RELATIVE HUMIDITY AND TEMPERATURE EFFECT ON BIOLOGICAL CONTAMINANT AT PUBLIC ACCESS BUILDING IN SEBERANG PERAI SELATAN, PULAU PINANG

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ABSTRAK

Secara umumnya, 90% manusia menghabiskan masa mereka di dalam ruangan bangunan. Dalam ICOP, 2010 juga menyatakan bahawa ruangan yang sihat dapat menghasilkan persekitaran kerja yang lebih baik. Tambahan pula, kajian sekarang menunjukkan bahawa bahan cemar biologi yang tinggi boleh membawa kepada Sindrom Bangunan Sakit (SBS). Kajian ini bertujuan untuk menentukan tahap suhu, kelembapan relatif dan hubungannya dengan bahan cemar biologi dalam masjid seperti yang ditetapkan dalam Kod Amalan Industri (ICOP), 2010. Hubungan bahan cemar biologi antara asal usul suhu (T) dan kelembapan relatif (RH) telah dikenal pasti. Penyiasatan keatas enam bangunan akses awam mengenai T, RH dan bahan cemar biologi telah dilakukan di Masjid Bukit Panchor, Masjid Nibong Tebal, Masjid Baru Sungai Bakap, Masjid Sungai Setar Besar, Masjid Kampung Besar dan Masjid Telok Ipil. Hasil daripada ujian tersebut menunjukkan bahawa T dan RH di dalam bangunan akses awam dipengaruhi oleh jumlah jemaah dan pengudaraan mekanikal. Masjid Nibong Tebal adalah salah satu masjid yang mempunyai suhu yang tinggi (32°C) serta mempunyai bilangan jemaah yang tinggi, sementara itu Masjid Kampung Besar juga mempunyai suhu yang paling tinggi (33°C) kerana pengudaraan pasif. Selain itu, Masjid Baru Sungai Bakap mempunyai purata RH% (74%) tertinggi yang melebihi had ICOP. Selanjutnya, kepekatan purata bahan cemar acuan untuk semua masjid dipantau tidak melebihi garis panduan had yang diterima. Sementara itu, Masjid Telok Ipil adalah satu-satunya masjid yang mempunyai kiraan bakteria yang tertinggi serta melebihi had yang diterima dengan 620 cfu/m³ selepas memvakum permaidani. Suhu dan kelembapan relatif tidak hanya menjadi sumber untuk pertumbuhan mikrob tetapi aktiviti manusia dan kewujudan permaidani juga merupakan salah satu penyumbang utama.

ABSTRACT

Generally, 90% of people spends their time indoor. In ICOP (2010) also stated that healthy indoor will produce better work environment. Furthermore, recent findings had shown that high biological contaminated could lead to Sick Building Syndrome (SBS). This study aims to determine the level of temperature, relative humidity and its relationship with biological contaminants in mosques as stipulated in Industry Code of Practice (ICOP), 2010. Biological contaminants relationship between provenances temperature (T) and relative humidity (RH) were identified. An investigation of six public access building regarding T, RH and biological contaminants were done at Masjid Bukit Panchor, Masjid Nibong Tebal, Masjid Baru Sungai Bakap, Masjid Sungai Setar Besar, Masjid Kampung Besar and Masjid Telok Ipil. Result of the study shown that level of T and RH in the public access building were influenced by the number of jemaah and mechanical ventilation. Masjid Nibong Tebal was one of the high temperature (32°C) mosque with a high number of jemaah, meanwhile Masjid Kampung Besar also had the highest temperature (33°C) because of the passive ventilation. Besides that, Masjid Baru Sungai Bakap had the highest average RH (74%) which exceed the ICOP limit. Further, the average concentrations of mold contaminants for all monitored mosques did not exceed the acceptable guideline limit. Meanwhile, Masjid Telok Ipil was the only mosque that had the highest bacterial count which exceed the acceptable limit with 620 cfu/m^3 after vacuuming the carpets. Temperature and relative humidity were not only sources for microbial growth but human activities and carpeting are also one of the main contributors.

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LIST OF ABBREVIATIONS

IAQ	**I**ndoor **A**ir **Q**uality
SBS	**S**ick **B**uilding **S**yndrome
ICMSF	**I**nternational **C**ommission on **M**icrobiological **S**pecifications for **F**oods
ICOP	**I**ndustry **C**ode **O**f Practice
BC	**B**illion **C**entury
NIOSH	**N**ational **I**nstitute of **O**ccupational **S**afety and **H**ealth
WHO	**W**orld **H**ealth **O**rganization
ASHRAE	**A**merican **S**ociety of **H**eating, **R**efrigeration and **A**ir Conditioning **E**ngineers
VOC	**V**olatile **O**rganic **C**ompound
HVAC	**H**eating and **V**entilating **A**ir **C**ondition
ACH	**A**ir **C**hanges per **H**our
AHU	**A**ir-**H**andling **U**nit
GNB	**G**ram **N**egative **B**acteria
CRI	**C**arpet and **R**ug **I**nstitute
BCF	**B**ulked **C**ontinuous **F**ilament
SPS	**S**eberang **P**erai **S**elatan
T	**T**emperature
RH	**R**elative **H**umidity
TVOC	**T**otal **V**olatile **O**rganic **C**ompound
CO_2	**C**arbon **D**ioxide
CO	**C**arbon **M**onoxide

CHAPTER 1

INTRODUCTION

1.1 Background

Indoor air quality (IAQ) bring a lot of attention as a major concern to people who spend a lot of their time in confining spaces such as public space or private space. As we know that almost 90% of people spend their time in confined space (Leech et al., 2002). Indoor air Quality (IAQ) is the quality of air inside any confined space, which leads to comforts and health of the occupants (Yau et al, 2012). Good indoor air quality (IAQ) is required for a healthy indoor work environment.

According to past studies, their result indicated that indoor air could be seriously polluted and many people are already exposed once they enter any confined space (Brooks and David, 1992; Jones, 1999; Hess-Kosa, 2011). Poor indoor air quality can cause a variety of short-term and long-term health problems. Recent findings have shown that contaminated indoor air was a major human health risk due to the exposure of air pollution (Kotzias, 2005). So it can be concluded that bad IAQ also can lead to sick building syndrome (SBS), a condition which people feel uneasy such as headache, sleepiness or decrease the ability to concentrate on any work while spending their time in certain building. Sick building syndrome is the sickness related to high indoor pollutions, especially the biological agents (Takigawa at al., 2009). Biological agents consist of fungal and bacteria contaminants, which derives as viruses and pollens. All the microscopic organisms in that contaminants may cause allergy symptoms, which is also reported to affect more than 20% of the adult population (Hess-Kosa, 2011).

According to Hess-Kosa, (2011), microbial contaminants that caused to allergy had two major categories, which are fungi and bacteria. Fungi has two types, which are molds and yeast. Molds can only stay alive in the air surrounding us if there is an existence of indefinite on inanimate objects. Then, yeast usually flourishes in habitats where sugars are present. While the bacteria that is different from fungi because it required special media and some require elevated incubation temperature. Both contaminants depended on the humidity in the buildings for growth requirement. Besides that Dacarro et al., (2003), stated that fungi and bacteria counting from observation in presence of central heating with lowest humidity is decreasing. The absences of visible signs of dampness and low airborne fungal levels are usually considered indications that there is little, if any biological contaminants (Nevalainen et al.,1991). As the International Commission on Microbiological Specifications for Foods (ICMSF), (1980), already stated that most of the fungi just required high moisture in order to grow. As shown in Table 1.1 below that most of that microorganisms require moisture content in excess of 80 percent, some just need as low as 60 percent.

Table 1.1: A moisture requirements of common microorganisms

Microorganism	***Water Activity (% Relative Moisture)***
Aspergillus halophilic and Aspergillus restictus	0.65-0.70
Aspergillus glaucus and Wallemia sebi	0.70-0.75
Aspergillus chevalieri, Aspergillus candidus, Aspergillus orchraceus, Aspergillus versicolor, and Aspergillus nidulans	0.75-0.80
Aspergillus flavus, Aspergillus versicolor, Penicillium citreoviride, and Penicillium citrinum	0.80-0.85
Aspergillus oryzae, Aspergillus fumigatus Aspergillus niger, Penicillium notatum Penicillium islandicum, and Penicillium urticae	0.85-0.90
Yeast, bacteria and many molds	0.95-1.00

(Source : ICMSF, New York (1980)

1.2 Problem Statement

Various air pollution were produced in this new era of development of economy. Apparently, people assuming that air pollution outdoor on their buildings would be worse than indoor air quality which due to the shielding effect of buildings and possible installation of ventilation and air cleaning devices. Chen and Zhao, (2011), have found that indoor air pollution concentrations is higher than outdoor.

Microbial contaminants are also classified as one of the criteria for indoor air pollution. As the result, the increasing of indoor microbial contaminants are affected by outdoor pollution (Ponce-Caballero et al., 2010). Besides that, human activities inside a building can also increase the growth on indoor microbial contaminants such as talking, sneezing, coughing, skin shedding microorganisms, and walking and toilet flushing (Cox and Wathes.,1995).

As we know, thermal comfort such as relative humidity, temperature and air flow are an important component of IAQ. Unfortunately, it had been the major effects of indoor microbial contaminants in a place that has these components (Storey et al., 2004). These components exist in mosque which lead it become a favourable place for microbial growth. Ahearn et al., (1997) study suggested that air-conditioning system in building contribute to rising of fungal contaminants. Apart from that, clean room also produces significant amounts of microbial contaminants (Favero et al., 1966). Therefore, it is reasonable for the existence of microbial in the mosques.

1.3 Objectives

Clean indoor air is considered a basic requirement for human being while they occupied or enter any public spaces such as mosques. Otherwise, it also help prevent the worst scenario on microbial allergy occurs. Therefore, it is important to ensure that this research will contribute to environmental engineering in indoor air quality for confined spaced. The first objective of this study is to compare the biological contaminants (bacteria and fungi) before vacuum and after vacuum at mosque building in accordance to Industry Code of Practice (ICOP), 2010. Then, the second objective is to study the effect of relative humidity and temperature on biological contaminants in mosque buildings.

1.4 Dissertation Outline

This thesis has five important parts and brief outlines of this study which are shown as the following points:

- Chapter 1 explained about an introduction of indoor air quality, microbial contaminants and humidity effects. Besides that, it discusses the problem statement and objectives.

- Chapter 2 provided literature reviews on the microbial contaminants, factors influencing indoor air quality, effects of different ventilation types to microbial growth, health effects and carpeting effects to microbial.

- Chapter 3 gives the information about the selection sites, which also include the material and methods that were used in this study.

- Chapter 4 presents the results obtained from data collection and data analysis. This chapter discusses on relative humidity with temperature relationship to microbial contaminants.

- Chapter 5 will conclude the overall study on this research and summarize all of the results and a few recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains about the definition of microbial contaminants, and the concept of indoor air quality in biological contaminants with the factors that can contribute microbe's air pollution. In addition, it also include the guideline of Industry Code of Practice (ICOP), 2010 for allowable limit on microbial contaminants. Besides that, this chapter will overview the health effects by indoor exposure to biological contaminants.

2.2 Microbial Contaminants

There had been many studies related to indoor microbial contaminants such as at a hospital (Claro et al., 2015; Openshaw et al., 2016) and school (Lee and Chang, 2000). Indoor microbial contaminants studies had increase because people start to realize that untreated air can bring a lot of disease such as asthma, sick building syndrome (SBS) and others that are related to respiratory system of human. As early as 1500 BC, the Egyptians realized that silicate dust produced by the cutting of construction stone can cause respiratory diseases called *papyrusebers* (Brooks and Davis., 1991). The first performed Indoor Air Quality (IAQ) investigation was by the National Institute of Occupational Safety and Health (NIOSH) in 1971. In order to understand the information, record regarding IAQ was increased from 1978 to 1989. (Burge and Hodgson., 1988). To reveal the IAQ issues, the understanding of that information needed first.

Microbial contaminant is a biological origin such as bacteria, viruses and fungi that can cause any disease by airborne transmission. There are very tiny organisms found in just about every ecosystem or elsewhere in the world and can associate with other diverse types of living things. Bacteria and viruses readily become airborne and remain suspended in air for hours. While fungi composed of networks of long hollow tubes called hyphae that are bordered by a rigid wall usually made of chitin the same material that forms the exoskeletons of insects (Godish, 2000). According to World Health Organization(WHO) (2010), all the microbial contaminant identified on the air include bacteria, either in vegetative status or spores, fungi, yeasts, microbial toxins and secondary metabolites like bacterial endotoxin, peptidoglycans or fungal β(1,3)-glucans, volatile organic compounds, pollens, pet and insect allergens, other allergens, viruses, protozoa and others.

2.2.1 Bacteria

Based on (Godish, 2000), bacteria are single- celled organisms that characterized by their lack of true nucleus and their relatively small size. The bacteria species had their own historically characterized group which the cells assume as three distinct morphological shapes such as spherical (coccus), rod-shaped (bacillus), and spiral/curved (spirillum, spirochete, vibrio). Figure 2.1 shows the bacteria shapes from a few studies regarding a bacteria. Besides that, bacteria was reproduced by simple fission. These organisms was vary to their environment requirements. These also include the existent of nutritional substrates, availability of oxygen, moisture levels, pH and temperature. Furthermore, water is one factor for the growth of individual cell of bacteria (Godish, 2000). Then, human activities and existence also factor for producing the common building-associated

bacteria called saprophytic bacteria from skin, mouth and nose. Other common bacteria of indoor environments include heterotrophic bacteria that grow in the water reservoirs or moist sites of the building. But, for moist building condition Actinobacteria (especially Streptomycetes), Bacillus species and various type of bacteria that growth rapidly (Nevalainen et al., 2009). Bacteria actively growing or accumulating in the indoor environment may cause health effects and may require specific actions to control growth and prevent the exposures.

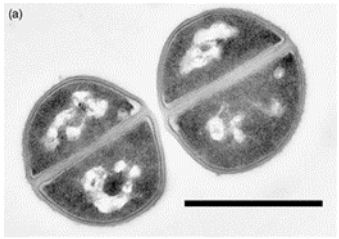	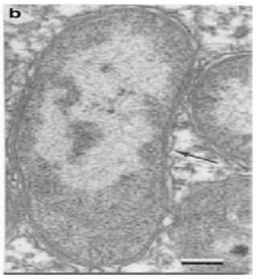	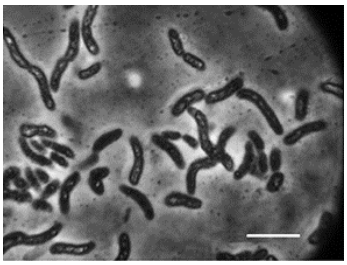
(a) Spherical shapes of cocci	(b) Rod-shaped of bacillus	(c) Spiral shapes of spirillum

Figure 2.1: Electron micrographs of bacteria
(Sources: Zapun et. al., 2008; Cavanaugh et. al., 2006; Lavrinenko et. al., 2010)

2.2.2 Fungal

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

Fungi can be present in both outdoor and indoor air. Furthermore, over 400 reports regarding pathogenic fungi species are widely distributed in damp location which were responsible for several infections (Chabasse et al., 2009), because water is a major limiting factor for fungi growth. With humidity of more than 70% are required for fungi to growt continuously. Fungal was a species that had broad tolerance range for its availability. In describing the moisture content, water activity (aw) is the humidity of the substrate expressed as a decimal fraction as 50% = 0.5aw. Then, it only needs approximately 0.55aw to 1.0aw for growth activities (Godish, 2000).

Penicillium, Aspergillus, Cladosporium, Alternaria, and yeast was the most common fungal genera occurring in indoor space (Nevalainen et. al., 2009).According to World Health Organization (year), fungi just need carbohydrates, proteins and lipids for growth. All the elements can be found in house dust, construction materials, paint, glue, wood, paper and stored food. Fungi also can growt on inert materials like ceramic tiles.

2.3 Physical Parameters and Biological Contaminants in Industry Code of Practice (ICOP), 2010

Indoor air pollution have been talked and studied nowadays because it can affect the health and well-being of human. So, Industry Code of Practice on Indoor Air Quality, (2010) was established to provide guidance on improving air quality (IAQ) and to set minimum standard for selected parameters which can avoid discomfort and adverse health effect on human being. These stated parameters as shown in Table 2.1 and Table 2.2 had been guideline to employees and other occupants while operating or occupied in a closed space building. In managing any building, the inspection need to be done regularly to overcome the existence of high microbial contaminants which can lead to certain diseases.

Table 2.1: Acceptable range for specific physical parameters.

Parameter	Acceptable range
(a) Air temperature	23 – 26 ^{o}C
(b) Relative humidity	40 – 70%
(c) Air movements	0.15 – 0.50 m/s

(Sources: ICOP, 2010)

Table 2.2: Biological contaminants and acceptable limits.

Indoor Air Contaminants	Acceptable limits (cfu/m^{3})
Biological Contaminants	
(a) Total bacterial counts	500
(b) Total fungal counts	1000

(Sources: ICOP, 2010)

2.4 Physical Parameters

A lot of indoor environments either in residential, hospitals, commercials, educations and others was prescribed to has a ventilation system which can flow in and out the air for increasing the comfortability. Thermal comfort can be prescribed as the existing of temperature, humidity and air movement. Unfortunately, that criteria are three critical requirement for the growth of microorganisms in any environment. Microbial can growt with the appropriate humidity, temperature, physical and nutritional substrata (Brooks and Davis., 1991).

2.4.1 Temperature

Yaglou et al. (1936) considered the effect of temperature on ventilation requirements in his study. As a result, the study shows that temperature is one of the most important factors in air quality and unless it is controlled the quality will suffer badly, no matter what the outdoor air supply, particularly when the air is overheated''. Even though, temperature was important but it have a profound impact upon the perception of indoor air quality. According to ASHRAE (2009), temperature in range 20-26ºC is acceptable for thermal comfort, depending on the occupational activity there. If the temperature is above this range it may increase the initial outgassing VOC (Volatile Organic Compound) from the material. 200 volatile organic compounds can produce fungi. The identification of the VOCs in indoor air shows that there is a fungal growth present, even if the quantitative measurements are negative (Haalen and Karuppayil., 2012). While, Jaakkola et al., (1987) made an observation on temperature above 24ºC in his study and it shows the statistical correlation with the development of typical SBS symptoms