that almost every day the office workers get inadequate fresh air and suffered health issues including fatigue (35.9%), headache (59.4%) and heavy headed (40.6%).

As mentioned earlier, the relative humidity was one of the factors reported that may influence worker's thermal comfort in office setting. According to the study by Ahmad & Hassim (2015), the relative humidity is inversely proportional with the temperature. By referring to the responses in this study, the respondents feel that the temperature in the indoor environments that they occupied was low for their comfort. This factors may be the reason for the affected their office with higher relative humidity, hence leads to the excessive dampness.

© COPYRIGHT UPM

A report by Ahmad & Hassim (2015), the relative humidity in the office building was higher (72.1%), exceeding the allowable range when compared with local standard (DOSH, 2010). Another study done by Zakaria et al (2016), found that relative humidity was recorded higher in management center. Monitoring for relative humidity was conducted in seven days and reading showed in a range of 70% to 85%.

The complexity of high relative humidity problems were not only caused dampness, but also trigger the growth of microbiological including bacteria and fungi (Orosa & Oliveira, 2012). Thus, their study discovered the association between high relative humidity problem in walls with indoor microbial. This study in lines with (Jaafar et al, 2015), reported that there is a positive correlation between relative humidity with bacteria growth. The report added that Malaysia's indoor air humidity could be a great reservoir for microbe to grow and proliferate, in some cases, this microbes will manage to spread the diseases in such condition.

The data yielded by this study found that, approximately 73.4% of the respondents are aware of moisture problems in their office. This was evidenced by the reports of the respondents where they often see the visible fungal growth (28.1%), discoloration of walls (21.9%) and experienced moldy odor (23.4%). Walls (59.6%) and ceilings (48.4%) indicated the highest target location for the fungal and bacterial overgrowth. The rest of the locations of fungi and bacteria are found include on tiles (6.3%), worker's desk (14.1%), wallboard (1.6%), and split-unit air conditioning (1.6%) and on MVAC system (1.6%).

© COPYRIGHT UPM

According to Orosa & Oliveira (2012), passive method solution can be used to replace MVAC system. On the evidence currently available, poor ventilation of the MVAC systems caused excessive moisture and contributes to poor indoor air conditions. Dehumidifier can be one of the solutions to be considered to solve this problem and 70.3% of the respondents are aware of the importance of dehumidifier at their work area. However, as presented in this study, only 9.4% of the respondents uses dehumidifier. Types of dehumidifier that were used such as charcoal dehumidifier (1.6%), silica gel (1.6%) and compressor dehumidifier (6.3%).

Conventional solution of non-energy consumption presented HCM as one of the alternative ideas to solve the problem related to MVAC system (Hu et al., 2017). As suggested by Ahmad & Hassim (2015), the concept of cradle to the grave before building development should be implemented. In earlier stage, the selected of building materials must be considered in order to achieve ultimate indoor humidity.

The production of ceramics as building materials in the market is really demanding (Yimaz & Ediz, 2008). In order to get rid of indoor humidity problems, ceramics can be used to intervene if it has humidity controlling and antimicrobial characteristics. If new product in the form of ceramic tiles which is chemical free, able to adsorb excessive humidity, have antimicrobial characteristics and has the ability to remove unpleasant odor, more than 66% of respondents strongly agreed and 20.3% agreed the current indoor air quality in office setting will be improved.

© COPYRIGHT UPM

Previous study by Othman et al., (2015) reported that the main factors that caused building defects in hospital building were moisture issues. These can be seen when bacteria and unnecessary viruses freely lives in moisture leaks location such as walls, floors, windows and doors. Therefore, this issues not only leads to uncomfortable environment to the occupants (Othman et al., 2015) . Furthermore, moisture issues were not only causes defects on the building surfaces but it can contribute to ill-health problems among the occupants when exposed to microbes (Othman et al., 2015). In this study, 39.1% of the respondents strongly agrees for building administrator to install new tiles in their occupied offices if the ceramic tiles can prevent respiratory health problems related with bad indoor air quality. Based on these findings, there is the positive expectation for such tiles to be used in offices after the building have been constructed as an intervention method to reduce problems related to excessive moisture and microbial growths.

© COPYRIGHT UPM

5.2 Humidity adsorption-desorption performance

All the four samples exhibit humidity adsorption-desorption performance. By comparing samples with the highest and the least percentage of DE, obviously, ceramic tiles with 80-10-10 formula that contain 80% of Diatomaceous Earth (DE) presented excellent in adsorption performance. Meanwhile the ceramic tile with formula of 50-10-10 that only had 50% of DE had approximately two times lower adsorption performance than 80% content of DE. As reported by Dinh-Hieu, Wang, Bui, & Bui, (2013), the ability of moisture adsorption – desorption increase as the percentage of DE increased.

In this study, desorption process took a day to reach 75%RH. Yet, for the desorption process, it only took 2 hours for it to be stabilized. The reading needs to be recorded immediately before the salt solution is fully saturated. The water vapors that were released by the salt solution will evaporated from the modified DE sample to the top of the glass desiccator. This condition was notable as the most suitable time to measure the weight difference of the sample.

© COPYRIGHT UPM

This finding was supported by Zheng et al., (2017), that found the adsorption process took longer than desorption process for it to stabilize. This occurrence was caused by pore capillary effects (Zheng et al, 2017). The existence of capillary will promote the water vapors to diffuse into the pore of the ceramics thus increasing the adsorption ability. DE has a porous surface and comprised of tiny capillary that has an ability to adsorb water vapor from atmosphere, thereby worthy for water vapor adsorption (Al-Ghouti et al, 2003). Study that was conducted by Qian et al, (2016) showed that DE powder has a cylindrical shape and numerous pores which categorized DE as material with high surface area and high porosity. This phenomenon revealed that DE has a characteristic of Humidity Control Materials (HCM).

© COPYRIGHT UPM

5.3 Antimicrobial assay performance

Hussin et al., (2011) determined that *S. aureus* was the highest number of bacteria found in indoor setting. *S. aureus* is a Gram-positive bacteria that grow in 'bunch of grapes' cluster, pairs and also can be found in form of clump. Normally, this staphylococcal bacteria causes deep-seated infection, skin infections including boils, impetigo, pimples, hence it could be infection to eyelid or known as styes (Foster et al., 2015). Foster et al (2015) described that these Gram-positive bacteria has a membrane damaging toxins (MDTs) or known as cytolysis or cytolytic toxin. This toxin was used for creating diseases, damaging host epithelial cells and neutrophils.

S. aureus not only can cause infecting to skin but people who get infected with this bacteria may get severe invasive infections including pneumonia, septic arthritis and osteomyelitis (Rao et al, 2018). *S. aureus* has been reported to cause nosocomial (originating in a hospitals) and community-associated (CA) bacterial infections in humans. Methicillin-susceptible *S. aureus* (MSSA) has been reported to commonly infect healthy persons or community who do not have risk factors meanwhile methicillin-resistant *S. aureus* (MRSA) infects health care practitioner which are usually involved in surgery.

A study done by Agbayani & Espinosa (2006) found out that oyster shells consist of 97.5% of $CaCO_3$. After heat treatment was applied onto this powder, the $CaCO_3$ converted into CaO. According to Xing et al., (2013), CaO, MgO and ZnO exhibited strong antimicrobial activity. In line with this study, and that nano particles of CaO showed excellent anti bactericidal activity towards *Staphylococcus epidermidis, Pseudomonas aeruginosa and Candida tropicalis* (Roy et al., 2013). They illustrated at high concentration of shell powder will significantly give an excellent result of antimicrobial behavior.

Tang et al, (2014) recognized the inorganic metal oxide such as MgO, CaO and ZnO as antibacterial properties. These metals may come within the size of nano particle. Thus, nanotechnology can help to improve the antimicrobial activity due to its size, surface properties and structure. Additionally, the smaller the size of inorganic metal oxide powder, the greatest the effects of antibacterial activity (Tang et al., 2014).

By referring the result in this study, CaO powder in oyster shell revealed that it could be used as antibacterial agents to kill gram-positive bacteria in indoor setting. However, heat treatment suppressed the ability of bactericidal activity of the ceramics, hence, reducing the efficiency of this material to kill the Gram-positive bacteria. Nevertheless, this study found that the inhibition zone was 22mm, which shows that at the 50-30-20 ratio, the ability of the ceramics to kill Gram-positive bacteria is existent. This makes it a suitable as ceramics with antibacterial characteristics.

Tang et al., (2014) reported the antibacterial mechanism of CaO powder involved alkaline effects. Thin water layer that forms around the oyster shell powder could be a reason in antibacterial mechanism. At this condition, the water may absorb to the oyster powder unintentionally during the grinding process and exposed to environment. All the powder were measured with pH meter in form of solution. The pH of oyster shell powder (after heat treatment) was higher than its equilibrium state in solution. Additionally, the high pH may have the possibility to cause destruction to the cell membrane of *S. aureus*, thus, resulting in cell death when in contact with that bacteria. The author reported that the alkaline effect has been considered as other causing factor in the antibacterial action of CaO. The adsorption of water moisture on the CaO nanoparticle surfaces, could form a thin water layer around the particles. The local pH of this water layer formed around the nanoparticles might be much higher than its equilibrium value in solution. When CaO are in contact with bacteria, the high pH in this thin surface water layer could damage the membrane, resulting in cells death (Tang et al, 2013).

© COPYRIGHT UPM

5.4 Impact strength test

Three different loads were dropped on each ceramics at similar height and 50-30-20 showed the greatest impact test when compared with other three samples. In this context, different formula of each ceramics will be considered. The ceramic sample 80-10-10 illustrated the weakest ceramics after three loads was applied. This can be seen when the waste glass and oyster powder was reduce to 10% meanwhile for 50-30-20, it contains 30% of waste glass and 20% of oyster powder.

Waste glass powder was added as an additive in ceramics product and can be as refractory materials. These refractory material has an ability to retain its physical shape after applied in high temperatures which is 1100° C is applied. In addition, silicon, sodium and calcium oxides that known as soda-lime glass, was a main composition in most waste glass. According to Haun (2005), this composition will be soften at 650° C to 750° C caused the ceramics formed from the waste glass powder to density at viscous-phase at sintering temperature (Haun, 2005). At this condition, the melted waste glass will bind with other components from DE and oyster shell powder.

© COPYRIGHT UPM

Furthermore, the transformation of calcium carbonate in oyster shell powder to calcium oxide after the heat treatment was applied strengthened the ceramics. Supported by Mohamad et al., (2016), the structure of shell powder will be increased drastically when sintering temperature increases. Moreover, the irregular shape of calcined shell powder will bonded with other components to form great aggregate, thus formed much immaculate surface (Mohamad et al., 2016).

© COPYRIGHT UPM

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study revealed that there is a need for the development of porous ceramics to help reduce humidity problems and the corresponding sick building syndrome in building offices. This study found that a suitable ratio for porous ceramics with humidity controlling and anti-bacteria characteristics could be developed by using 50% modified DE. The modified DE added with local and low-cost materials have the potential to solve the problem of humidity imbalance and microbial growth in office settings can be solved in order to reduce sick building syndrome and ensure productivity of workers is maintained.

6.2 Recommendations

This study used salt solution in glass desiccator to get specific relative humidity. However, relative humidity recorded cannot retain for the expected duration of time. For further study, humidity chamber is the best instrument that can be used to replace this method. This instruments has ability to give constant reading of relative humidity for a longer period and physiologically ideal environment for simulation of real conditions.

© COPYRIGHT UPM

Apart from that, X-ray diffraction (XRD) should be conducted to identify the mineral phases in the ceramics. In this study, XRD is not being conducted due to budget constraint. The composition in ceramics such as calcium oxide is only determine by reviewing from previous studies.

© COPYRIGHT UPM

REFERENCES

A., M., L., M., Valle, L., & D., C. (2012). Gum Arabic: More Than an Edible Emulsifier. *Products and Applications of Biopolymers*. https://doi.org/10.5772/33783

Abidin, Z. E., Mahmud, Z. & Jasni, A. S. (2017). Occupational Exposures to Bioaerosol and its Link with Respiratory Symptoms among Workers in Companion Animal Clinics : A Cross-Sectional Study, *4*(6), 22–40.

Act, I. S., & From, F. (2017). JIS A 1475 : 2004 Method for measuring equilibrium moisture content of building materials, 1–12.

Ahmad, N., & Hassim, M. H. (2015). Assessment of Indoor Air Quality Level and Sick Building Syndrome According to the Ages of Building in Universiti Teknologi Malaysia. *Jurnal Teknologi*, *1*, 163–170.

Al-Ghouti, M. A., Khraisheh, M. A. M., Allen, S. J., & Ahmad, M. N. (2003). The removal of dyes from textile wastewater: A study of the physical characteristics and adsorption mechanisms of diatomaceous earth. *Journal of Environmental Management*, *69*(3), 229–238. https://doi.org/10.1016/j.jenvman.2003.09.005

Agbayani, A, M, V. & Espinosa, A, A. (2006). Ceramic Tiles from Crassostrea iredalei (Oyster Shells). Retrieved from https://docgo.net/philosophy-of-money.html?utm_source=ceramic-tiles-from-crassostrea-iredalei-oyster-shells-yWxvkk3

ASHRAE. (2017). Thermal Environmental Conditions for Human Occupancy. *ASHRAE. Atlanta, USA., 2017.*

ASHRAE (2003). Ventilation for acceptable indoor air quality. Atlanta GA, American Society of Heating, Refrigerating and Air Conditioning Engineers.

Bunch, T. R.; Bond, C.; Buhl, K.; Stone, D. 2013. *Diatomaceous Earth General Fact Sheet*; National Pesticide Information Center, Oregon State University Extension Services.

Bo, Z., & Qian, C. Z. (2016). The study of the interior wall putty with temperature adjustment, humidity controlling and anti-bacteria. *International Conference on Indoor Air Quality Ventilation & Energy Conservation in Buildings*

Blood agar. (2018, April 24) Retrieved from **http://www.austincc.edu/microbugz/blood_agar_test.php**

Centers for Disease Control and Prevention (2017). Mold. Retrieved from https://www.cdc.gov/mold/default.htm

Chinnam, R. K., Bernardo, E., Will, J., Boccaccini, A. R., Bernardo, E., Will, J., … Boccaccini, A. R. (2015). Processing of porous glass ceramics from highly crystallisable industrial wastes Processing of porous glass ceramics from highly crystallisable industrial wastes, *6753*. https://doi.org/10.1179/1743676115Y.0000000053

Deya, C., & Bellotti, N. (2017). Biosynthesized silver nanoparticles to control fungal infections in indoor environments. *Advanced in Natural Sciences; Nanoscience and Nanotechnology*.

Dinh-Hieu, V., Wang, K.-S., Bui, H. B., & Bui, X. N. (2013). Humidity control materials prepared from diatomite and volcanic ash. *Construction and Building Materials*, *38*(January), 1066–1072. https://doi.org/10.1016/j.conbuildmat.2012.09.040

DOSH. (2010). Department of Safety and Health. Industry Code of Practice on Indoor Air Quality. *Ministry of Human Resources Department of Occupational Safety and Health*, 1–50.

Ediz, N. (2008). The use of raw and calcined diatomite in cement production, *30*, 202–211. https://doi.org/10.1016/j.cemconcomp.2007.08.003

El Hassni, M., El Hadrami, A., Daayf, F., Barka, E. A., & El Hadrami, I. (2004). Chitosan, antifungal product against Fusarium oxysporum f. sp. albedinis and elicitor of defence reactions in date palm roots. *Phytopathologia Mediterranea*, *43*(2), 195–204. https://doi.org/10.14601/Phytopathol_Mediterr-1743

Esquenazi, D., Wigg, M. D., Miranda, M. M. F. S., Rodrigues, H. M., Tostes, J. B. F., Rozental, S., … Alviano, C. S. (2002). Antimicrobial and antiviral activities of polyphenolics from Cocos nucifera Linn. (Palmae) husk fiber extract. *Research in Microbiology*, *153*(10), 647–652. https://doi.org/10.1016/S0923-2508(02)01377-3

Fernández, M. A., & Bellotti, N. (2017). Silica-based bioactive solids obtained from modified diatomaceous earth to be used as antimicrobial filler material, *194*, 130–134. https://doi.org/10.1016/j.matlet.2017.01.144

Fraga, D., Gyozova, A., Kozhukharov, S., Allepuz, S., Làzaro, C., Trilles, V., & Carda, J. B. (2011). Development of New Ecological Ceramic Tiles by Recycling of Waste Glass and Ceramic Materials. *Научни Трудове* …, 8–12. Retrieved from http://conf.uni-ruse.bg/bg/docs/cp11/9.1/9.1-1.pdf

Foster, Timothy, J. & Geoghegan, John, A. (2015). *Molecular Medical Microbiology (Second Edition)*. Retrieved from https://doi.org/10.1016/B978-0-12-397169-2.00037-8

Goldstein, W. E. (Ed). (2012). Sick Building Syndrome and Related Illness: Prevention and Remediation of Mold Contamination, (pp. 48-50). Boca Raton, US: Taylor & Francis Group

Hamidi, A., & Zulkifle, B. I. N. (2013). Decomposition of Calcium Carbonate in Cockle Shell, *7*(May), 1–10.

Hu, Z., Zheng, S., Jia, M., Dong, X., & Sun, Z. (2017). Preparation and characterization of novel diatomite / ground calcium carbonate composite humidity control material. *Advanced Powder Technology*, *28*(5), 1372–1381. https://doi.org/10.1016/j.apt.2017.03.005

Hu, Z., Zheng, S., Tan, Y., & Jia, M. (2017). Preparation and characterization of diatomite/silica composite humidity control material by partial alkali dissolution. *Material Letters*. 196,234-237.

Humidity buffering by absorbent materials in walls. (2017), *7*, 1–16.

Hussin, N. H. M., Sann, L. M., Shamsudin, M. N., & Hashim, Z. (2011). Characterization of bacteria and fungi bioaerosol in the indoor air of selected primary schools in Malaysia. *Indoor and Built Environment*, *20*(6), 607–617. https://doi.org/10.1177/1420326X11414318

JIS-A-1475-2004. Method of test for hygroscopic sorption properties of building materials.

Kim, K.-H., et al., Airborne Bio aerosols and their impact on human health, J. Environ. Sci. (2017), https://doi.org/10.1016/j.jes.2017.08.027

Lodins, E., Rozenstrauha, I., Rundans, M., Sperberga, I., Zake, I., & Svinka, R. (2011). Production of glass-ceramics from sewage sludge and waste glass Production of glass-ceramics from sewage sludge and waste glass. https://doi.org/10.1088/1757-899X/25/1/012016

Maqbool, M., Ali, A., Ramachandran, S., Smith, D. R., & Alderson, P. G. (2010). Control of postharvest anthracnose of banana using a new edible composite coating. *Crop Protection*, *29*(10), 1136–1141. https://doi.org/10.1016/j.cropro.2010.06.005

Mohamad, S. F. S., Mohamad, S., & Jemaat, Z. (2016). Study of calcinations condition on decomposition of calcium carbonate in waste cockle shell to calcium oxide using thermal gravimetric analysis. *ARPN Journal of Engineering and Applied Sciences*, *11*(16), 9917–9921.

Norhidayah et al. (2013). Indoor Air Quality and Sick Building Syndrome in Three Selected Buildings. *Procedia Engineering*, *53*(2010), 93–98. https://doi.org/10.1016/j.proeng.2013.02.014

Orosa, J. A., & Oliveira, A. C. (2012). Expert Systems with Applications An indoor air perception method to detect fungi growth in flats, *39*, 3740–3746. https://doi.org/10.1016/j.eswa.2011.09.072

OSHA. (1994). Law of Malaysia Act 514 Occupational Safety and Health Act 1994, (1), 1–5. https://doi.org/10.1007/s13398-014-0173-7.2

Othman, N. L., Jaafar, M., Harun, W. M. W., & Ibrahim, F. (2015). A Case Study on Moisture Problems and Building Defects. *Procedia - Social and Behavioral Sciences*, *170*, 27–36. https://doi.org/10.1016/j.sbspro.2015.01.011

Penney, D., Benignus, V., Kephalopoulos, S., Kotzias, D., Kleinman, M., & Agnes Verrier. (2010). Guidelines for indoor air quality. *WHO Guidelines*, *9*, 454. https://doi.org/10.1186/2041-1480-2-S2-I1

© COPYRIGHT UPM

Qian, T., Li, J., & Deng, Y. (2016). Pore structure modified diatomite-supported PEG composites for thermal energy storage. *Scientific Reports*, *6*(May), 1–14. https://doi.org/10.1038/srep32392

R, N. F., &, & Juliana, J. (2012). Indoor Air Quality (IAQ) and Sick Buildings Syndrome (SBS) among Office Workers in New and Old Building in Universiti, *3*(2), 98–109.

Rao, Q., Shang, W., Hu, X., & Rao, X. (2018). Staphylococcus aureus ST121 : a globally disseminated hypervirulent clone, (2015), 1462–1473. https://doi.org/10.1099/jmm.0.000185

Rios, J. L. de M., Boechat, J. L., Gioda, A., Santos, C. Y. dos, Aquino Neto, F. R. de, & Lapa e Silva, J. R. (2009). Symptoms prevalence among office workers of a sealed versus a non-sealed building: Associations to indoor air quality. *Environment International*, *35*(8), 1136–1141. https://doi.org/10.1016/j.envint.2009.07.005

Rohizan, N. A. & Abidin, E. Z. (2015). Assessment on Physical Factors of Thermal Comfort, Sick Building Syndrome Symptoms and Perception of Comfort among Occupants in a Public Research University Laboratory Building. *International Journal of Public Health and Clinical Sciences*, *2*(3), 59–70.

Roy, A., Gauri, S. S., Bhattacharya, M., & Bhattacharya, J. (2013). Antimicrobial Activity of CaO Nanoparticles, *9*(xx), 1–8. https://doi.org/10.1166/jbn.2013.1681

Sit, P. S., Teh, C. S. J., Idris, N., Sam, I. C., Syed Omar, S. F., Sulaiman, H., … Ponnampalavanar, S. (2017). Prevalence of methicillin-resistant Staphylococcus aureus (MRSA) infection and the molecular characteristics of MRSA bacteraemia over a two-year period in a tertiary teaching hospital in Malaysia. *BMC Infectious Diseases*, *17*(1), 1–14. https://doi.org/10.1186/s12879-017-2384-y

© COPYRIGHT UPM

Stridh, A. &. (1991). The use of Standardized Questionnaires in Building-related Illness (BRI) and Sick Building Syndrome (SBS). NATO/CCMS Pilot Study on Indoor Air Quality. 4th Plenary Meeting : Epidemiology and Medical Management of Building Related Complaints and Illnesses, report on a meeting held in Oslo, Norway,.

Sun, C., Huang, C., Liu, W., Zou, Z., & Shen, L. (2017). Home dampness-related exposures increase the risk of common colds among preschool children in shanghai, china: modified by household ventilation. *Building and Environment*, 124(2017), 31-41.

Strecker & Costa (2014). Formulation of Ceramic Glazes by Recycling Waste Glass. Retrieved from https://doi.org/10.4028/www.scientific.net/MSF.775-776.659

Tang, Z., & Lv, B. (2014). MgO Nanoparticels as Antibacterial Agent : Preparation and Activity, *31*(3), 591–601.

US20090280313A1.pdf. (n.d.)

Understanding MRSA Infection – the Basics. (2018, April 22). Retrieved from https://www.webmd.com/skin-problems-and-treatments/understanding-mrsa#1.

Vu, D. H., Wang, K. S., Nam, B. X., Bac, B. H., & Chu, T. C. (2011). Preparation of humidity-controlling porous ceramics from volcanic ash and waste glass. *Ceramics International*, *37*(7), 2845–2853. https://doi.org/10.1016/j.ceramint.2011.04.118

Vu, D., Wang, K., Bac, B. H., & Nam, B. X. (2013). Humidity control materials prepared from diatomite and volcanic ash. *Construction and Building Materials*. 38,1066-1072.

Wang, J. Y., Belie, N. D., & Verstraete, W. (2012). Diatomaceous earth as protective vehicle for bacteria applied for self-healing concrete. *J Ind Microbiol Biochemical*. 39,567-577.

WHO. (2009). In: Heseltine, E., Rosen, J. (Eds). WHO Guidelines for Indoor Air Quality:Dampness and Mould. Druckpartner Moser, Copenhagen. *WHO Guidelines for Indoor Air Quality*. Retrieved from http://books.google.com/books?hl=en&lr=&id=PxB8UUHihWgC&oi=fnd&%0Apg=PR7&dq=WHO+Guidelines+for+Indoor+Air+Quality:+Dampness+and+%0AMould&ots=9zIVP0MZEJ&sig=taXxWW9qb104EkfeGZb88KRBixk).

Xing, R., Qin, Y., Guan, X., Liu, S., Yu, H., & Li, P. (2013). Comparison of antifungal activities of scallop shell, oyster shell and their pyrolyzed products. *Egyptian Journal of Aquatic Research*, *39*(2), 83–90. https://doi.org/10.1016/j.ejar.2013.07.003

Yilmaz, B., & Ediz, N. (2008). The use of raw and calcined diatomite in cement production. *Cement & Concrete Composites*. 30, 202-211.

Zakaria, S., Leman, A. M., Feriyanto, D., Hariri, A., & Nazri, A. A. (2016). (2016). Indoor Air Quality (IAQ) Monitoring in Academic Management Centre. *Journal of Occupational Safety and Health*, *13*(1), 33–40.

Zheng, J., Shi, J., Ma, Q., Dai, X., & Chen, Z. (2017). Experimental study on humidity control performance of diatomite-based building materials. *Applied Thermal Engineering*, *114*, 450–456. https://doi.org/10.1016/j.applthermaleng.2016.11.203

Zuliza et al. (2016). Indoor Air Quality and Prevalence of Sick Building Syndrome among University Laboratory Workers. *International Journal of Sciences: Basic and*

© COPYRIGHT UPM

Applied Research (IJSBAR), *4531*, 130–140. https://doi.org/http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

© COPYRIGHT UPM

APPENDICES

APPENDIX 1:

CONSENT FORM

© COPYRIGHT UPM

JAWATANKUASA ETIKA UNIVERSITI UNTUK PENYELIDIKAN MELIBATKAN MANUSIA (JKEUPM)
UNIVERSITI PUTRA MALAYSIA, 43400 UPM SERDANG, SELANGOR, MALAYSIA

FORM 2.4: RESPONDENT'S INFORMATION SHEET AND INFORMED CONSENT FORM

Please read the following information carefully and do not hesitate to discuss any questions you may have with the researcher.

1. STUDY TITLE :

Development of Porous Ceramics with Humidity Controlling and Antimicrobial Characteristics from Modified DE : Improving Indoor Air to Reduce Sick Building Syndrome

2. INTRODUCTION:

Indoor humidity is one of the issues arising in Malaysian Offices. The imbalance of relative humidiy closely related with health problems and affects to the energy consumption and construction durability. When the relative humidity too high, leads to increasing moisture levels and resulting growth of mold. If the air too dry or relative humidity is low, it can makes furniture crack and misshape and cause skin irritation and respiratory problems to human. Use of air-conditioning and air-purifier has long been practiced to control environmental humidity, however this solutions suffers from energy consumption and costly. Calcium chloride, silica gel has been used as wall materials but these materials exhibit poor water absortion-desoprtion performance. This study is to develop porous ceramics with humidity-controlling, antimicrobial characteristics.

3. WHAT WILL YOU HAVE TO DO?

You need to answer the questionnaire that will be distributed to gather all the needs informations on socio-background, employment information, health and well-being information, present symptoms and work conditions.

4. WHO SHOULD NOT PARTICIPATE IN THE STUDY?

Workers who work less than a year

5. WHAT WILL BE THE BENEFITS OF THE STUDY:

(a) TO YOU AS THE SUBJECT?

This study will develop porous ceramics with humidity-controlling ability, anti-bacterial and anti-fungal characteristics which can reducing indoor humidity problems in Malaysian offices._Indoor humidity commonly related with ventilation system or the usage of air conditioning in office setting. Therefore, the demands of air conditioning, the needs to regulate every working days are quite costly and leads to increasing of indoor humidity. The development of this porous ceramics can regulate indoor humidity without spend a lot of money continuosly. Hence, the cost to regulate air conditioning can be reduced by using this porous ceramics. In addition, mold problem which attributable from the accumulation of bacteria and fungi on some building materials including walls, furniture and tiles can be solved by using this porous ceramics. It has an ability to kill any fungi and bacteria that lay on this ceramics in turn reducing mold problem in office setting. Next, this problem were not only harmed to building materials but affects on human health as well. Allergies, rhinitis, respiratory problem related with asthma are some other problem that arising nowadays. The usage of this porous ceramics with these characteristics can minimize health problem related with mold contamination.

(b) TO THE INVESTIGATOR?

This study will help the investigator to determine the performance of modified diatomaceous earth (DE) as humidity control materials, anti-bacterial and anti-fungal characteristics for new formulations of the new porous ceramics.

6. WHAT ARE THE POSSIBLE RISKS?

There is no risk available in this study

7. WILL THE INFORMATION THAT YOU PROVIDE AND YOUR IDENTITY REMAIN CONFIDENTIAL?

The gathered information in this study will remain confidential

8. WHO SHOULD YOU CONTACT IF YOU HAVE ADDITIONAL QUESTIONS DURING THE COURSE OF THE RESEARCH?

If you have any queries, you may contact the researcher Nurul Hafizah binti Ahmad at 019-41159893 or email at nurulhafizah2101@gmail.com or Supervisor of the study reseacrh Dr. Emilia binti Zainal Abidin at 03-89472643 or email at za_emilia@upm.edu.my

© COPYRIGHT UPM

Please initial here if you have read and understood the contents of this page______

9. CONSENT

I ……………………………………… Identity Card No. ……………………………… address…… …… ………………………………………………………………..hereby voluntarily agree to take part in the research stated above *(clinical /drug trial/video recording/ focus group/interview-based/ questionnaire-based).

I have been informed about the nature of the research in terms of methodology, possible adverse effects and complications (as written in the Respondent's Information Sheet). I understand that I have the right to withdraw from this research at any time without giving any reason whatsoever. I also understand that this study is confidential and all information provided with regard to my identity will remain private and confidential.

I* wish / do not wish to know the results related to my participation in the research

I agree/do not agree that the images/photos/video recordings/voice recordings related to me be used in any form of publication or presentation (if applicable)

* delete where necessary

Signature …………………………………… (Respondent)

Date :…………………………………………..

Signature …………………………………… (Witness)

Name :…………………………………………

I/C No. :…………………………………………

I confirm that I have explained to the respondent the nature and purpose of the above-mentioned research.

Date ……………………………………

Signature …………………………………… (Researcher)

© COPYRIGHT UPM

JAWATANKUASA ETIKA UNIVERSITI UNTUK PENYELIDIKAN MELIBATKAN MANUSIA (JKEUPM)
UNIVERSITI PUTRA MALAYSIA, 43400 UPM SERDANG, SELANGOR, MALAYSIA

BORANG 2.4: PENERANGAN DAN PERSETUJUAN RESPONDEN

Sila baca maklumat berikut dengan teliti. Sekiranya anda mempunyai sebarang pertanyaan, sila kemukakan kepada penyelidik.

1.TAJUK KAJIAN

Penghasilan seramik berliang dengan berciri kawalan kelembapan and antimikrob daripada pengubahsuaian tanah diatom:Meningkatkan kawalan udara dalam bangunan bagi mengurangkan sindrom bangunan sakit

2. PENGENALAN

Kelembapan dalaman merupakan antara isu yang timbul di dalam pejabat di Malaysia terutamanya. Ketidakseimbangan kelembapan di dalam kawasan yang bertutup berkait rapat dengan masalah kesihatan serta mempengaruhi penggunaan tenaga elektrik dan ketahanan pembinaan. Apabila kelembapan relatif terlalu tinggi, ia boleh meningkatkan kadar kelembapan di dalam pejabat dan berisiko untuk kulat dan bakteria membiak. Jika udara kering, ia mengurangkan kadar kelembapan di dalam pejabat seterusnya menyebabkan perabot menjadi rosak. Udara kering tidak hanya merosakkan perabot terapi menyumbang pada ketidakselesaan di pejabat seperti kerengsaan kulit. Masalah pernafasan kepada manusia juga merupakan salah satu kesan daripada udara kering. Contohnya, udara kering menyebabkan perabot menjadi rosak dan reput. Kesan daripada itu, habuk yang terhasil berkemungkinan memasuki ruang pernafasan manusia, seterusnya menyebabkan masalah pernafasan seperti asma. Penggunaan penghawa dingin dan penulen udara telah lama diamalkan untuk mengawal kelembapan alam sekitar di dalam kawasan bertutup, namun penyelesaian ini meningkatkan penggunaan tenaga elektrik secara berlebihan dan mahal. Kalsium klorida, silika gel telah digunakan sebagai bahan dinding tetapi bahan-bahan ini menunjukkan prestasi penyerapan air-desopripsi yang buruk. Kajian ini adalah untuk menghasilkan seramik berliang dengan mempunyai ciri-ciri kawalan kelembapan, anti-bakteria dan anti-kulat.

3. APAKAH YANG PERLU ANDA LAKUKAN?

Anda perlu menjawab semua bahagian yang terkandung di dalam soal selidik ini. Antara informasi yang terkandung adalah maklumat latar belakang, maklumat perkerjaa, kesihatan dan kesejahteraan, gejala-gejala masalah kesihatan sekarang dan keadaan ditempat kerja anda.

4. SIAPA YANG TIDAK BOLEH MENYERTAI KAJIAN INI?

Pekerja yang bekerja kurang daripada setahun

5. APAKAH FAEDAH MENYERTAI KAJIAN INI?

a) KEPADA ANDA SEBAGAI PESERTA?

Kajian ini akan menghasilkan seramik berliang dengan keupayaan mengawal kelembapan, anti-bakteria dan anti-kulat seterusnya mengurangkan masalah kelembapan yang berlaku di dalam pejabat di Malaysia. Kelembapan dalaman biasanya berkait rapat dengan sistem pengudaraan atau penggunaan penghawa dingin di dalam pejabat. Selain itu, tuntutan penyaman udara, keperluan untuk mengawal selia setiap hari bekerja agak mahal dan menyebabkan peningkatan kelembapan dalaman. Perkembangan seramik berliang ini dapat mengawal kelembapan dalam ruangan tanpa perlu mengeluarkan wang secara berterusan untuk penyelenggaraan. Oleh itu, kos untuk mengawal penyaman udara boleh dikurangkan dengan menggunakan seramik berliang ini. Di samping itu, masalah acuan yang disebabkan oleh pengumpulan bakteria dan kulat pada beberapa bahan binaan termasuk dinding, perabot dan jubin boleh diselesaikan dengan menggunakan seramik berliang ini. Ia mempunyai keupayaan untuk membunuh mana-mana kulat dan bakteria yang terletak pada seramik ini seterusnya mengurangkan masalah acuan dalam suasana pejabat. Seterusnya, masalah ini tidak hanya merosakkan bahan binaan tetapi juga memberi kesan kepada kesihatan manusia. Alergi, rhinitis, masalah pernafasan yang berkaitan dengan asma adalah masalah lain yang timbul sekarang. Penggunaan seramik berliang ini dengan ciri-ciri ini dapat meminimumkan masalah kesihatan yang berkaitan dengan pencemaran acuan.

b) KEPADA PENYELIDIK?

Kajian ini akan membantu penyelidik untuk menyelidik keupayaan *Diatomacous Earth* (DE) sebagai bahan utama dalam penghasilan bahan kawalan kelembapan, mempunyai bericir antimikrob untuk penghasilan seramik berliang yang baru.

6. ADAKAH IA BERISIKO?

Tiada risiko yang wujud di dalam penyelidikan ini.

7. ADAKAH MAKLUMAT DAN IDENTITI SAYA KEKAL RAHSIA?

Maklumat yang terkumpul dalam kajian ini akan dirahsiakan.

© COPYRIGHT UPM

8. SIAPA YANG SAYA PERLU HUBUNGI SEKIRANYA SAYA MEMPUNYAI SOALAN TAMBAHAN SEMASA MENGIKUTI PENYELIDIKAN INI?

Jika anda mempunyai sebarang pertanyaan, anda boleh menghubungi saya melalui emel nurulhafizah2101@gmail.com dan melalui telefon bimbit 019-4115893 atau penyelia penyelidikan kajian ini Dr.Emilia binti Zainal Abidin di 03-8947 2643 atau emel di za_emilia@upm.edu.my

Sila tandatangan di sini sekiranya anda telah membaca dan memahami kandungan halaman ini

____

© COPYRIGHT UPM

9. PERSETUJUAN

Saya……………………………………………… No Kad Pengenalan. …………………………… beralamat……………………………………………………………………………………………… ……………………………………..dengan ini bersetuju untuk mengambil bahagian secara sukarela dalam penyelidikan yang tersebut di atas *(kajian klinikal/percubaan ubat-ubatan/rakaman video/kumpulan sasaran/temuduga/ soal selidik).

Saya telah diberi penjelasan secara menyeluruh mengenai penyelidikan ini dari segi metodologi, risiko dan komplikasi (seperti tertulis pada Helaian Penerangan Responden). Saya memahami bahawa saya berhak menarik diri dari penyelidikan ini pada bila-bila masa tanpa memberi sebarang alasan.Saya juga memahami bahawa sebarang maklumat yang berkaitan identiti saya akan dirahsiakan.

Saya* berminat / tidak berminat untuk mengetahui keputusan kajian yang melibatkan saya.

I setuju/tidak bersetuju untuk imei/gambar/rakaman video/ rakaman suara digunakan dalam apa jua bentuk penerbitan atau pembentangan. (sekiranya berkaitan).

*potong yang tidak berkenaan

Tandatangan ……………………………………
(*Responden*)

Tandatangan ……………………………………
(*Saksi*)

Tarikh :……………………………………………

Nama :……………………………………………

No. K/P: …………………………………………..

Saya mengesahkan bahawa saya telah menerangkan kepada responden ini sifat dan tujuan penyelidikan yang tersebut di atas.

Tarikh ……………………………………

Tandatangan ……………………………………
(*Penyelidik*)

© COPYRIGHT UPM

APPENDIX 2:

(QUESTIONNAIRE- ENGLISH VERSION)

© COPYRIGHT UPM

ID :

Date :

TITLE:

DEVELOPMENT OF POROUS CERAMICS WITH HUMIDITY CONTROLLING AND ANTIMICROBIAL CHARACTERISTICS FROM MODIFIED DIATOMACEOUS EARTH (DE) : POTENTIAL TO IMPROVE INDOOR AIR QUALITY

Questionnaire

There are **SIX** sections to this questionnaire and it should take about 5 to 10 minutes to complete answering the questionnaire. Please answer the question by TICKING or WRITING in the spaces provided. Your contribution is important and will help to provide information on how to improve indoor air quality.

© COPYRIGHT UPM

SECTION A: SOCIO-DEMOGRAPHIC INFORMATION

This page contains questions which relates to your background information. Please answer each question completely as best as you can.

1. Age: _____ years old
2. Gender: ☐ Male ☐ Female
3. Ethnic group: ☐ Malay ☐ Chinese ☐ Indian ☐ Others
4. Marital status: ☐ Single ☐ Married
5. Do you smoke?
   - ☐ Never smoke
   - ☐ Yes, started smoking from _______ month / _______ year
   - ☐ Have stopped smoking since ____ month/ ______ year
6. Is there any occupants who lives in your home that smokes in the past one year?
   - ☐ Yes
   - ☐ No
7. Have you ever had asthmatic problems?
   - ☐ Yes
   - ☐ No
8. Have you ever suffered from sinusitis?
   - ☐ Yes
   - ☐ No
9. Have you ever suffered from eczema?
   - ☐ Yes
   - ☐ No
10. Does anybody else in your immediate family suffer from allergies (e.g. asthma, hay fever, eczema?
    - ☐ Yes
    - ☐ No

Please identify the family member (e.g. mother, siblings):__________________________

© COPYRIGHT UPM

SECTION B: EMPLOYMENT INFORMATION

1. How long have you worked in this building?

   _______________ Month (s) _______________ Year (s)

2. In the **LAST WEEK**, how many days did you work in this building?

   _______________ Days

3. How many **HOURS in a DAY** do you work in this building?

   _______________ Hours in a day

4. Which of the following best describe the space in your current workstation?

   ☐ Private office
   ☐ Shared private office
   ☐ Open space with partner
   ☐ Open space without partner
   ☐ Others (please specify; _______________)

5. How many people work in the room in your workstation including yourself ?

   ☐ 1
   ☐ 2 – 3
   ☐ 4 – 7
   ☐ 8 or more

6. What type of ventilation system is available in the room that you occupy in your office and how long does the ventilation system is run in a day?

   ☐ Split Unit Air conditioning
   ______ Hours in a day

   ☐ Mechanical Ventilation Air conditioning (MVAC)

© COPYRIGHT UPM

SECTION C: SICK BUILDING SYNDROME (SBS) SYMPTOMS

Please choose the appropriate box; if you are unsure of the answer, please choose no.

In the last **12 month** have you had any of the following symptoms?

	YES	NO
1. Wheezing or whistling in the chest	☐	☐
2. Chest tightness in the morning	☐	☐
3. Shortness of breath	☐	☐
4. Coughing	☐	☐
5. Phlegm in the morning	☐	☐
6. Asthma attack	☐	☐
7. Nauseas/Dizziness	☐	☐
8. Difficulties in concentrating	☐	☐
9. Itching, burning or irritation of the eyes	☐	☐
10. Fatigue	☐	☐
11. Feeling heavy-headed	☐	☐
12. Headache	☐	☐
13. Irritated, stuffy or runny nose	☐	☐
14. Hoarse, dry throat	☐	☐
15. Hands dry, itching, red skin	☐	☐
16. Dry or flushed skin	☐	☐

© COPYRIGHT UPM

SECTION D: WORKING ENVIRONMENT

Have you been bothered during the **LAST TWELVE MONTHS** by any of the following factors at your workplace?

	Yes, often (Every week)	Yes, often (Sometimes)	No (Never)
1. Visible fungal growth	☐	☐	☐
2. Moldy odor	☐	☐	☐
3. Stain / Discolor on walls	☐	☐	☐
4. Room temperature too high	☐	☐	☐
5. Room temperature too low	☐	☐	☐
6. Inadequate ventilation	☐	☐	☐
7. Dry air	☐	☐	☐
8. Passive smoking	☐	☐	☐
9. Dust, dirt	☐	☐	☐

© COPYRIGHT UPM

SECTION D: EXTENSION OF HUMIDITY PROBLEMS AT THE WORKPLACE

1. Do you aware moisture problems at your work area?

☐ Yes
☐ No

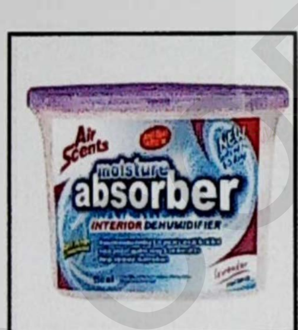
2. If **YES**, please state place where you find mold problems.

☐ Ceilings	☐ Under window sills
☐ Wall	☐ Curtains
☐ Tiles	☐ Split Unit Air Conditioning
☐ Desk	☐ MVAC

3. Is there any dehumidifier that you used at your work area?

☐ Yes
☐ No (Proceed to No.14)

4. If yes, what type of dehumidifier that you use?

☐ 

Moisture Absorber

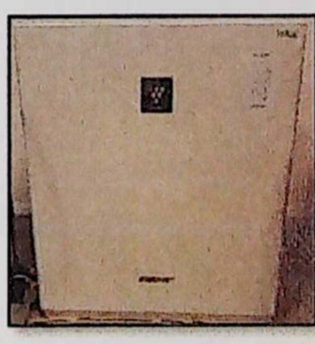
☐ 

Charcoal dehumidifier

☐ 

Silica Gel Dehumidifier

☐ 
Air Dry System

☐ 
Compressor Dehumidifier

☐ Others, please state ______________

© COPYRIGHT UPM

5. Are you aware the importance of using dehumidifier at your work area?

- [ ] Yes
- [ ] No

6. When do you think the room temperature is **TOO LOW**?

- [ ] Morning (8.00am – 11.00 am)
- [ ] Afternoon (11.00 am -2.00 pm)
- [ ] Evening (2.00pm – 5.00pm)

7. When do you think the room temperature is **TOO HIGH?**

- [ ] Morning (8.00am – 11.00 am)
- [ ] Afternoon (11.00 am -2.00 pm)
- [ ] Evening (2.00pm – 5.00pm)

© COPYRIGHT UPM

SECTION E: INTERVENTION TO IMPROVE INDOOR AIR QUALITY IN OFFICES

1 – Strongly Agree
2 – Agree
3 – Undecided
4 – Disagree
5 – Strongly Disagree

Please refer to the above information to answer the following questions

1. If there is a new product in a form of ceramic tiles which has the following characteristics, do you think that the current indoor air quality of your office will be improved?

   ✓ Chemical free
   ✓ Adsorb excessive humidity
   ✓ Kills bacteria or reduce bacteria growth
   ✓ Kills fungi or reduce mould growth
   ✓ Remove unpleasant odour

   ☐ (please rate 1 - 5)

2. If the ceramic tiles can prevent respiratory health problems related to bad indoor air quality, would you agree if the building administrator install the new tiles in your room?

   ☐ (please rate 1 - 5)

3. If the ceramic tiles is cheap and non-toxic, would you install the tiles in your home?

   ☐ (please rate 1 - 5)

4. If the current Indoor Air Quality is improved with the installation of new tiles in your office,do you think your work productivity will be further improved?

   ☐ (please rate 1 - 5)

End of Questionnaire. Thank you for your valuable time and contribution.

© COPYRIGHT UPM

APPENDIX 3:

(QUESTIONNAIRE- MALAY VERSION)

ID :

Tarikh : ______________

UPM
UNIVERSITI PUTRA MALAYSIA
BERILMU BERBAKTI

Tajuk:

PENGHASILAN SERAMIK BERLIANG DENGAN BERCIRI KAWALAN KELEMBAPAN DAN ANTIMIKROB DARIPADA PENGUBAHSUAIAN TANAH DIATOMAT : POTENSI MENINGKATKAN KUALITI UDARA

Borang Kaji Selidik

Borang kaji selidik ini mempunyai **ENAM** bahagian dan hanya mengambil masa 5 hingga 10 minit sahaja untuk dilengkapkan. Sila tandakan (/) pada kotak disediakan dan isi tempat kosong pada ruang yang disediakan. Sumbangan anda serta maklumat yang diberikan akan membantu untuk meningkatkan kualiti udara di ruang kerja anda.

© COPYRIGHT UPM

BAHAGIAN A: MAKLUMAT SOSIO-DEMOGRAFI

1. Umur: _____ tahun
2. Jantina: ☐ Lelaki ☐ Perempuan
3. Etnik: ☐ Melayu ☐ Cina ☐ India ☐ Lain-lain
4. Marital status: ☐ Bujang ☐ Berkahwi
5. Adakah anda merokok?
   - ☐ Tidak pernah
   - ☐ Ya, sudah merokok sejak _______ bulan / _______ tahun
   - ☐ Sudah berhenti sejak _______bulan/ ______ tahun
6. Adakah dirumah anda terdapat penghuni yang merokok sejak setahun yang lalu?
   - ☐ Ya
   - ☐ Tidak
7. Adakah anda mempunyai asma?
   - ☐ Ya
   - ☐ Tidak
8. Adakah anda mempunyai resdung?
   - ☐ Ya
   - ☐ Tidak
9. Adakah anda mempunyai ekzema?
   - ☐ Ya
   - ☐ Tidak
10. Adakah dirumah anda terdapat penghuni atau ahli keluarga yang mempunyai asma, resdung atau ekzema?
    - ☐ Ya
    - ☐ Tidak

Siapakah ahli keluarga tersebut (e.g. ibu, ayah, adik-beradik?) :____________

© COPYRIGHT UPM

BAHAGIAN B: MAKLUMAT PEKERJAAN

1. Berapa lama anda sudah berkerja di bangunan ini?

_______________ Bulan _______________ Tahun

2. Pada **MINGGU SEBELUMNYA**, berapa lamakah anda bekerja dalam (hari)?

_______________ Hari

3. Dalam **SEHARI**, berapa **JAM** kah anda bekerja dalam bangunan ini?

_______________ Jam dalam sehari

4. Antara pilihan berikut, yang manakah menerangkan ruang tempat kerja anda sekarang?

- ☐ Pejabat Persendirian
- ☐ Pejabat Persendirian (berkongsi)
- ☐ Ruang terbuka dan berkongsi
- ☐ Ruang terbuka, tidak berkongsi
- ☐ Lain-lain (Sila nyatakan; _______________)

5. Berapa ramai pekerja di pejabat anda (termasuk diri anda)?

- ☐ 1
- ☐ 2 – 3
- ☐ 4 – 7
- ☐ 8 dan lebih

6. Apakah jenis sistem pengudaraan yang terdapat di ruang tempat anda duduk dan berapa jam sistem pengudaraan digunakan dalam sehari?

☐ *Split Unit Air conditioning*
______ Jam dalam sehari

☐ *Mechanical Ventilation Air conditioning* (MVAC)
______ Jam dalam sehari

© COPYRIGHT UPM

BAHAGIAN C: *SICK BUILDING SYNDROME (SBS)* ATAU SINDROM BANGUNAN SAKIT (SBS)

Sila (/) dikotak berkaitan, jika TIDAK PASTI, sila (/) pada kotak TIDAK

Sekitar 12 **BULAN YANG LEPAS**, adakah anda mempunyai simptom berikut?

	YA	TIDAK
1. Nafas berbunyi	☐	☐
2. Sesak dada pada waktu pagi	☐	☐
3. Kesukaran bernafas	☐	☐
4. Batuk	☐	☐
5. Kahak	☐	☐
6. Serangan asma	☐	☐
7. Loya / Pening	☐	☐
8. Sukar untuk fokus	☐	☐
9. Gatal pada mata	☐	☐
10. Penat berlebihan	☐	☐
11. Kepala terasa berat	☐	☐
12. Pening kepala	☐	☐
13. Hidung tersumbat dan berair	☐	☐
14. Tekak kering	☐	☐
15. Tangan kering	☐	☐
16. Gatal pada tangan dan kulit menjadi merah	☐	☐

© COPYRIGHT UPM

BAHAGIAN D : PERSEKITARAN RUANG KERJA

Adakah anda terganggu oleh mana-mana faktor berikut sekitar **DUA BELAS BULAN LALU** di pejabat anda?

	Ya, selalu (Setiap minggu)	Ya, selalu (Kadang)	Tidak Pernah
1. Pembiakan tompok kulat pada dinding	☐	☐	☐
2. Bau kulat (bau hapak)	☐	☐	☐
3. Perubahan warna pada dinding	☐	☐	☐
4. Suhu bilik terlalu tinggi	☐	☐	☐
5. Suhu bilik terlalu rendah	☐	☐	☐
6. Kurang pengudaraan	☐	☐	☐
7. Udara kering	☐	☐	☐
8. Perokok pasif	☐	☐	☐
9. Berhabuk dan kotor	☐	☐	☐

© COPYRIGHT UPM

BAHAGIAN E: LANJUTAN MASALAH KELEMBAPAN DI TEMPAT KERJA

1. Adakah anda sedar masalah udara lembap boleh menyebabkan pertumbuhan kulat diruang kerja anda?

   ☐ Ya
   ☐ Tidak (**Sila ke soalan 3**)

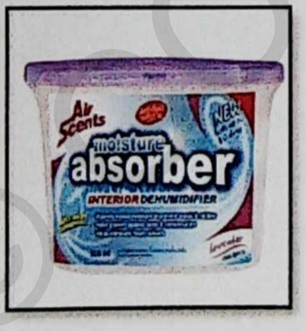
2. Jika **YA**, sila (/) di kawasan yang bermasalah dengan pertumbuhan kulat.

   ☐ Siling ☐ Tingkap
   ☐ Dinding ☐ Langsir
   ☐ Jubin ☐ *Split Unit Air Conditioning*
   ☐ Meja ☐ *MVAC*

3. Adakah anda ada menggunakan perangkap habuk di ruang kerja anda?

   ☐ Ya
   ☐ Tidak (**Sila ke soalan 5**)

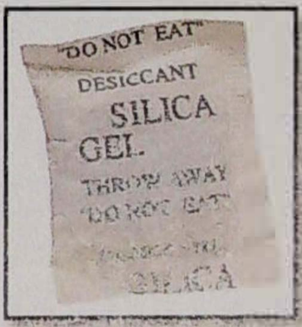
4. Jika **YA**, sila (/) pada kotak berkaitan

☐ 

Penyerap udara berlebihan

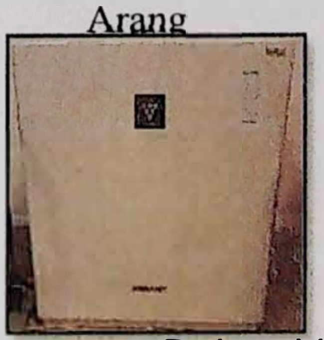
☐ 

Arang

☐ 

Silica Gel

☐ 
Air Dry System

☐ 
Compressor Dehumidifier

☐ Lain-lain ______________

© COPYRIGHT UPM

5. Adakah anda sedar kepentingan perangkap habuk dan udara (wap air berlebihan di ruang kerja anda?

- [ ] Ya
- [ ] Tidak

6. Pada masa bilakah anda merasakan **SUHU TERLALU RENDAH?**

- [ ] Pagi (8.00am – 11.00 am)
- [ ] Tengahari (11.00am -2.00 pm)
- [ ] Petang (2.00pm – 5.00pm)

7. Pada masa bilakah anda merasakan **SUHU TERLALU TINGGGI?**

- [ ] Pagi (8.00am – 11.00 am)
- [ ] Tengahari (11.00am -2.00 pm)
- [ ] Petang (2.00pm – 5.00pm)

© COPYRIGHT UPM

BAHAGIAN E: USAHA DALAM MENINGKATKAN KUALITI UDARA DALAM PEJABAT

1 – Sangat setuju
2 – Setuju
3 – Tidak pasti
4 – Tidak setuju
5 – Sangat tidak setuju

Sila rujuk kotak diatas untuk menjawab soalan seterusnya

1. Sekiranya terdapat produk baru dalam bentuk **JUBIN SERAMIK** yang mempunyai ciri-ciri berikut, adakah anda berpendapat bahawa kualiti udara akan bertambah baik?

   ✓ Bebas kimia
   ✓ Menyerap **wap air** berlebihan
   ✓ Mengurangkan pertumbuhan bakteria
   ✓ Mengurangkan masalah kulat
   ✓ Menyelesaikan **masalah bau** hapak dan busuk

   ☐ Ya (Sila rating 1-5)

2. Jika jubin seramik ini dapat mengelakkan masalah paru-paru atau pernafasan berkaitan kualiti udara yang buruk, adakah anda bersetuju jika pentadbir bangunan (*Building Administrator*) memasang jubin baru di dalam pejabat anda?

   ☐ Ya (Sila rating 1-5)

3. Jika jubin seramik ini murah dan tidak toksik, adakah anda bersetuju untuk memasang di rumah anda?

   ☐ Ya (Sila rating 1-5)

4. Sekiranya dengan pemasangan jubin baru dipejabat anda dapat meningkatkan kualiti udara, adakah anda fikir produktiviti kerja anda akan bertambah baik?

   ☐ Ya (Sila rating 1-5)

Soalan tamat. Terima kasih atas masa dan sumbangan anda

© COPYRIGHT UPM

APPENDIX 4:

(ETHICS APPROVAL)

© COPYRIGHT UPM

ETHICS COMMITTEE FOR RESEARCH INVOLVING HUMAN SUBJECTS (JKEUPM)
UNIVERSITI PUTRA MALAYSIA

Research title	:	**Development of Porous Ceramics**
Study Site	:	**FPSK, UPM**
JKEUPM Ref No.	:	**JKEUPM-2017-203**
Researcher	:	**Nurul Hafizah Ahmad**
Supervisor	:	**Dr. Emilia Zainal Abidin**

Documents received and reviewed with reference to the above study:

1. Ethics Application Form, Version 1 dated 31/10/2017
2. Respondent Information Sheet & Consent (English), Version 2 dated 24/11/2017
3. Respondent Information Sheet & Consent (Malay), Version 2 dated 24/11/2017
4. Proposal (English), Version 2 dated 7/12/2017
5. Questionnaire (English), Version 1 dated 31/10/2017
6. Curriculum Vitae of:
   a. Dr. Emilia Zainal Abidin
   b. Prof. Ir. Dr. Mohd Sapuan Salit
   c. Dr. Azmiza Syawani Jasni

The University Research Ethics Committee, Universiti Putra Malaysia (JKEUPM) operates in accordance to the ICH-GCP Guidelines.

Decision by JKEUPM:

[X] Approved

[ ] **Permission MUST BE OBTAINED from the respective hospitals/ institutions before conducting the research**

[ ] Disapproved

Please note that the approval is **VALID UNTIL 10 JANUARY 2019**

Researchers should comply with the following:

I. Complete a Study Final Report upon study completion (Form 3.2).

© COPYRIGHT UPM

APPENDIX 5:

(APPROVAL FROM FACULTY OF MEDICINE AND HEALTH SCIENCES)

© COPYRIGHT UPM