UNIVERSITI PUTRA MALAYSIA

RELATIONSHIP BETWEEN INDOOR AND OUTDOOR LEVELS OF $PM_{2.5}$ AND BIOAEROSOLS IN DAYCARE CENTERS, BANGI

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RELATIONSHIP BETWEEN INDOOR AND OUTDOOR LEVELS OF $PM_{2.5}$ AND BIOAEROSOLS IN DAYCARE CENTERS, BANGI

BY

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Thesis submitted in fulfillment of the requirement for the degree of Bachelor Science (Environmental and Occupational Health) from the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.

ACKNOWLEDGMENTS

Foremost, I would like to express my utmost gratitude to my supervisor, Dr. Nor Eliani Ezani for all her encouragement, guidance, help, and support, without which this work would not have been possible. I am also thankful to my co-supervisor, Dr. Nurshahira Sulaiman, who had spent time and effort to guide me in generating ideas for my thesis. I would like to thank all lab assistants, caretakers at the selected daycare centers, parents and children for their help and cooperation during the data collection period.

I would like to thank my beloved parents, family, and friends for their help, support, and understanding for me during the course of this thesis. Thank you very much to my friends for being there with me during my data collection and analysis and also supporting each other throughout this research.

Last but not least, I give my gratitude to God Almighty. For with His permission, this thesis could be completed.

Ainul Farhanah Binti Mohd Yahya

June 2019

ABSTRACT

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AINUL FARHANAH BINTI MOHD YAHYA

Introduction: Indoor air quality is becoming an emerging issue in public health due to increasing associations with respiratory health effects such as wheezing, allergy, and asthma especially in children. Particulate matter (PM) and bioaerosols are some of the indoor air pollutants that have shown association with the aforementioned respiratory problems. Daycare centers pose as an important environment of interest as children with immature immune systems and poor hygienic behavior are crowded together, there is an increased risk of disease transmission. **Objectives:** This research was done to study the indoor and outdoor relationship of IAQ ($PM_{2.5}$, bacterial and fungal concentrations) in daycare centers in Bangi. **Methodology:** A cross-sectional study design was conducted in three purposively selected daycare centers in Bangi, Selangor from January 2019 to March 2019. Meteorological parameters (temperature and relative humidity) and IAQ parameters ($PM_{2.5}$, bacteria, and fungi) were recorded. Meteorological parameters were recorded using a Kestrel Meter 5500 Weather Meter (Kestrel, Pennsylvania, USA). IAQ parameter for $PM_{2.5}$ was observed using SidePak Personal Aerosol Monitor AM520 (TSI Incorporated, Minnesota, USA) while a single stage Andersen impactor, DUO SAS SUPER 360 (International PBI, Milan, Italy) with two types of agar media; trypticase soy agar (TSA) and malt extract agar (MEA) were used for counting of bacteria and fungi respectfully. All parameters were monitored at both the indoor and outdoor environment of the daycare centers. A self-administered questionnaire taken from the International Study of Asthma and Allergies in Childhood (ISAAC) was distributed to the parents to determine health symptoms experienced by the children. Statistical analysis was run using IBM SPSS Statistics Version 23. I/O ratio for IAQ parameters and the bioaerosol inhalation dose rate for children were also calculated. **Results:** Indoor bacterial concentrations in all daycare centers showed a higher level compared to outdoor levels, with the highest mean observed in Daycare 1 (1206 CFU^{-3} and 440 CFU^{-3} respectively). I/O ratios also support this as all the I/O ratios for IAQ parameters are more than >1, signifying that the source of pollution could originate from indoors. $PM_{2.5}$ showed higher mean concentration outdoors compared to indoors (0.0417$\mu g/m^3$ and 0.0309$\mu g/m^3$ respectively). Children in Daycare 3 have the highest inhalation dose rate of bioaerosols particles (4.62 x 104) while rhinitis showed a high prevalence (65.9%) among the studied population. **Conclusion:** This study found no association between indoor and outdoor parameters however meteorological parameters (temperature and relative humidity) was found to be correlated with $PM_{2.5}$ and fungi concentration respectively.

Keywords: indoor/outdoor ratio, $PM_{2.5}$, bioaerosols, daycare centers, respiratory health symptoms

ABSTRAK

HUBUNGAN DI ANTARA $PM_{2.5}$ DAN BIOAEROSOL DI DALAMAN DAN LUARAN PUSAT JAGAAN HARIAN, BANGI

AINUL FARHANAH BINTI MOHD YAHYA

Pengenalan: Kualiti udara dalaman semakin menjadi isu kesihatan awam disebabkan oleh kesan kesihatan pernafasan yang semakin meningkat seperti nafas berbunyi, alahan, dan asma terutamanya dikalangan kanak-kanak. Bahan partikulat (PM) dan bioaerosol adalah antara bahan pencemar udara dalaman yang menunjukkan hubungkait dengan masalah pernafasan yang telah disebutkan. Pusat jagaan harian adalah persekitaran yang berisiko bagi kanak-kanak untuk mendapat penyakit disebabkan oleh sistem imun mereka yang lemah serta keadaan pusat jagaan yang sesak dan tidak bersih. **Objektif:** Kajian ini dijalankan untuk mengkaji hubung kait antara parameter IAQ ($PM_{2.5}$, bakteria dan kulat) di udara dalaman dan luaran pusat jagaan harian, Bangi. **Kaedah:** Kajian berbentuk rentas telah dijalankan di tiga pusat jagaan harian terpilig di Bangi, Selangor sejak Januari hingga Mac 2019. Parameter meteorologi (suhu dan kelembapan relatif) dan parameter IAQ ($PM_{2.5}$, bakteria, dan kulat) telah direkod. Parameter meteorologi direkod menggunakan Meter Cuaca Kestrel Meter 5500 (Kestrel, Pennsylvania, Amerika Syarikat). Parameter IAQ untuk $PM_{2.5}$ telah diambil kira menggunakan SidePak AM520 (TSI Incorporated, Minnesota, Amerika Syarikat) manakala DUO SAS SUPER 360 (International PBI, Milan, Itali) dengan dua jenis media agar; trypticase soy agar (TSA) dan malt extract agar (MEA) digunakan untuk mengira jumlah bakteria dan kulat. Soal selidik yang diolah berdasarkan International Study of Asthma and Allergies in Childhood (ISAAC) telah diedarkan kepada ibu bapa untuk menentukan gejala-gejala kesihatan yang dialami oleh anak-anak. Analisis statistik dijalankan dengan menggunakan SPSS IBM Versi 23. Nisbah dalaman dan luaran (I/O) untuk parameter IAQ dan kadar dos sedutan bioaerosol untuk kanak-kanak juga dikira. **Keputusan:** Jumlah bakteria dalaman di semua pusat penjagaan harian berada di tahap yang lebih tinggi berbanding dengan paras luaran, dengan purata tertinggi yang dilihat pada DC1 (1206 CFU^{-3} dan 440 CFU^{-3}). Nisbah I/O juga menyokong dapatan ini kerana semua nisbah I/O untuk parameter IAQ lebih daripada >1, menandakan bahawa sumber pencemaran berasal dari dalaman. $PM_{2.5}$ menunjukkan kepekatan purata yang lebih tinggi di luaran berbanding dengan udara dalaman (0.0417$\mu g/m^3$ dan 0.0309$\mu g/m^3$). Kanak-kanak di DC3 mempunyai kadar dos sedutan tertinggi bioaerosol (4.62×10^4) manakala rinitis menunjukkan kekerapan yang tinggi (65.9%) di kalangan kumpulan kajian. **Kesimpulan:** Kajian ini mendapati tiada kaitan antara parameter dalaman dan luaran tetapi parameter meteorologi (suhu dan kelembapan relatif) didapati berkorelasi dengan kepekatan $PM_{2.5}$ dan kulat.

Kata kunci: nisbah I/O, $PM_{2.5}$, bioaerosol, pusat jagaan harian, simptom pernafasan

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LIST OF ABBREVATIONS

CFU	Colony Forming Unit
COPD	Chronic Obstructive Pulmonary Disease
DC	Daycare Centers
DOSH	Department of Occupational, Safety and Health
I/O	Indoor/Outdoor ratio
IAQ	Indoor Air Quality
ISAAC	International Study of Asthma and Allergies
NAAQS	National Ambient Air Quality Standards
NHAPS	National Human Activity Pattern Survey
PM	Particulate matter
RH	Relative Humidity
TPM	Total Particulate Matter
US EPA	United State Environmental Protection Agency
WHO	World Health Organization

Chapter 1

INTRODUCTION

1.1 Background

Over the past decade, indoor air quality (IAQ) has been a growing issue in both fields of environmental and public health. The Environmental Protection Agency (EPA) defined IAQ as "the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants" (EPA, 2016). It have also been reported that air pollutants indoors are two to five times higher than outdoors and in some cases, can even reach up to 100 times higher (EPA, 2015). The National Human Activity Pattern Survey (NHAPS) has revealed that the average person spend up to 90% of their time indoors (Klepeis et al., 2001), where exposure to many air pollutants mainly occurs. There is increasing evidence that poor indoor environmental conditions substantially affect the occupants' health in the short and long term (EPA, 2016). Previous research has revealed acute health problems such as fatigue, headache, nausea, and respiratory infection (Tebbe H, 2017) as well as chronic health effects such as asthma, lung cancer, heart disease, and even cancer (Pecingina & Popa, 2014).

Particulate matter (PM) is a combination of solid and liquid particles in the air that if inhaled causes health problems (WHO, 2014b). Particulate matter is classified by size, in that PM_{10} is 10 micrometers or smaller in diameter, and $PM_{2.5}$ or "fine particles" are 2.5 micrometers or smaller in diameter. Common PM include dust, dirt, cigarette smoke, soot, smoke, all of which can be found in the typical home. Exposure to $PM_{2.5}$ has a variety of effects, such as heart attacks, aggravated asthma, and irritation of airways (WHO, 2014b). It is also thought to lead to both short and long-term respiratory complications, including asthma in children (EPA, 2014). Populations most sensitive to PM are people with lung disease, children, and older adults (EPA, 2016).

Bioaerosols are particulates from biological origin which includes bacteria, fungi, viruses, pollen, and their products (Nasir et al. 2012; Wang et al. 2010). The most important bioaerosols are bacterial and fungal spores (Pastuszka et al. 2000). The aerodynamic diameter of the fungal spores and bacteria is approximately 1–30 and 0.25–8 μm, respectively (Jones and Harrison 2004). Bioaerosols with an aerodynamic diameter of 5–10 μm are mostly trapped in the upper parts of the respiratory system and can develop allergic symptoms, while those smaller than 5 μm (a number of bacterial and fungal spores), also known as respirable particles, can penetrate deep into the alveoli and cause allergic alveolitis (Pastuszka et al. 2000). Small particles size increases these particles' permeability into the respiratory tract and sometimes even the blood stream (U.S. Environmental Protection Agency [EPA], 2014). Adequate assessment of human exposure to (PM) and bioaerosols has been

recognized as an important need as many studies have linked to considerable adverse health effects (WHO, 2014b; Abdel Hameed et al. 2009; Nasir et al. 2012).

Airborne particles such as particulate matter and bioaerosols are also called aerosols. The most important parameter of concern for aerosols is the particle size, as the size of the particle determine its behavior and possible health effects due to the disposition of the aerosol in the respiratory system.

1.2 Research Justification

Many infants and young children spend as much as ten hours per day, five days per week, in the daycare centers. As of 2016, a total of 200, 745 and 332, 641 students were enrolled in public and private pre-school respectively (Department of Statistics, 2017) and the numbers are only expected to double. Nearly 1 million of children under 5 years die every year due to exposure from indoor air pollutant (WHO, 2006). Studies conducted during the last decade have highlighted the important role of day care centers (DCCs) as unique places where young children with immature immune systems and poor hygienic behavior are crowded together resulting in an increased risk of respiratory tract pathogens (Hai-feng et al., 2014). They can be exposed to different physical, chemical, and biological factors that may adversely impact their health.

Among the different age groups IAQ can affect the health of young children significantly. They are uniquely at risk from indoor environmental pollution hazards in a number of ways. Firstly, they have greater exposure than adults to airborne

pollutants because they inhale a much greater amount of air in relation to body weight than adults (inhalation of 0.53 m3·kg-1·day-1 of air for an adult and 0.2 m3·kg-1·day-1 for a 1 year old child) (Cheraghi & Salvi, 2009). Children are more often than adults, breathe through their mouths and, therefore, bypassing the filtering effect of the nose (EPA, 2011).

Second, they are often more susceptible to the health effects of air pollution because their immune systems and developing organs are still immature. Irritation or inflammation caused by pollution is more likely to obstruct their narrower airways and may take less exposure to a pollutant which can trigger an asthma attack or other breathing ailment due to the sensitivity of a child's developing respiratory system. Exposure to toxic air contaminants during childhood could also affect the development of the respiratory, nervous, endocrine and immune systems, and increase the risk of cancer later in life.

Third, children are consistently in have close contact to contaminated surfaces. They are known to touch, play with, and ingest contaminated objects. In addition to increased ingestion and dermal exposures, children's behaviours can put them at risk for increased inhalation exposures. At specific ages, children begin engaging in daily activities such as crawling and running. These activities put children at greater risk because they are generally closer to the ground, where many of the pollutants can exist and be resuspended (Hwang, Hwang, Moon, & Lee, 2012).

Bioaerosol levels in indoor environments depend on numerous physical and biological factors. In recent years, several studies investigated the concentration of bioaerosols in various indoor environments such as primary schools, elderly homes,

residential homes, and child care centers (Mentese et al., 2009; Madureira et al., 2015; Paciência et al., 2016). These studies have reached a similar conclusion where the highest bioaerosols exposure were found in child care settings. Therefore, assessment of microbiological quality of indoor air in daycare centers is necessary from a public health point of view, especially for protection of vulnerable groups such as children.

1.3 Problem Statement

Airborne particles such as particulate matter and bioaerosols are ubiquitous and can be found in the general indoor environment yet, there is limited data on the levels and exposures in childcare settings, especially from Malaysian perspectives. Previous studies have been primarily done in other countries and large urban areas. Exposure to these indoor air contaminants garner more attention as the numbers of children being sent to daycares are rapidly increase from time to time and health problems among this particular population has risen.

Biological particles have received less attention than other aerosol particles such as: sulfates, mineral dust and ash (Friedlander, 2000) due to theiraverage concentrations have been assumed to be insignificant compared to non-biological particles (Penner et al., 2001; Kuhn and Ghannoum, 2003). Various monitoring studies were done in Malaysia (Cionita T., 2013; 2014; Khamal et al., 2016; Shahidah et al., 2017) had found that for indoor bioaerosols concentrations are two to five times higher than outdoor concentrations, in which signify that good air

circulation within an indoor environment is highly in demand. In many daycare centres, it is noted that there are insufficient ventilation and crowded with children with insufficient hygiene which favor the transmission of infectious agents among child attendees and adult staffs (Danuta et al., 2013).

The indoor air quality of daycare center involves particles both of outdoor and indoor origin. This view is supported by data showing that the concentrations and characteristics of respirable particles indoors are largely affected by both ambient air quality and by indoor sources including numerous indoor activities (Jones et al., 2000). Comparing the aerosol levels present in indoor environments with those in the outdoor areas can be a useful tool to indicate whether the concentration of indoor aerosol particulates is affected by both indoor and outdoor environments. Therefore, this study is proposed to quantify the indoor and outdoor exposure of airborne particulates ($PM_{2.5}$ and bioaerosols) that children are exposed to in daycare centers, therefore willdetermine relationship between indoor and outdoor concentrations.

1.4 Conceptual Framework

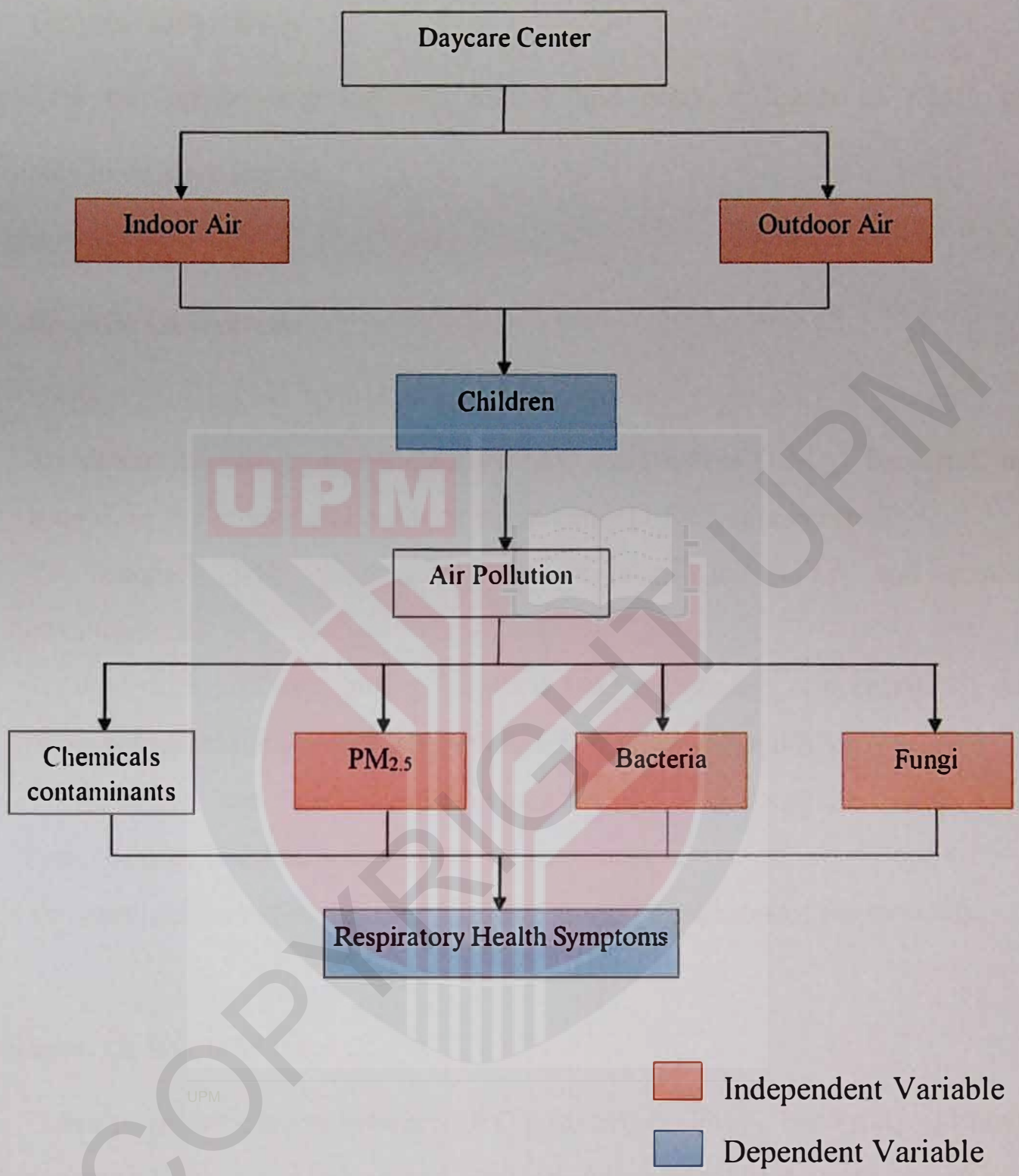

Figure 1-1: Conceptual Framework

1.5 Objectives

1.5.1 General Objective

To analyse the relationship between indoor and outdoor levels of $PM_{2.5}$ and bioaerosols in daycare centers.

1.5.2 Specific Objectives:

1. To determine the concentration of IAQ parameters ($PM_{2.5}$, bacterial, and fungal) in the indoor and outdoor environment of daycare centres.
2. To compare IAQ parameters concentrations in indoor and outdoor environment.
3. To determine the relationship between IAQ parameters concentrations with meteorological parameters (temperature and relative humidity).
4. To determine the relationship between indoor IAQ parameters with health symptoms of children attending daycare centres.
5. To calculate the estimated bacterial and fungal dose rates of respondents.

1.6 Research Hypotheses

1. There is an association between IAQ parameters ($PM_{2.5}$, bacterial, and fungal) concentrations in the indoor and outdoor environment of daycare centres.
2. There is significant correlation between outdoor air levels and meteorological parameters (temperature, relative humidity, and wind direction) on indoor IAQ parameters concentrations.
3. There is significant relationship between indoor IAQ parameters with health symptoms of children attending daycare centres.

Chapter 2

LITERATURE REVIEW

2.1 Indoor Air Quality

The EPA defines indoor air quality as "the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants" (EPA, 2016). Air quality testing in homes across the United States estimated that 96% of homes had at least one problem with IAQ and up to 85% had high levels of particulates and bioaerosols and up to 71 percent were filled with odours and potentially harmful chemicals and gases (Crowder et al., 2007).

The indoor environment serves as the most important environment to human health because people spend as much as 90% of their time indoors, coupled with the fact that air pollutants inside are two to five times higher than outside and sometimes as high as 100 times greater compared to outside air (Hess-Kosa, 2011; EPA, 2016). Air pollution is "the presence in the atmosphere of a foreign substance composition of normal or important change in the proportions of its component, which can be harmful and/or directly or indirectly induce changes on health (Pecingina & Popa,

2014). According to the World Health Organization (WHO), each year approximately 1.3 million deaths are attributed to urban air pollution (WHO, 2014a) and poor air quality has been shown to exacerbate chronic respiratory diseases (WHO, 2016).

Over the past few decades, the importance on air pollution has been addressed with the development of regulations such as the Environmental Quality Act 1974 and in response, there has been a decrease in outdoor pollution but an increase in indoor pollution (Mendes et al., 2013). IAQ problems arise from interactions between the building materials, activities that occur in the building, climate and the building occupants (Kike-Parsis, 2004). These problems may arise from inadequate temperature, poor ventilation systems, indoor air contaminants, or from insufficient outdoor air intake (EPA, 2016a). In general, the types of pollutants that may affect IAQ are biological, chemical, particles and aerosol pollutants. Biological pollutants include bacteria, fungi, pollen, and animal dander. Chemical pollutants include adhesives, cleaners, solvents, combustion by-products and emissions from floor or wall coverings. Particles and aerosols are solids and liquids suspended in air, from dust, construction, smoking, or combustion (EPA, 2016b). For the purposes of this study, the stressors discussed will include particulate matter ($PM_{2.5}$), biological pollutants (bactria and fungi), and the meteorological parameters (temperature and relative humidity).

2.2 Particulate Matter

Particulate matter (PM) is a mixture of small particles and droplets in the air that can cause health problems if inhaled. Some PM are visible while others are not, except under a powerful electron microscope. The most common sizes are $PM_{0.1}$ (< 0.1 micrometers), $PM_{2.5}$ (< 2.5 micrometers), and PM_{10} (< 10 micrometers). Total particulate matter (TPM) is all respirable particles. Large particles can be deposited in upper airways through sedimentation or impaction while in the lower airways Brownian diffusion can deposit them in the alveoli. Smaller particles have the greatest health concern because they can travel deep in the lungs and cause heart and lung disease. Ultrafine particles can translocate to blood-circulating and be deposited in the liver, spleen or brain, although they might also penetrate through trans-synaptic mechanisms (Falcon-Rodriguez et. al, 2016).

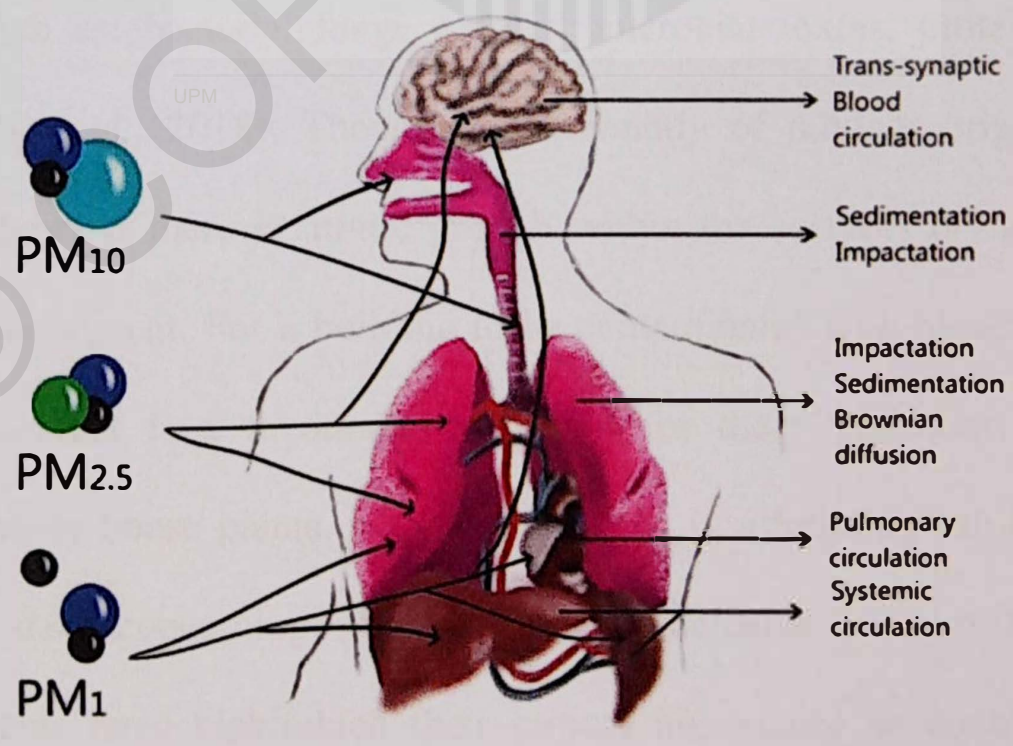

Figure 2-1: Size and Dynamic of particles in the lung and other tissues. Available from: https://www.researchgate.net/figure/Size-and-Dynamic-of-particles-in-the-lung-and-other-tissues-Large-particles-can-be_fig2_291335773 [accessed 21 Apr, 2019]

Vulnerable populations that are most affected by PM are people with lung disease, children, and older adults (Liu et al., 2008) Common PM includes dust, dirt, soot, or smoke. Indoor PM sources include activities such as cooking, cleaning (sweeping or vacuuming), and burning (candles, smoking, incense) (Tebbe H, 2017). In addition, PM can be from general activities such as walking and flailing one's arms, which may recirculate particles (Diapouli et al., 2011). Research showed that human activity accounted for high indoor levels of PM and that cooking on a gas stove had the largest impact on elevated $PM_{2.5}$ and PM_{10} concentrations (Zuraimi, 2008).

2.3 Bioaerosols

Biological particles/bioaerosols are particles of biological origin suspended in the air such as: bacteria, fungi, viruses, microbial toxins, proteins and enzymes (Alghamdi et al., 2014). Though predominantly of outdoor origin, fungi can be traced indoors if there is mould growth within the surfaces or 'amplifiers' in the indoor environment. For a building to be contaminated with bioaerosols there must be a place that is a favourable condition for their replication such as molds, humidifiers or house plants, where moist areas in a building can be found. Indoor exposure data concerning non-infectious bioaerosols both at home and work environments have highlighted their critical importance as contributors many of

today's most relevant public health problems, e.g., respiratory symptoms, asthma, and clusters of autoimmune diseases (Sippula et al., 2013).

Bioaerosol levels and the characterization of both indoor and outdoor environments have become an important issue due to their adverse health effects. Exposure to bacteria and fungi, as well as their metabolites and fragments, can induce infections, hypersensitivity diseases, and toxic reactions in humans (Mentese et al., 2009). Bioaerosols represent, roughly, all biologically originated aerosols and can be found both indoors and outdoors. The most studied bioaerosols are the airborne bacteria and fungi. Health impacts of certain fungi species, such as Penicillium spp., Aspergillus spp., Mucor spp., and Rhizopus spp., are commonly related with allergy, infection, irritation, and toxicity. Among these fungi, species of Aspergillus, Cladosporium and Penicillium were shown to be the most frequently found genera associated with allergy and exist in both indoor and outdoor environments (Mentese et al., 2009; Husna et al., 2011).

Factors such as human activities, geographic conditions, seasonal changes, meteorological parameters, type and extent of vegetation, and air pollution affect the composition and concentration of outdoor bioaerosols (Abdel Hameed et al. 2009; Nasir et al. 2012). On the other hand, air conditioning systems, ventilation, vegetation, resuspension of dust, indoor sources (the presence of people, kitchen, and bathroom), temperature, and humidity are among the factors affecting the composition and concentration of indoor bioaerosols (Mentese et al. 2009; Nasir et al. 2012; Faridi et al., 2015).

Outdoor air quality influences the indoor air quality by means of penetration of air from outdoors to indoors, which mainly depends on the ventilation efficiency. Contribution of outdoor air to indoor air pollution depends on the concentration and composition of bioaerosols present in the outdoor air. Some researchers showed that, even if the outdoor concentrations affect the indoor air, the indoor to outdoor (I/O) ratio will mostly be more than 1. This is due to several sources of indoor bioaerosols that contribute to the increase in indoor bioaerosol levels (Husna et al., 2011). Zuraimi et al., (2008) through his study on IAQ of child care centers in Singapore concluded that there is a significant difference between temperature and relative humidity. Relative humidity, temperature and seasons showed positive correlations with concentration of microorganisms in indoor air.

According to Nazaroff (2016), there are three main concerns regarding the indoor biological air quality. First, exposure to bioaerosol material can cause or can contribute to many important diseases. Inhaling indoor air is the primary means by which humans are exposed to airborne microorganisms responsible for respiratory tract infections and the typical transmission for these bioaerosol is via air (Danuta et al., 2013). Second, adverse respiratory symptoms correlate well with indicators of indoor dampness. Although not yet well established, it is a reasonable hypothesis that the underlying cause of these associations is microbial. Third, the microbiology of spaces occupy may influence the human microbiome in ways that could confer health benefits.

2.4 Meteorological Parameters

Meteorological parameters such as temperature and humidity are important in maintaining good IAQ (Davis, et al., 2016). Thermal comfort is affected by air temperature, temperature of the surrounding surfaces, air movement, relative humidity, and the rate of air exchange (Ormandy and Ezratty, 2012). Relative humidity (RH) is the amount of water vapor that the air is holding compared to the amount it can hold at a specific temperature (Spengler, Samet, & McCarthy, 2001). Temperature and RH have been shown to increase concentrations of air pollutants because of the dense air holding the pollutants (Bentayeb et al., 2015).

2.5 Health Effects

Health effects related to poor IAQ depend on upon several factors: the effect of each contaminant, concentration, duration of exposure, and individual sensitivity (Hess-Kosa, 2010). Indoor air contaminants can cause acute or chronic health problems. Acute health effects are usually from short-term exposure at higher concentrations, whereas chronic health effects are often long-term exposure at lower concentrations (EPA, 2016c). Acute health concerns of exposure to PM and bioaerosols are respiratory issues such as wheezing and coughing (Bentayeb et al., 2015; Bentayeb et al., 2013; Maio et al., 2015; Curtis et al., 2006).

Chronic effects of PM and bioaerosols exposure have been linked to cardiovascular problems, increased asthma and COPD (Bentayeb et al., 2013; Curtis et al., 2006). PM exposure has been linked to premature death in people with heart or

lung disease, heart attacks, a decrease in lung function, and irregular heartbeat (Bernstein et al., 2008; Bentayeb et al., 2015; Curtis et al., 2006; Bentayeb et al., 2013). Early exposure to indoor air pollutants among children attending daycare centers was found to be a risk factor for asthmatic symptoms- usually wheezing and night cough especially among children less than five years old (Gern et al., 2017).

2.6 Indoor Air Quality Standard

To create a healthy working indoor environment, a good indoor air quality (IAQ) is an essential factor. In Malaysia, general IAQ assessments were established in the Code of Practice by the Department of Occupational Safety and Health (DOSH, 2010) as shown in Table 1.

Table 2.1: List of indoor air contaminants and the acceptable limits

Indoor air contaminants	**Acceptable limits**		
	ppm	**mg/m^3**	**cfu/m^3**
Chemical contaminants			
(a) Carbon monoxide	10	-	-
(b) Formaldehyde	0.1	-	-
(c) Ozone	0.05	-	-
(d) Respirable particulates	-	0.15	-
(e) Total volatile organic compounds (TVOC)	3	-	-
Biological contaminants			

(a) Total bacterial counts	-	-	500*
(b) Total fungal counts	-	-	1000*
Ventilation performance indicator			
(a) Carbon dioxide	C1000	-	-

In this study, the acceptable limits for total bacterial count and total fungal count will be used to assess the IAQ in the daycare centers. This guideline was constructed for workplaces using mechanical ventilation and air conditioning (MVAC) system including aircooled split unit. Based on observation, most daycare centers uses a mix of natural and mechanical ventilation, therefore this guideline might not be a fitting comparison standard. As such, policy makers may use the information considering the variation caused by the ventilation strategies as scientific evidence to establish acceptable IAQ parameter levels in non-industrial settings such as daycare centers.

As PM is not included in the Malaysian IAQ standard, the National Ambient Air Quality (NAAQ) guidelines from Environmental Protection Agency (United States) or USEPA (2010) was used. The EPA has set National Ambient Air Quality Standards for six principal pollutants, which are called "criteria" air pollutants. Periodically, the standards are reviewed and may be revised. The current standards are listed below. Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air (μg/m3).

Pollutant		Primary/ Secondary	Averaging Time	Level
Carbon Monoxide (CO)		Primary	8 hours	9 ppm
			1 hour	35 ppm
Lead (Pb)		Primary and secondary	Rolling 3 month average	0.15 $\mu g/m^3$ (1)
Nitrogen Dioxide (NO_2)		Primary	1 hour	100 ppb
		Primary and secondary	1 year	53 ppb (2)
Ozone (O_3)		primary and secondary	8 hours	0.070 ppm (3)
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 $\mu g/m^3$
		secondary	1 year	15.0 $\mu g/m^3$
		primary and secondary	24 hours	35 $\mu g/m^3$
	PM_{10}	primary and secondary	24 hours	150 $\mu g/m^3$
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb (4)
		secondary	3 hours	0.5 ppm

Chapter 3

METHODOLOGY

3.1 Study Design

The study design of this research is quantitative study with a cross-sectional design to determine the relationship between indoor-outdoor bioaerosols exposure to children daycare centers.

3.2 Study Location

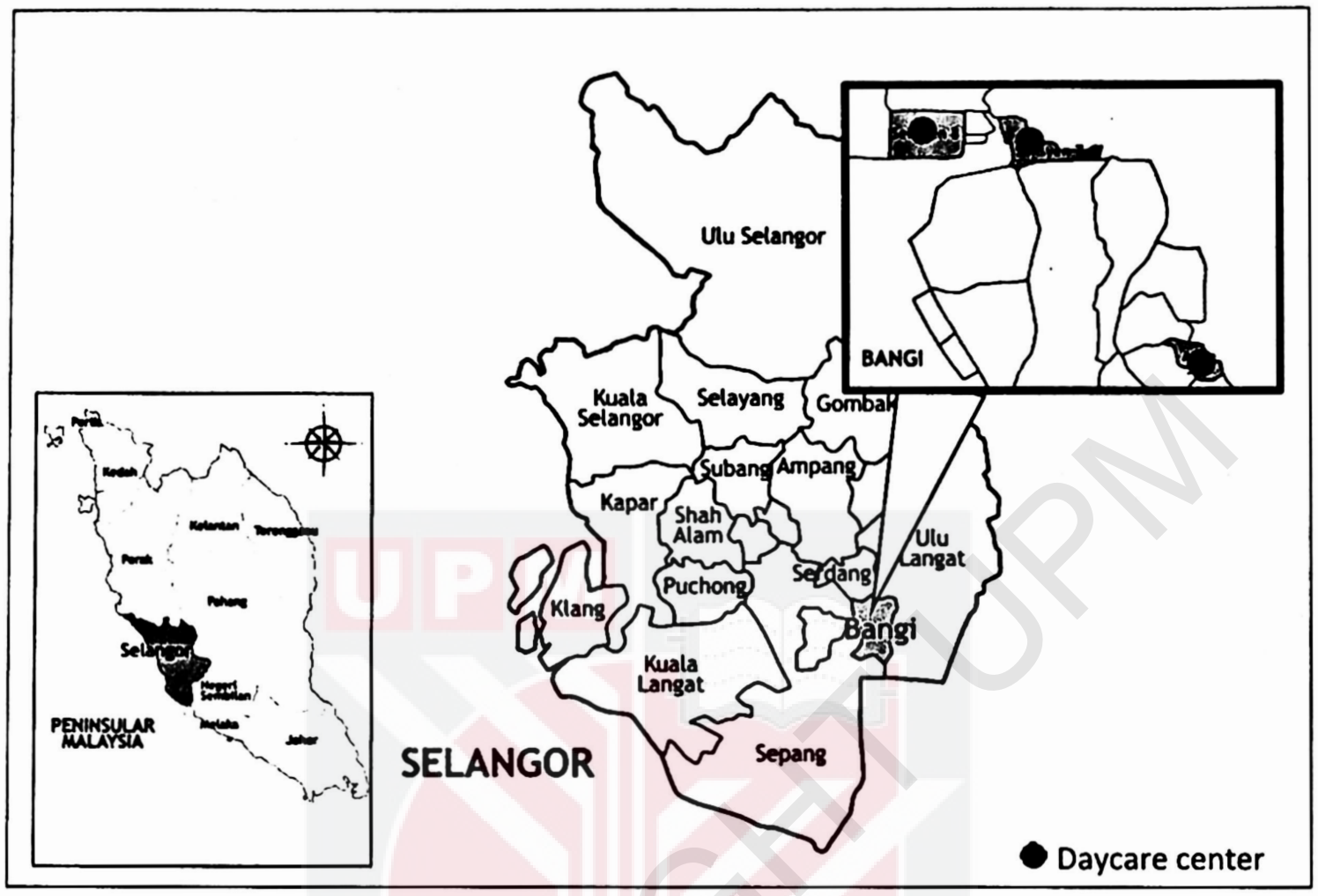

Figure 3-1: Location of the selected daycare centers in Bangi, Selangor

The state of Selangor is chosen because of it is located in the diverse location area such as industrial, main road, and residential areas, allowing bioaerosols to be studied in different types of background. Using purposive sampling based on the inclusive criteria, three daycare centers was selected as the main sampling locations, namely daycare 1 (DC1), daycare 2 (DC2), and daycare 3 (DC3). Figure 3-2, 3-3, 3-4 shows the floor plan for each day care (source: https://floorplancreator.net/plan/).

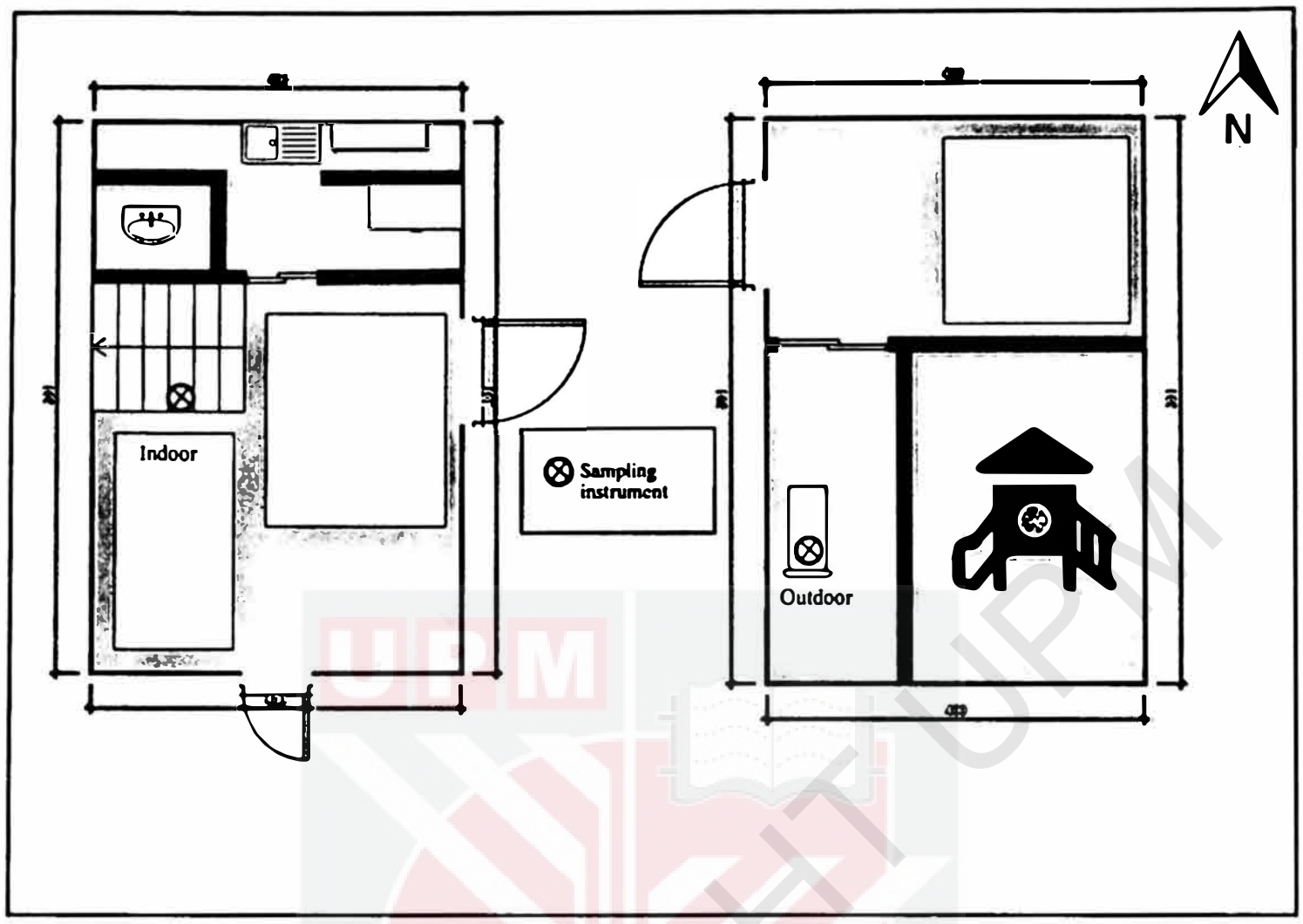

Figure 3-2: Layout diagram for indoor and outdoor sampling points at DC1

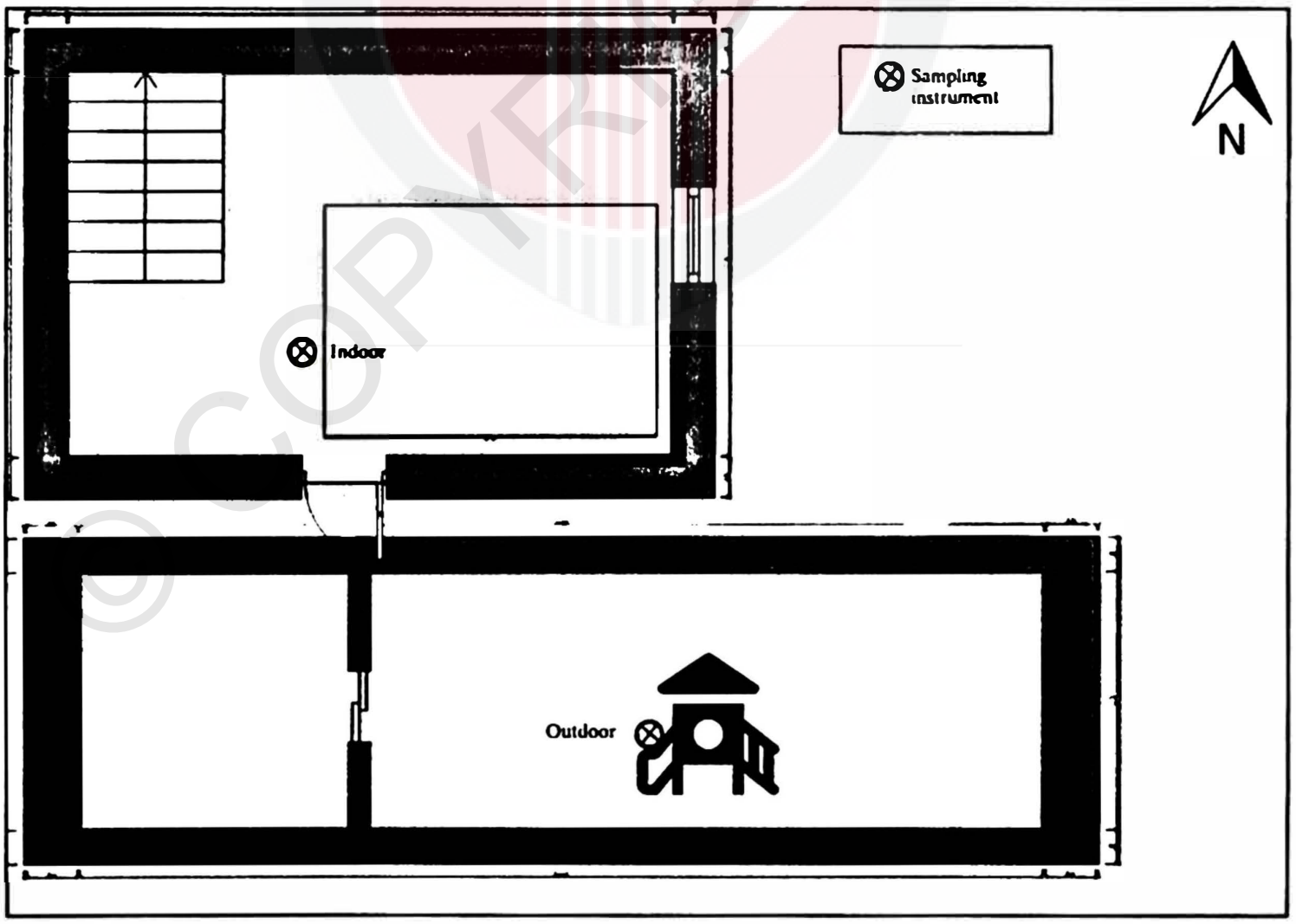

Figure 3-3: Layout diagram for indoor and outdoor sampling points at DC2

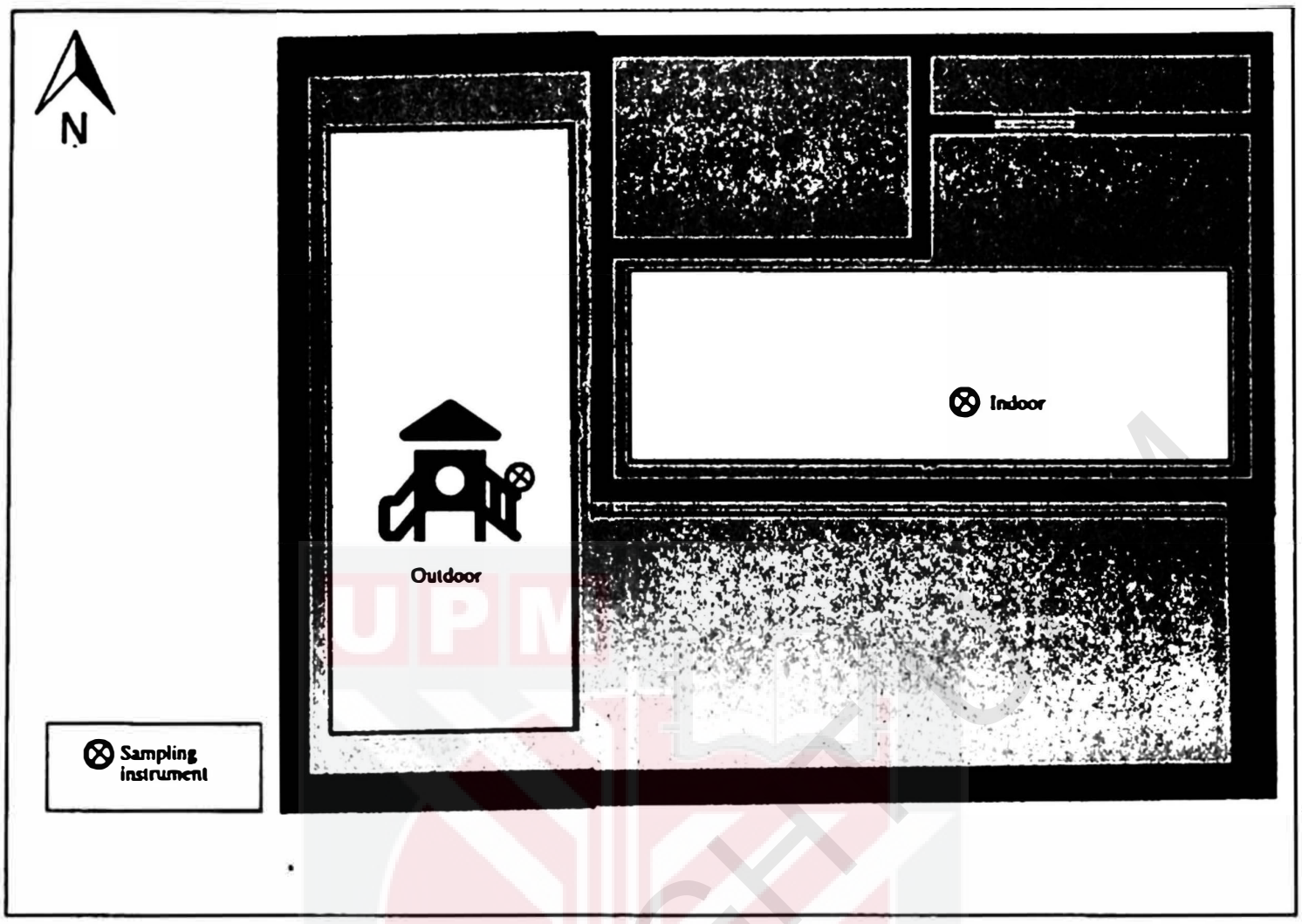

Figure 3-4: Layout diagram for indoor and outdoor sampling points at DC3

3.3 Sampling

3.3.1 Study Population

Children attending selected daycare centers.

3.3.2 Study Sample

Children that are currently attending the three selected daycare centers that fit the inclusion criteria.

3.3.3 Sampling frame

The sampling frame for this study is the list of selected day care centers in Bangi area. The list of children were obtained from each DCs.

i. List of daycare centers registered with Social Welfare Department in Bangi.

ii. List of children currently attending the selected daycare centers.

3.3.4 Selection criteria

3.3.4.1 Selection Criteria of Daycare Center

Inclusive Criteria

1. Daycare Center registered with the Welfare Department in the Ministry of Women, Family, and Community Development.
2. Utilized natural or mechanical ventilation.
3. Provides an outdoor play space.

3.3.4.2 Selection Criteria of respondents

Inclusive Criteria:

1. Children aged 1-6 years old.
2. Malay ethnic
3. Attends the daycare center on weekdays (Monday-Friday) only.

Exclusive criteria

1. Infants under the age of 1 and children aged 7 years old and above.
2. Attends daycare center on weekdays and weekends (Monday-Saturday).

3.3.5 Sample Size

Based on the study done by previous study (Faridi et al., 2015), the correlation coefficient (r^2) between indoor and outdoor concentrations in the school dormitory were 0.57 and 0.53 for bacteria and fungi respectively.

To calculate sample size of indoor and outdoor air sample required to make a correlation in this study, the formula from Hulley et al., (2013) is used:

$$N = [(Z_\alpha + Z_\beta)/C]^2 + 3$$

Where,

r = expected correlation coefficient,

$C = 0.5 \times \ln [(1 + r)/(1 - r)]$,

N = Total number of subjects required

Thus,

N (bacteria) = 22 N (bacteria) = 66

N (fungal) = 26 N (fungal) = 78

The total number of samples for bacteria and fungi needed for each daycare center are 22 and 26 respectively and the total number of samples for bacteria and fungi needed for this study are 66 and 78 respectively. A total of 144 samples are needed.

To calculate sample size of respondents for proportion of one group, the formula from (Kirkwood, 1988) is used:

$$N = (Z/e)^2 (p)(1-p)$$

Where:

N = Sample size

p = prevalence of respiratory symptoms

= 14% (Hussin et. al., 2011)

= 0.14

e = sampling error (0.05)

Therefore, the sample size is:

$$n = (1.96/0.05)^2 (0.14)(1-0.14)$$

= 185 respondents

10% added for strength of study, thus:

ΣN = 204 respondents

However due to the limitation of the number of investigated daycare centers, only 88 respondents were obtained.

3.4 Data collection

3.4.1 Walkthrough survey and checklist

Prior to any measurement, a walkthrough assessment was done to; identify sampling locations, to determine the presence of any signs of dampness or mold, and potential contaminant sources (including flower plant, carpet, curtains). Two sampling locations were chosen from each daycare; indoor sampling point (playroom) and outdoor sampling point.

3.4.2 Meteorological Sampling

Temperature and relative humidity are environmental parameters recorded during the sampling period. Indoor air temperature and relative air humidity were monitored using Kestrel Meter 5500 Weather Meter (Kestrel, Pennsylvania, USA) at both sampling points.

3.4.3 IAQ Sampling

SidePak Personal Aerosol Monitor AM520 (TSI Incorporated, Minnesota, USA) was used for monitoring $PM_{2.5}$ for a minimum of 20 minutes for each session. The $PM_{2.5}$ readings obtained were adjusted using the correction factor based from Abidin et al. (2014). A single stage Andersen impactor, DUO SAS SUPER 360 (International PBI, Milan, Italy) was used to collect bacterial and fungal air samples according to NIOSH method 0800. Two types of agar media; trypticase soy agar (supplemented with 100 mg L-1 chloramphenicol) and malt extract agar

(supplemented with 500 mg L-1 cycloheximide) were used for counting of bacteria and fungi.

Air was drawn through the sampler for 200 L. The volume and duration of biological air sampling were the same for all daycare centers at indoor and outdoor.

For each sampling day, one field blank per culture medium was used along with duplicate samples. The air sampler was always disinfected using isopropyl alcohol swabs between sample collections. Both the SidePak and DUO SAS were situated 0.8 meters above the floor, mimicking the breathing height of children. Sampling period were done twice daily, in the morning (8 am-10 am) and afternoon (2 pm-4 pm).

3.4.4 Calculation of bioaerosol concentration

To quantify the bacterial and fungal concentrations, the agar plates were incubated at 37±1 ^{0}C for 24 hours and 25±3^{0}C for two days respectively (EN 13098, 2000). The bacteria and fungi colonies were then counted using the naked eye and concentrations evaluated in CFU/m^{-3} after making adjustment for positive hole correction.

The following formula was used to calculate bacterial and fungal colony-forming unit per cubic meter (CFU/m^{-3}) in the active method (Faridi et al., 2015:

$$CFU\ m^{-3} = \frac{T\ x\ 1000}{t\ (min)\ x\ F\ (\frac{L}{min})}$$

where T is the number of bacterial or fungal colonies, 1000 is conversion factor of liter to cubic meter, t is the duration of sampling, and F is the pump flow.

3.4.5 Dose rate

An estimate of the dose rate of bacterial and fungal concentration breathed in by children was calculated by using the following formula, which was validated in previously published studies (Castro et al., 2011; Fonseca et al., 2014; Kalaiarasan et al., 2009):

$$D = \left(\frac{BR_{WA}}{BW} \right) \times C_{WA} \times OF \times N$$

In this equation, D is the age-specific dose rate (CFU/kg^{-1}/day); BR_{WA} is the age-specific weighted average breathing rate (L/min); BW is body weight (kg); C_{WA} is weighted average bacteria or fungi concentrations (CFU/L); OF is the occupancy factor and N is the total time per day spent in the location of exposure (min/day).

The age-specific inhalation factors were retrieved from the US EPA Exposure Factors Handbook (2011) since there is no available information concerning the Malaysian population. The BR_{WA} for children attending child care centers corresponds to 4.8 L/min. Body weight of 18.6 kg for 3–5-year old children will be used (U. S. Environmental Protection Agency, 2011). C_{WA} will be estimated using the bacteria and fungi mean concentrations and the OF will always be considered as 1 since children stay in their respective location. In child care centers, children have similar daily schedules and/or activity patterns, spending about 6 hours indoors.

3.4.6 Reported health symptoms

A self-administered questionnaire taken from the International Study of Asthma and Allergies (ISAAC) with some modifications was used to assess the respiratory health of children. The questionnaire was translated to Malay language and was distributed to the children's parents to get with personal information such as socio-demography and health status of the respondents. The first section focus on the socio-demographic background such as age, gender, and race, duration of attending DCC, frequency of weekly DCC attendance. Second section will include information about health status.

3.5 Statistical methods

Statistical analysis were done using SPSS (Version 23) and Shapiro-Wilk test was used for normality testing. The distributions were normal; thus the following results will be described using mean, min and max. The indoor to outdoor (I/O) ratio was calculated to determine the impact of outdoor sources on indoor air concentrations. To study the association and differences between $PM_{2.5}$, bacterial and fungal pollutant concentration and the respiratory health of children, t-test and Chi-square were used. Spearman's rank correlation coefficient was used to calculate the influence of temperature and relative humidity measurements on $PM_{2.5}$, bacteria and fungi concentrations. Statistical significance was defined as $p < 0.05$.

3.6 Study ethics

This study obtained ethical clearance by the Universiti Putra Malaysia, Faculty of Medicine and Health Science, Ethical Committee.

i. Only daycare centers with the management approval were taken as study locations.

ii. Briefing on the study was carried out on the respondents' parents prior to the commencement of the study.

iii. Consent letter was distributed to the parents and only children with written consent from parents were taken as respondents.

Chapter 4

RESULT

4.1 Building characterisation

A total of three daycare centers (DC) that accomodate for children 1 to 6 years old situated in Bangi, Selangor were sampled from January to March 2019. Visual observations and inspection were made for the ventilation system of each DC, building age, the volume of the playroom, number of occupants and signs of dampness are shown in Table 4.1. All DCs were less than 10 years old and used mechanical (fans) and natural (open windows and doors) ventilation. DCs were located in residential areas in the Bangi district and were cleaned daily by mopping and/or vacuuming.

Table 4.1: Summarization of building characteristics

Characteristics	DC1	DC2	DC3
Ventilation system	Mechanical and natural	Mechanical and natural	Mechanical and natural
Building age	5 years	10 years	5 years
Volume of playroom	229.8m^3	38.7m^3	155.26m^3
Number of occupants	35	24	38
Presence of air purifier	No	Yes	Yes
Signs of dampness/ mold growth	Water pipe leaking in the kitchen	Water leak from toilet	N/A

4.2 IAQ Parameters

4.2.1 Concentration of IAQ Parameters in selected DC

The IAQ parameters ($PM_{2.5}$, bacterial and fungal) and meteorological variables (temperature and relative humidity) recorded from the selected daycare centers are presented at Table 4.2.

The average outdoor concentration of $PM_{2.5}$ are higher than average indoor concentration for all DCs with the highest outdoor concentration found in DC1 (13.58 ± 5.16 μg/m^3). While the average indoor $PM_{2.5}$ concentration recorded in the daycare centers ranged from 3.95 μg/m^3 to 28.60 μg/m^3. The lowest indoor and outdoor $PM_{2.5}$ concentrations were recorded at DC3 (9.29 ± 10.0 μg/m^3 and 12.52 ± 11.01μg/m^3 respectively).

For bacterial concentrations, the highest average concentration is also found in the indoor and outdoor environment of DC1 (1206 CFU m^{-3} and 440 CFU m^{-3} respectively), two times higher compared to DC2 (480 CFU m^{-3} and 242 CFU m^{-3}) and DC3 (497 CFU m^{-3} and 141 CFU m^{-3}). For all DCs, the indoor average concentrations of bacterial counts are higher than outdoor concentrations.

For fungi concentrations, majority of the fungal concentrations indoor are higher than outdoor except for DC1 where the average outdoor concentration is higher than the average indoor concentration (249 ± 131 CFU m^{-3} and 246 ± 110 CFU m^{-3} respectively). The indoor fungal concentrations for DC1 and DC3 are found to be highest, 246 ± 110 CFU m^{-3} and 246 ± 158 CFU m^{-3} respectively.

Independent *t*-test analysis Table 4.2 showed that there was no significant difference ($p>0.05$) observed regarding indoor and outdoor levels of IAQ parameters ($PM_{2.5}$, bacterial and fungal concentrations) for all three DCs.

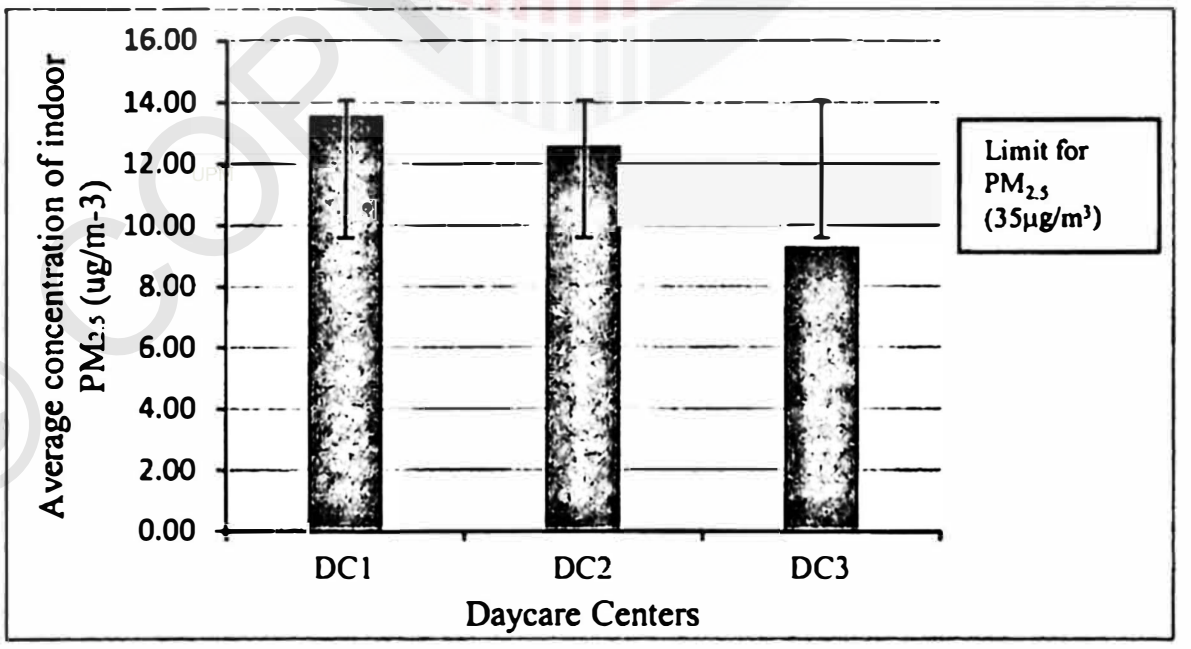

Figure 4-1: Comparison of $PM_{2.5}$ levels in each of the investigated DCs against NAAQ standard

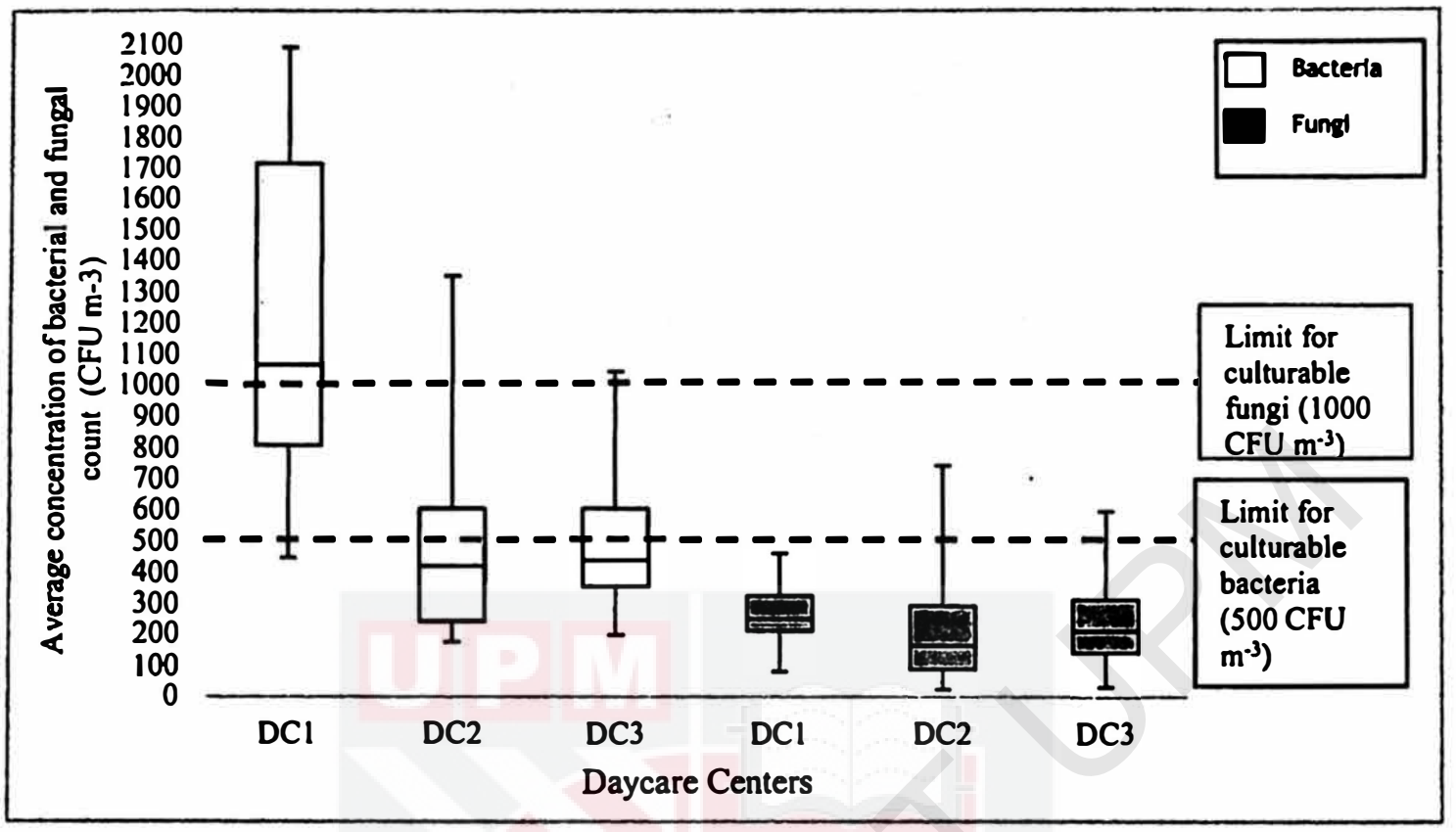

Figure 4-2: Comparison of total culturable bacteria counts and total culturable fungi counts in each of the investigated DCs against DOSH standard

Table 4.2: Descriptive statistics of indoor and outdoor concentrations of temperature, relative humidity, bacteria and fungi and I/O ratios of bacteria and fungi concentrations with DOSH and NAAQ standards

		Daycare 1			Daycare 2			Daycare 3			DOSH	NAAQ
	N	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Malaysia	USEPA
Temperature (°C)												
Indoor	18	32.7 ± 2.9	29.4	37.8	34.1 ± 1.6	30.7	36.2	33.2 ± 1.9	27.6	35.2	23-26	N/A
Outdoor	18	32.5 ± 2.8	27.2	36.4	35.0 ± 1.5	32.2	37.6	34.1 ± 3.0	25.5	38.6		
Relative Humidity (%)												
Indoor	18	63.1 ± 7.9	51	71.3	59.5 ± 7.8	46.9	74.3	65.0 ± 7.7	51.5	81.8	40-70	N/A
Outdoor	18	65.7 ± 12.8	50.3	84.7	60.1 ± 8.7	50.3	81.8	58.8 ± 9.5	42.7	69.3		
$PM_{2.5}$ ($\mu g/m^3$)												
Indoor	36	13.6 ± 5.2	4.0	28.6	12.6 ± 7.3	3.1	36.7	9.3 ± 10.0	0.93	26.8	N/A	35
Outdoor	36	14.2 ± 5.8	6.8	24.4	13.8 ± 5.2	5.8	23.1	12.5 ± 11.0	2	32.0		
I/O ratio		0.9			0.9			0.7				
Bacteria ($CFU\ m^{-3}$)												
Indoor	36	1206 ± 554	445	2090	480 ± 303	175	1350	497 ± 233	200	1043	500	N/A
Outdoor	36	440 ± 420	75	1365	242 ± 422	10	1660	141 ± 182	10	685		
I/O ratio		5.1	-	-	6.6	-	-	11.8				
Fungi ($CFU\ m^{-3}$)												
Indoor	36	246 ± 110	80	445	210 ± 181	25	740	246 ± 158	33	593	1000	N/A
Outdoor	36	249 ± 131	50	505	177 ± 95	25	330	188 ± 145	43	558		
I/O ratio		1.2			1.6	-	-	1.6				

N= number of samples, DOSH = Department of Occupational Safety and Health, and NAAQ = National Ambient Air Quality

This summary table has averaged the readings into a one day measurement. Specific details on morning and afternoon measurements can be found in appendix.

4.2.2 Relationship between indoor and outdoor IAQ parameters

Table 4.2.2 shows the relationship between the indoor and outdoor IAQ parameters. Independent *t*-test analysis showed that there was no significant difference ($p>0.05$) observed regarding indoor and outdoor levels of IAQ parameters ($PM_{2.5}$, bacterial and fungal concentrations) for all three DCs (DC1, DC2 and DC3)

Table 4.2.2: Comparisons of IAQ parameters in the indoor and outdoor air

	DC1		DC2		DC3	
	Mean ± SD	p	Mean ± SD	p	Mean ± SD	p
$PM_{2.5}$						
Indoor	13.58 ± 7.49	0.851	12.60 ± 7.10	0.039	9.29 ± 9.78	0.443
Outdoor	14.20 ± 5.4		13.80 ± 5.02		12.52 ± 10.70	
Bacteria						
Indoor	1206 ± 554	0.53	480 ± 303	0.589	497 ± 233	0.262
Outdoor	440 ± 420		242 ± 422		141 ± 182	
Fungi						
Indoor	246 ± 110	0.262	210 ± 181	0.091	246 ± 158	0.808
Outdoor	249 ± 131		177 ± 95		188 ± 145	

4.2.3 Relationship between indoor IAQ parameters

Table 4.4 shows the ANOVA test between indoor IAQ parameters to see if the parameters are associated. It is found that no significant difference between means of $PM_{2.5}$, bacterial and fungal concentration in studied areas.

Table 4.2.3: The difference of concentration between indoor IAQ

	DC1		DC2		DC3	
	F-statistics	p-value	Mean ± SD	p	Mean ± SD	p
$PM_{2.5}$						
Bacteria	0.048	0.828	0.323	0.573	0.844	0.365
Fungi						

4.2.4 Indoor/Outdoor relationship

The results for I/O ratio for IAQ parameters are shown in Table 4.2.4. For all three DCs, the mean I/O ratios for bacteria and fungi were higher than 1, with the highest I/O ratio for bacteria concentrations were observed in DC3 being 11.83. While I/O ratio for $PM_{2.5}$ are all lower than < 1.

Table 4.2.4: I/O ratio of IAQ parameters

Variables	DC1	DC2	DC3
$PM_{2.5}$ ($\mu g/m^3$)	0.93	0.91	0.74
Bacteria (CFU m^{-3})	5.13	6.6	11.83
Fungi (CFU m^{-3})	1.21	1.6	1.57

4.2.5 Relationship between IAQ parameters with meteorological parameters

Table 4.2.5, Table 4.2.6 and Table 4.2.7 presents the correlation coefficients (r_2) between temperature and relative humidity on IAQ parameters ($PM_{2.5}$, bacterial and fungal concentrations) for the three DCs. While there was no significant correlation between the parameters in DC1, it was found that there weak negative correlation between relative humidity and bacterial concentrations. A significant correlation was also observed between relative humidity and fungal concentrations in DC3, however it is a weak positive correlation.

Table 4.2.5: Spearman's rank correlation coefficients between meteorological parameters and IAQ parameters in DC1

	$PM_{2.5}$		Bacteria		Fungi	
	r_2	p	r_2	p	r_2	p
Temperature	0.268	0.114	0.152	0.376	0.005	0.977
RH	-0.093	0.591	-0.014	0.934	0.038	0.826

Table 4.2.6: Spearman's rank correlation coefficients between meteorological parameters and IAQ parameters in DC2

	$PM_{2.5}$		Bacteria		Fungi	
	r_2	p	r_2	p	r_2	p
Temperature	-0.251	0.14	0.252	0.138	-0.81	0.638
RH	0.295	0.081	-0.443**	0.007	0.08	0.6643

** Correlation significant at the 0.01 level

Table 4.2.7: Spearman's rank correlation coefficients between meteorological parameters and IAQ parameters in DC3

	$PM_{2.5}$		Bacteria		Fungi	
	r_2	p	r_2	p	r_2	p
Temperature	0.295	0.08	-0.247	0.147	0.2	0.242
RH	-0.57	0.741	0.24	0.159	0.354	0.034*

* Correlation significant at the 0.05 level

4.2.6 Dose rate analysis

The inhalation dose rates of bacteria and fungi were estimated for 1-5 year old children (Table 4.2.6). DC3 showed the highest levels for bacteria and fungi dose rate (4.62×10^4 and 2.29×10^4 respectively). Similar fungi dose rate was also observed in DC1 (2.29×10^4).

Table 4.2.8: Inhalation dose rates of bacteria and fungi for children in selected daycare centers

Daycare Center	Dose Rate (CFU/kg^{-1}/day)	
	Bacteria	Fungi
DC1	1.12×10^5	2.29×10^4
DC2	4.46×10^4	1.95×10^4
DC3	4.62×10^4	2.29×10^4

4.3 Respiratory symptoms of respondents

4.3.1 Sociodemographic data of respondents

The results in Table 4 show the characteristics of respondents from the three DCs investigated. A total of 88 Malay children between the ages of 1 to 6 years old participated in this study. The majority of them are children aged 3 to 4 years old, and most of them had an early exposure to DC, starting from one years old. More than 50% of the respondents had family history of allergy. The children who took part in this study have at least attended the daycare for more than one month from when this study was conducted.

Table 4.3.1: Sociodemographic characteristics of respondents

Variables		N (%)
Total	n	88
Gender		
	Male	47 (53.4)
	Female	41 (46.6)
Age		
	1-2 years	36 (40.9)
	3-4 years	48 (54.5)
	5-6 years	2 (2.3)
Age entering DC		
	Less than 1 year	18 (35.1)
	1-2 years	50 (42.3)
	More than 2 years	20 (22.6)
History of family allergy		
	Yes	49 (55.7)
	No	37 (42.0)

4.3.2 Respiratory symptoms of respondents

Table 4.3.2 shows the prevalence of respiratory symptoms was higher among studied children for rhinitis (76.3%), followed by dry cough (37.5%), wheeze (31.8%) and asthma (14.8%).

Table 4.3.2: Prevalence of respiratory and allergy symptoms of respondents

Respiratory and allergy symptoms	N (N=88)	Prevalence
Wheeze ever	28	31.8
Wheeze in the previous 12 months	8	9.1
Dry cough in the previous 12 months	33	37.5
Breathlessness in the previous 12 months	5	5.7
Asthma ever	13	14.8
Asthma attack in the previous 12 months	6	6.8
Rhinitis ever	58	65.9
Rhinitis in the previous 12 months	45	76.3

Chapter 5

DISCUSSION

5.1 Overview

Data were collected at three daycare centers in Bangi residential area from January to March 2019. IAQ parameters ($PM_{2.5}$, bacterial and fungal concentration) together with meteorological parameters (temperature and relative humidity) were measured in three playrooms indoors and an outdoor comparison.

5.2 IAQ and meteorological parameters

The indoor air levels were compared with the Indoor Air Quality Code of Practice by the Department of Occupational Safety and Health (DOSH, 2010) for temperature, relative humidity, bacterial count, and fungal count. The standard guideline for $PM_{2.5}$ is not yet available in Malaysia, therefore the $PM_{2.5}$ levels were compared with the National Ambient Air Quality guidelines from Environmental Protection Agency (United States) or USEPA (2010). It was found that, all DCs had at least one IAQ parameter that exceeded the acceptable levels (Table 4.2).

The results in Table 4.2 show that DC1 had two IAQ parameters exceeding the acceptable levels, namely temperature and bacterial count. All DCs had temperature exceeding acceptable levels (23-26°C). Figures 4-1 and 4-2 show IAQ parameters in each DCC that exceed the acceptable levels.

Based on Figure 4-1 it's shown that the levels of $PM_{2.5}$ in all DCs does not exceeded the NAAQ standard for tolerable indoor concentration (35μg/m^3), however it was noted that in DC2 the highest concentration recorded was 36.7μg/m^3. The number of occupants, activities, as well as cleanliness were expected to determine the concentration of $PM_{2.5}$ within the daycare centers. Based from the observation done prior to the sampling, sources of $PM_{2.5}$ pollutants that can be identified includes signs of dampness or mold within the premises and also cooking gases. DC1 and DC3 were observed to have cooking activities in their premises and the distance of the kitchen is close to the playroom.

From Figure 4-2, it was demonstrated that the bacterial concentration are high in all daycare centers and are close to exceeding the acceptable limit. Daycare centers plays an important environment for children, as children are prone to infections and allergic reactions, due to their immature immune system (WHO, 2009). DC1 showed the highest bacterial concentrations compared to the other two DCs. One possible cause for this result may be the higher activity level of children in relatively small spaces. Based from the researcher observation of children activity throughout the sampling period, it was found that children in DC1 are much more mobile and also spent more time playing outside compared to the other two DCs. In

DCs, children's activities such as talking, sneezing, coughing, walking, and toilet flushing can generate airborne biological particulate matter (Khamal R. et. al, 2019).

These findings might also be due to poor ventilation, taking into account that all the DCs are naturally ventilated (Table 4.1) and associated with higher occupant densities. Ventilation system has a significant effect on indoor air pollutant levels, where hybrid ventilation system causes lower indoor air pollutants (Shahidah et al., 2017). Due to the daycare relying on natural ventilation, air permeability from outdoors would also infiltrate indoor air, which in turn could influence air pollutant levels. It was also found that both DC2 and DC3 have air purifiers installed in the playroom. In general, it was demonstrated that the indoor concentrations of airborne bacteria and fungi were higher in the indoor environment even with daily cleaning. This shows that the current cleaning practice of daycare centers are not sufficient to disinfect bioaerosols.

However, the standard available was constructed for workplaces using mechanical ventilation and air conditioning, which does not fit the characteristics of this study's daycare centers. This is one of the limitations for not only this study, but also for most indoor air quality studies done in Malaysia as there has yet to be a standard made for indoor air quality in non-industrial settings.

Independent *t*-test analysis showed that there was no significant difference ($p>0.05$) observed regarding indoor and outdoor levels of IAQ parameters ($PM_{2.5}$, bacterial and fungal concentrations) for all three DCs. Meaning indoor air pollutant concentration are not influenced by outdoor air pollutant concentration. ANOVA test

found no significant difference between means of $PM_{2.5}$, bacterial and fungal concentration in studied areas [(F (2, 105) = 1.351, p = 0.263)].

5.3 Indoor/Outdoor relationship

The results for I/O ratio for IAQ parameters are shown in Table 4.2.4. For all three DCs, the mean I/O ratios for bacteria and fungi were higher than 1, with the highest I/O ratio for bacteria concentrations were observed in DC3 being 11.825. While I/O ratio for $PM_{2.5}$ are all lower than <1. The I/O ratio gives some indication on where the source of bioaerosol exists. If the ratio is greater than 1, the source of pollutant most likely originate from the indoor environment (Madureira et al., 2015). This indicates that the main sources of bacterial and fungal pollutants in DCs might be any activities carried out in the indoor environment, density of occupation, and/or ventilation. Thus indoor sources had a greater effect than the inflow from the outside. However, statistical test results showed that there was no significant difference between IAQ parameters for indoor and outdoor environments between DC1, DC2, and DC3 in this study (p-value > 0.05).

The bacterial I/O ratio for DC3 was the highest at 11.83, which indicated that their major sources for bacterial concentration might be due to the density of children (Table 1) and ventilation where it was observed that the windows in DC3 were closed most of the time and ventilation might be insufficient (Mantese et. al, 2009). Similar this study, other studies have also pointed to lower concentrations of bacteria outdoors when compared to indoors, and that the occupancy, indoor activities, and/or indoor sources are determinant for the observed differences (Mentese et. al, 2009; WHO, 2009; Hospodsky et. al, 2012).

The impact of indoor sources for fungi was less evident. The results show that I/O ratio was slightly lower compared to bacterial I/O but still higher than 1. Statistical analysis showed that fungi concentration has a significant relationship with related humidity. The humidity level in all DCs did not exceed the standard, however humidity in the range of 60-69 % have been associated with high indoor fungi concentration in spring (Mika F. et. al, 2012).

5.4 Influence of temperature and relative humidity

Table 4.2.5 presents the correlation coefficients (r_2) between temperature and relative humidity on IAQ parameters ($PM_{2.5}$, bacterial and fungal concentrations). While there was no significant correlation between the parameters in DC1, it was found that there weak negative correlation between relative humidity and bacterial concentrations. A significant correlation was also observed between relative humidity and fungal concentrations in DC3, however it is a weak positive correlation.

Many studies suggested that temperature and relative humidity affected the growth and viability of microorganisms prominently (Zhong et. al, 2016; Mouli et. al, 2005), where higher temperature and relative humidity could promote the growth of bacteria and fungi. Higher temperature and relative humidity could promote the growth and release of microorganisms, but may also reduce the viability of bacteria. However in our study found that both RH and temperature did not influence the IAQ parameters. Based on our observations during the monitoring campaign, all DCs using mixed natural and mechanical ventilation and frequently opened their main

door. Our study also conducted measurment in a short period of monitoring (time xx-). Of these might affect the measurement of RH and temperature.

Wu et. al, (2012) in their study of ambient bacterial level at Taipei, found that meteorological factors including wind speed, wind direction, temperature and relative humidity were significant predictors of ambient bacterial level. Wind may suspend bacteria from soil and plant surfaces into air.

5.5 Dose rate analysis

The inhalation dose rates of bacteria and fungi were estimated for 1-5 year old children (Table 4.2.6). DC3 showed the highest levels for bacteria and fungi dose rate (4.62×10^4 and 2.29×10^4 respectively). Similar fungi dose rate was also observed in DC1 (2.29×10^4). These results are associated with the increased concentration and I/O ratio in DC3 and DC1.

Considering the high susceptibility of children, these results demonstrate that daycare centers play an important environment as a source of exposure to bacterial and fungal concentrations in the early life of children. Due to their size, physiology, behavior, and activity level, the inhalation rates of children differ from those of adults (USEPA, 2011). Children have a higher oxygen consumption rate per unit of body weight than adults because of their relatively larger lung surface area per unit of body weight. Children breathe through their mouths more often than adults, therefore the air filtering of the nose is less efficient in children. Thus, the deposition of particles in the lower respiratory tract may be greater for children (Foos et. al, 2008).

Information regarding children dose rates to bacteria and fungi are limited and thus, it is difficult to compare the results from this study to other studies due to the different methodologies and microenvironments. Therefore, the dose rates estimated within this study could not be compared with other studies.

5.6 Respiratory symptoms of respondents

The results in Table 4.3.1 show the characteristics of respondents from the three DCs investigated. A total of 88 Malay children between the ages of 1 to 6 years old participated in this study. The majority of them are children aged 3 to 4 years old, and most of them had an early exposure to DC, starting from one years old. More than 50% of the respondents had family history of allergy. The children who took part in this study have at least attended the daycare for more than one month from when this study was conducted.

Table 4.3.2 shows that the prevalence of respiratory symptoms was higher among studied children for rhinitis (76.3%) and dry cough (37.5%). In Malaysia, the study conducted by Zakaria et. al, (2012) among school children in Klang Valley revealed that the presence of particulate matter can influence the severity of asthma among primary school children in urban, industrial, and rural areas of Selangor and Kuala Lumpur.

Chapter 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study fills a gap by providing information on $PM_{2.5}$ and bioaerosol particle levels, the influence of indoor and outdoor sources on those concentrations, and exposure dose rates experienced by children attending the selected daycares in Bangi, Selangor, as there are few data available for this area.

The concentration of IAQ parameters (PM2.5, bacterial and fungal) were measured in both indoor and outdoor environment of DCs and were compared. Results from all three DCs were constant where indoor bioaerosols were higher than their outdoor counterparts while $PM_{2.5}$ showed higher concentration outdoors. DC1 showed the highest concentration compared to other daycares and should be noted.

I/O levels showed that the source of air pollutants are from indoor origin, however there was no significant difference between indoor and outdoor parameters. In this study, we determined that there were no relationship between indoor and outdoor concentration of pollutants, nor association between the pollutants. This

shows that each IAQ parameter, in both indoor and outdoor environment, are independent of each other.

A correlation test shows that there is significant correlation between the meteorological parameter (temperature and relative humidity) with bacterial and fungi concentration, respectively. Similar to previous studies, we determined that meteorological parameters are an important factor that determines the concentration of indoor air pollutant.

The findings of this study was unable to prove the hypothesis that there are associations between indoor and outdoor parameters. The hypothesis that there are significant relationship between indoor parameters with health symtotms of children was also rejected. However, the hypothesis that there is significant correlation between outdoor air levels and meteorological parameters was accepted.

In this study, we determined the inhalable dose rate for bioaerosols to children in selected DCs. Particulates such as $PM_{2.5}$ and bioaerosols are of concern due to their nature of penetrating deep into the human respiratory tract. Results showed that children in the selected daycares have at least one respiratory problem despite being so young. Data on inhalable dose rates are limited and not widely used yet therefore the importance of analysing and evaluation of these biological particles should be emphasized. Conclude on relationship that you were looking for? (this will reflect to yoru objective) This study demonstrated that IAQ in the daycare centers is a high priority environment for children.

6.2 Study Limitation

This study discloses some limitations such as time constraint. Sampling duration could only be done in three months and it is not enough to make an association with asthma as it is a chronic disease that emerges over a long time of exposure. Short sampling time may also introduce variations between measurements resulting in poor reproducibility and weak consistency in comparisons. There was also a shortage of instruments making the duration of sampling longer. The number of respondents in this study were also limited and cannot be used as a representative data for the population in Bangi. The self-reporting system of the symptoms through questionnaire may lead to information biases by the parents.

6.3 Recommendation

In this study, the exposure to bioaerosols are only calculated and the specific species were not determined. To further understand how bioaerosol affects children and their dose-response relationship, the species and pathogenicity of the bacteria and fungi should be identified.

In accessing the respiratory symptoms and other health effects due to exposure to particulates, more sensitive and specific tests should be conducted using blood or sensitivity/allergenic test instead of just using ISAAC questionnaire. Data from questionnaire may help in providing background information of respondents, their exposure details and self-reported respiratory symptoms while clinical test may help in determining the specific causative agent.

In this study, it is shown that sources of pollutant are indoors. Other than occupants, future research should include wallpapers and building materials as a possible source of pollutant. Future research is recommended to investigate more IAQ parameters such as nitrogen dioxide (NO_2), carbon dioxide, (CO_2) and volatile organic compounds (VOC). The DCs in this study were all in residential areas and in close proximity to road. Nitrogen dioxide is a common traffic pollutant that originates from car emissions and is a known pollutants that irritates the respiratory system. Volatile organic compounds are emitted gases from common household items such as paint, varnishes, cleaning agents, and more. EPA has listed VOCs as an indoor pollutant that can cause adverse health effects related to the respiratory and nervous systems. Carbon dioxide are not necessarily pollutants however high levels of CO_2 are an indication that there is not sufficient ventilation for the number of occupants in the room.

This study found that the DCs equipped with air purifiers (DC1 and DC2) had better bioaerosols levels compared to DC1. Therefore it is recommended that an intervention study using air purifiers be done to investigate the efficiency of air purifiers in improving the indoor air quality in DCs. Daycares mainly have toddlers (age 0-1) that crawl on the floor and also older children (age 3-6). Due to the nature of indoor pollutants where the particles are mostly airborne, a study at different heights are also suggested to compare the exposure level for children of different stages.

Particulate matter and bioaerosol concentration vary mainly due to hygienic conditions and activities of occupants. Due to the nature of daycare centers being full of organic materials (human, toys, and diapers), it is recommended for the daycare centers to adopt a cleaning routine that includes disinfectants such as Dettol. Caretakers should also encourage children to wash their hands and feet regularly, especially after any activities done outside.

CHAPTER 6 REFERENCES

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APPENDICES

Appendix 1: Summary of Indoor & Outdoor Measurement Separated Into Morning and Afternoon

Table 1: Summary of indoor and outdoor IAQ parameters for DC1

Parameters	Indoor		Outdoor	
	AM	PM	AM	PM
	Mean ± SD		Mean ± SD	
Temperature (°C)	33.9 ± 0.71	32.4 ± 2.24	34.9 ± 0.83	33.3 ± 3.91
Relative Humidity (%)	61.7 ± 6.43	68.3 ± 6.93	56.3 ± 5.19	61.4 ± 11.44
$PM_{2.5}$ ($\mu g/m^3$)	12.53 ± 7.85	14.62 ± 6.9	13.09 ± 5.23	15.32 ± 5.82
Bacteria (CFU m^{-3})	1200 ± 460	1212 ± 606	432 ± 303	449 ± 491
Fungi (CFU m^{-3})	282 ± 96	226 ± 95	291 ± 131	211 ± 111

Table 2: Summary of indoor and outdoor IAQ parameters for DC2

Parameters	Indoor		Outdoor	
	AM	PM	AM	PM
	Mean ± SD		Mean ± SD	
Temperature (°C)	34.5 ± 1.32	33.7 ± 1.73	35.1 ± 1.48	34.8 ± 1.38
Relative Humidity (%)	59.5 ± 5.09	59.5 ± 9.51	60.0 ± 5.18	60.2 ± 10.74
$PM_{2.5}$ ($\mu g/m^3$)	10.17 ± 3.25	15.04 ± 8.85	13.32 ± 3.41	14.29 ± 6.19
Bacteria (CFU m^{-3})	411 ± 209	550 ± 346	173 ± 268	312 ± 505
Fungi (CFU m^{-3})	185 ± 209	235 ± 129	93 ± 104	117 ± 65

Table 3: Summary of indoor and outdoor IAQ parameters for DC3

Parameters	Indoor		Outdoor	
	AM	PM	AM	PM
	Mean ± SD		Mean ± SD	
Temperature (°C)	33.9 ± 0.71	32.4 ± 2.24	34.9 ± 0.83	33.3 ± 3.91
Relative Humidity (%)	61.8 ± 6.43	68.3 ± 6.94	56.6 ± 5.19	61.4 ± 11.44
$PM_{2.5}$ ($\mu g/m^3$)	9.05 ± 9.57	9.53 ± 9.97	13.10 ± 11.00	11.94 ± 10.37
Bacteria (CFU m^{-3})	529 ± 208.28	466 ± 239.14	126 ± 14.27	158 ± 203.48
Fungi (CFU m^{-3})	264 ± 141.58	229 ± 163.04	228 ± 158.38	150 ± 107.80

APPENDIX 2: Research Gantt Chart

Task	Activity by Months from the start of the project									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Writing thesis										
Location survey										
Equipment test run										
Proposal presentation										
Pilot study										
Data collection										
Data analysis										

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

Research title	:	**Relationship Between Indoor and Outdoor Levels of PM2.5 and Bioaerosols in Daycare Center Selangor**
Study Site	:	**Selangor**
JKEUPM Ref No.	:	**JKEUPM-2018-393**
Researcher	:	**Ainul Farhanah binti Yahya**
Supervisor	:	**Dr. Nor Eliani Ezani**

Documents received and reviewed with reference to the above study:

1. Ethics Application Form, Version 1 dated 29/10/2018
2. Respondent Information Sheet & Guardian's/Parent's Consent (English), Version 1 dated 29/10/2018
3. Respondent Information Sheet & Guardian's/Parent's Consent (Malay), Version 1 dated 20/12/2018
4. Proposal (English), Version 3 dated 30/1/2019
5. Questionnaires/ Interviews (English), Version 1 dated 29/10/2018
6. Questionnaires/ Interviews (Malay), Version 1 dated 20/12/2018
7. Curriculum Vitae of:
    a. Dr. Nor Eliani binti Ezani
    b. Dr. Nurshahira Sulaiman

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

Decision by JKEUPM:

[X] Approved

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

[ ] Disapproved

Please note that the approval is **VALID UNTIL 12 FEBRUARY 2020**

Researchers should comply with the following:

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

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

BORANG 2.5: PENERANGAN DAN PERSETUJUAN IBUBAPA/PENJAGA

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

1.TAJUK KAJIAN

HUBUNGKAIT ANTARA $PM_{2.5}$ DAN BIOAEROSOL UDARA DI DALAMAN DAN DI LUARAN PUSAT JAGAAN HARIAN, SELANGOR.

2. PENGENALAN

Isu pencemaran kualiti udara dalam bangunan merupakan isu yang semakin mendapat perhatian sejak kebelakangan ini kerana ia boleh menjejaskan tahap kesihatan masyarakat terutamanya kanak-kanak. Kanak-kanak mudah diserang penyakit kerana organ (seperti paru-paru) dan sistem pertahanan badan mereka yang belum matang.

Pusat jagaan kanak-kanak selalunya dipenuhi oleh puluhan kanak-kanak dan mempunyai sistem pengudaraan yang tidak berkesan. Keadaan ini menggalakkan pertumbuhan mikroorganisma di dalam bangunan. Pendedahan kepada mikroorganisma bakteria dan kulat boleh menyebabkan pelbagai kesan kepada kesihatan termasuklah penyakit pernafasan (asma), paru-paru dan mengurangkan daya produktiviti kanak-kanak.

Oleh itu kajian ini dicadangkan untuk mengkaji hubungkait antara pencemar udara (PM2.5, bakteria, dan kulat) di dalam dan di luar bangunan pusat jagaan kanak-kanak di Bangi. Selain itu, untuk membuat anggaran jumlah mikroorganisma yang memasuki badan kanak-kanak dengan mengira kadar dos pendedahan kepada mikroorganisma semasa kanak-kanak berada di pusat jagaan kanak-kanak.

3. APAKAH YANG PERLU ANDA LAKUKAN?

Anda cuma perlu menandatangani Borang Kebenaran Bertulis untuk menyatakan kesediaan anda untuk membenarkan anak anda menyertai kajian ini sebagai responden. Sekiranya anda bersetuju untuk membenarkan anak anda menyertai kajian ini, Borang Kebenaran Bertulis akan digunakan untuk merekodkan keizinan anda. lanya boleh dilakukan setelah anda membaca dan memahami isi kandungan penerangan ini borang kebenaran ini perlu dipulangkan kepada penyelidik sebelum kajian dijalankan.

Kajian ini memerlukan penglibatan secara sukarela daripada semua responden. Setiap responden mempunyai hak untuk membatalkan keizinannya dan menarik diri pada bila-bila masa sekiranya responden merasa tidak selesa untuk memberikan maklumat kepada penyelidik.

Ibu bapa atau penjaga kepada responden akan diberi borang soal selidik dan diminta menjawab soalan-soalan yang diberi sebaik mungkin.

4. SIAPA YANG TIDAK BOLEH MENYERTAI KAJIAN INI?
Kanak-kanak yang baru mendaftar di Pusat Jagaan kurang daripada satu bulan.

5. APAKAH FAEDAH MENYERTAI KAJIAN INI?
Anda dan anak anda tidak akan mendapat sebarang ganjaran dalam bentuk bayaran dengan mengikuti kajian ini. Namun, semua maklumat yang diberikan dan diperolehi daripada kajian ini akan menguntungkan responden di mana ia akan memberikan peluang kepada responden untuk mengetahui tahap pendedahan kepada mikroorganisma berbahaya di Pusat Jagaan kanak-kanak dan implikasi pendedahan tersebut terhadap kesihatan responden seperti asma. Hasil daripada kajian ini akan diunjurkan kepada pihak bertanggungjawab agar tindakan penambahbaikan dapat dilakukan. Dengan itu tahap kesihatan dan produktiviti kanak-kanak dapat ditingkatkan dalam merealisasikan wawasan negara.

a) KEPADA ANAK/JAGAAN SAYA SEBAGAI PESERTA?
Tiada ganjaran dalam bentuk kewangan/barangan akan diberikan kepada responden.

b) KEPADA PENYELIDIK?
Kajian ini akan membantu penyelidik untuk mendapat maklumat berkenaan tahap pencemaran mikroorganisma di Pusat Jagaan dan simptom-simptom kesihatan dikalangan kanak-kanak.

6. ADAKAH IA BERISIKO?
Tiada sebarang risiko pada jangka masa pendek dan panjang kepada responden yang mengambil bahagian dalam kajian ini.

7. ADAKAH MAKLUMAT DAN IDENTITI ANAK/JAGAAN SAYA KEKAL RAHSIA?
Semua maklumat yang diberikan oleh responden di dalam borang kaji selidik adalah di jamin sulit. Tiada huraian individu akan dibuat pada mana-mana bahagian di dalam kajian dan sebarang kesimpulan akan diringkaskan menjadi kesimpulan bersama sebagai kumpulan kanak-kanak dan bukan sebagai individu.

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

Sila berhubung kepada penyelidik di bawah sekiranya penerangan lebih lanjut diperlukan:

AINUL FARHANAH BINTI MOHD YAHYA

Pelajar Tahun Akhir, Emel: ainul.myahya@gmail.com

Bacelor Sains (Kesihatan Persekitaran dan Pekerjaan), No. tel: 011-21092339

Fakulti Perubatan dan Pekerjaan,

Universiti Putra Malaysia.

DR. NOR ELIANI BINTI EZANI

Penyelia Projek Ilmiah Tahun Akhir Emel: elianiezani@upm.edu.my

Jabatan Kesihatan Persekitaran dan Pekerjaan, No. tel: 03-8609 2937

Fakulti Perubatan dan Sains Kesihatan,

Universiti Putra Malaysia,

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

9. PERSETUJUAN

Saya..... No Kad Pengenalan. ..... beralamat..... .....dengan ini secara sukarela bersetuju membenarkan *anak / jagaan saya ..... menyertai **penyelidikan tersebut di atas soal selidik.**

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

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

I setuju / tidak bersetuju untuk imej/gambar/rakaman video/ rakaman suara berkaitan dengan anak/ jagaan saya digunakan dalam apa jua bentuk penerbitan atau pembentangan. (sekiranya berkaitan).

***potong yang tidak berkenaan**

Tandatangan ..... **Tandatangan .....**
(*Ibubapa/ Penjaga*) **(*Saksi*)**

Tarikh :..... **Nama :.....**

No. K/P: .....

Saya mengesahkan bahawa saya telah menerangkan kepada ibubapa/penjaga responden mengenai sifat dan tujuan penyelidikan tersebut di atas.

Tarikh ..... **Tandatangan .....**
(*Penyelidik*)

BAHAGIAN I: Maklumat Peribadi Anak dan Sosiodemografi

No.	Soalan	Jawapan
1.	Soal selidik dilengkapkan oleh	☐ Ibu ☐ Bapa ☐ Penjaga
2.	Nama	
3.	Umur	_____ tahun
4.	Jantina	☐ Lelaki ☐ Perempuan
5.	Umur anak ketika mendaftar diri di Pusat Jagaan ini	_____ tahun

ARAHAN: SILA TANDAKAN (/) PADA KOD JAWAPAN YANG BERKAITAN

BAHAGIAN II: Simptom Sesak Nafas, Nafas Berbunyi dan Bronkitis

No.	Soalan	Kod	Jawapan
6.	Pernahkan anak anda mengalami sesak nafas ataupun nafas berbunyi di dada pada bila-bila masa yang lepas? Jika anda menjawab "Tidak", sila terus ke soalan 14	☐ 1 ☐ 2	Ya Tidak
7.	Adakah anak anda mengalami sesak nafas ataupun nafas berbunyi tidak ada dalam 12 bulan yang lepas? Jika anda menjawab "Tidak", sila terus ke soalan 14	☐ 1 ☐ 2	Ya Tidak
8.	Pernahkah anak anda mengalami sesak nafas atau nafas berbunyi ini semasa tidak menghidap selsema?	☐ 1 ☐ 2	Ya Tidak
9.	Berapa kalikah serangan sesak nafas atau nafas berbunyi yang dialami dalam 12 bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak
10.	Pada 12 bulan yang lepas, berapa kerapkah secara puratanya tidur anak anda diganggu oleh masalah sesak nafas atau nafas berbunyi?	☐ 1 ☐ 2	Tidak pernah terjaga disebabakan sesak nafas atau nafas berbunyi Kurang dari satu malam seminggu

BAHAGIAN I: Maklumat Peribadi Anak dan Sosiodemografi

No.	Soalan	Jawapan
1.	Soal selidik dilengkapkan oleh	☐ Ibu ☐ Bapa ☐ Penjaga
2.	Nama	
3.	Umur	_____ tahun
4.	Jantina	☐ Lelaki ☐ Perempuan
5.	Umur anak ketika mendaftar diri di Pusat Jagaan ini	_____ tahun

ARAHAN: SILA TANDAKAN (/) PADA KOD JAWAPAN YANG BERKAITAN

BAHAGIAN II: Simptom Sesak Nafas, Nafas Berbunyi dan Bronkitis

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7.	Adakah anak anda mengalami sesak nafas ataupun nafas berbunyi tidak ada dalam 12 bulan yang lepas? Jika anda menjawab "Tidak", sila terus ke soalan 14	☐ 1 ☐ 2	Ya Tidak
8.	Pernahkah anak anda mengalami sesak nafas atau nafas berbunyi ini semasa tidak menghidap selsema?	☐ 1 ☐ 2	Ya Tidak
9.	Berapa kalikah serangan sesak nafas atau nafas berbunyi yang dialami dalam 12 bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak
10.	Pada 12 bulan yang lepas, berapa kerapkah secara puratanya tidur anak anda diganggu oleh masalah sesak nafas atau nafas berbunyi?	☐ 1 ☐ 2	Tidak pernah terjaga disebabkan sesak nafas atau nafas berbunyi Kurang dari satu malam seminggu

		☐ 3	Satu atau lebih malam dalam seminggu
11.	Pernah ke anak anda terjaga dengan rasa tegang di dada dalam 12 bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak
12.	Pada 12 bulan yang lepas, adakah masalah kesesakan nafas anak anda berada di tahap yang serius sehingga membataskan percakapan kepada hanya satu atau dua patah perkataan sahaja di antara nafas?	☐ 1 ☐ 2	Ya Tidak
13.	Pernahkah anak anda tercungap-cungap apabila berkeadaan sesak nafas?	☐ 1 ☐ 2	Ya Tidak
14.	Pernahkah anak anda menghidapi asma?	☐ 1 ☐ 2	Ya Tidak
15.	Pada 12 bulan yang lepas pernahkah dada anak anda berbunyi semasa atau selepas bersenam?	☐ 1 ☐ 2	Ya Tidak
16.	Pada 12 bulan yang lepas pernah kah anak anda mengalami batuk tanpa kahak pada waktu malam?	☐ 1 ☐ 2	Ya Tidak
17.	Pernahkah anak anda terjaga kerana sesak nafas dalam 12 bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak
18.	Pernahkah anak anda terjaga kerana batuk dalam 12 bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak
19.	Pernahkah anak anda mendapat serangan sesak nafas yang datang tiba-tiba ketika berehat dalam 12 bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak
20.	Pernahkah anda-anda mendapat serangan sesak nafas yang datang selepas melakukan aktiviti yang berat pada bila-bila masa dalam 12 yang lepas?	☐ 1 ☐ 2	Ya Tidak
21.	Pernahkah anak anda mengalami sesak nafas atau nafas berbunyi walaupun tidak melakukan aktiviti yang berada dalam 12 bulan dia lepas?	☐ 1 ☐ 2	Ya Tidak

22.	Manakah antara yang berikut menerangkan pernafasan anak anda	☐ 1 ☐ 2 ☐ 3	Saya tidak pernah atau jarang mengalami masalah dengan pernafasan Saya selalu mengalami masalah dengan pernafasan saya, tetapi selalunya akan segera pulih Saya selalu mengalami masalah pernafasan.

~~BAHAGIAN III:~~ Asma dan Alahan

No.	Soalan	Kod	Jawapan
23.	Pernah ada anak anda mengidap asma? Jika anda menjawab "Tidak", sila terus ke soalan 28	☐ 1 ☐ 2	Ya Tidak
24.	Adakah anak anda masih menghidap asma? Jika anda menjawab "Tidak", sila terus ke soalan 28	☐ 1 ☐ 2	Ya Tidak
25.	Adakah asma itu dikesan oleh doktor?	☐ 1 ☐ 2	Ya Tidak
26.	Pernahkah anak anda mendapat serangan asma dalam 12 bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak
27.	Adakah anak anda mengambil apa-apa ubat untuk asma sekarang? (semburan, inhaler, ubat biji, dan sebagainya)?	☐ 1 ☐ 2	Ya Tidak
28.	Pernahkah anak anda mendapat jangkitan pada paru-paru?	☐ 1 ☐ 2	Ya Tidak
29.	Berapa banyak kah jangkitan pada paru-paru yang anak anda alami semasa tiga bulan yang lepas?		Nyatakan: _____ (nombor)
30.	Adakah anak anda menghidapi apa-apa Penyakit yang memerlukan anda berjumpa dengan doktor?	☐ 1 ☐ 2	Ya Tidak Jika ya, nyatakan _____

31.	Adakah anak anda mengambil antibiotik (contoh: penicillin) semasa enam bulan yang lepas?	☐ 1 ☐ 2	Ya Tidak Jika ya, nyatakan _____
32.	Adakah anak anda sensitif/alah kepada kucing?	☐ 1 ☐ 2	Ya Tidak
33.	Adakah anak anda sensitif/alah kepada anjing?	☐ 1 ☐ 2	Ya Tidak
34.	Adakah anak anda sensitif/alah kepada objek yang berkulat?	☐ 1 ☐ 2	Ya Tidak
35.	Adakah anak anda sensitif/alah kepada debunga?	☐ 1 ☐ 2	Ya Tidak
36.	Adakah anak anda sensitif/alah kepada makanan?	☐ 1 ☐ 2	Ya Tidak
37.	Adakah anak anda sensitif/alah kepada habuk?	☐ 1 ☐ 2	Ya Tidak
38.	Lain-lain alahan?		Nyatakan _____ _____
39.	Adakah terdapat ahli keluarga lain yang mempunyai alahan?	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7	Tiada Ayah Ibu Kakak Abang Adik Lebih dari seorang ahli keluarga

BAHAGIAN IV: Simptom- simptom hidung

No.	Soalan	Kod	Jawapan
40.	Pernahkah anak anda mempunyai masalah bersin, hidung berair serta tersebut semasa anda TIDAK menghadapi selsema ataupun demam? Jika anda menjawab "Tidak", sila terus ke soalan 46	☐ 1 ☐ 2	Ya Tidak

41.	Dalam 12 bulan yang lepas, adakah anak anda mempunyai masalah bersin, ataupun hidung berair atau tersebut semasa anda tidak menghadapi selsema ataupun demam? Jika anda menjawab "Tidak", sila terus ke soalan 46	☐ 1 ☐ 2	Ya Tidak
42.	Dalam 12 bulan yang lepas pernahkah masalah hidung ini disertai dengan mata berair yang gatal?	☐ 1 ☐ 2	Ya Tidak
43.	Dalam 12 bulan yang lepas berapa kerapkah masalah hidung ini mengganggu aktiviti harian anak anda?	☐ 1 ☐ 2	Ya Tidak
44.	Adakah anak anda pernah mengalami simptom alahan pada habuk? (gatal dan merah pada mata hidung dan tekak)	☐ 1 ☐ 2	Ya Tidak
45.	Pernahkah anak anda mendapat jangkitan pada paru-paru?	☐ 1 ☐ 2	Ya Tidak
46.	Adakah anak anda kerap bersin pada waktu pagi?	☐ 1 ☐ 2	Ya Tidak

SOALAN TAMAT

TERIMA KASIH ATAS KERJASAMA ANDA