
**UNIVERSITI PUTRA MALAYSIA**

# *INDOOR AIR QUALITY AND RESPIRATORY HEALTH IMPLICATION AMONG MALAY PRE-SCHOOL CHILDREN IN PUCHONG AND HULU-LANGAT, SELANGOR, MALAYSIA*

**ONWUSEREAKA CYNTHIA OLUCHI**

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By

**ONWUSEREAKA CYNTHIA OLUCHI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science**

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**December 2017**

**Chairman : Associate Professor Juliana Jalaludin, PhD**
**Faculty : Medicine and Health Sciences**

**Background:** Indoor air quality (IAQ) refers to the nature of air that circulates throughout the space where we live. Indoor air pollutant in the environment has caused a greater impact on the health of occupants' especially preschool age who are still growing. The increased of respiratory symptoms in children have been linked to the exposure to indoor air pollutants. Children were exposed to indoor air pollutants because they spend most of their time indoors, either in school or at home. **Objective**: This study aimed to determine the association between indoor air pollutants ($PM_{2.5}$, $PM_{10}$, VOCs, temperature, mold and relative humidity) and respiratory implications among Malay preschool children in selected areas in Selangor. **Methodology:** A cross sectional comparative study design was used on healthy preschools children in Puchong (n=135), as the study group and Hulu Langat (n=135) as the comparative group. Preschool children in this study were selected based on inclusion criteria such as; those who are between the age of 5 and 6 years old, healthy children, those that have been in the school for at least 6 months and Malays. The respiratory symptoms were assessed using questionnaire adapted from American Thoracic Society. Indoor air quality monitoring was conducted using the following equipment; DustTrak Aerosol monitor for particulates, PbbRAE portable VOC Monitor (pbbRAE 3000) for VOCs, Q-Trak plus Model 8554 Monitor for temperature and relative humidity, TSI VelociCalc Plus Model 8386 for air velocity; Pbi DuoSAS Super 360 and Sabroud Dextrous Agar for sampling and identification of mold. Chestgraph HI-101 spirometer for lung function test. **Results:** Statistical analysis shows a significant higher indoor levels of $PM_{2.5}$, $PM_{10}$and mold in the study area except relative humidity which was higher in comparative area ($p = 0.049$). Besides, indoor home exposure was also assessed, analysis showed that homes of preschool children in the study area had significantly higher VOCs, Temperature, mold, $PM_{2.5}$, and $PM_{10}$, except relative humidity which was significantly higher in the comparative area. There was a

significant difference in $FEV_1$/FVC% (p= 0.001) and $FEV_1$% (p=0.008) predicted among the study and comparative group. A significant association was found between the indoor air pollutant levels of $PM_{2.5}$ ($\chi^2$= 15.008, p=<0.001), $PM_{10}$ ($\chi^2$= 8.816, p=0.003) and cough. Exposure to indoor $PM_{10}$ ($\chi^2$= 6.842, p=0.009) and VOCs ($\chi^2$= 12.153, p=<0.001) were significantly associated with FVC%. VOCs was significantly associated with $FEV_1$% ($\chi^2$= 14.382, p=<0.001). Mold isolated from preschools in study and comparative area include; *Candida albican, Aspergillus niger, Microsporium canis, Penicillium spp.* Logistics regression was used to determine the main factor that influenced the respiratory symptom and the abnormality of lung function after all confounders have been controlled. Analysis showed that the risk of $FEV_1$% abnormality increased significantly with increased in the level of $PM_{10}$ (AOR=2.1, 95% CI= 2.509-8.221), VOC (AOR= 5.3, 95% CI= 1.912-14.835) and RH (AOR=14.3, 95% CI= 1.451-14.306). **Conclusion**: This study found a higher exposure to indoor air pollutants which may increase the respiratory symptoms and reduced lung function among preschool children in the exposed area. It is recommended that the building of the preschools should be located in places that is less expose to outdoor sources of indoor air pollutants. Mold growth was observed more in preschools that had moisture damaged building materials. Therefore, the moisture damaged building materials need to be replaced to avoid mold growth.

**Keywords***:* Preschool children; indoor air quality; respiratory symptoms; mold.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**KUALITI UDARA DALAMAN DAN IMPLIKASI KESIHATAN RESPIRATORI DALAM KALANGAN KANAK-KANAK PRASEKOLAH MALAYA DI PUCHONG DAN HULU- LANGAT, SELANGOR, MALAYSIA**

Oleh

**ONWUSEREAKA CYNTHIA OLUCHI**

**Disember 2017**

**Pengerusi : Profesor Madya Juliana Jalaludin, PhD**
**Fakulti : Perubatan dan Sains Kesihatan**

**Latar belakang:**Peningkatan simptom respiratori dalam kalangan kanak-kanak telah dikaitkan dengan pendedahan kepada pencemar udara dalaman. Kanak-kanak terdedah kepada pencemar udara dalaman kerana mereka menghabiskan kebanyakan masa mereka di kawasan tertutup, sama ada di sekolah atau di rumah.

**Objektif**: Kajian ini bertujuan untuk menentukan kaitan antara pencemar udara dalaman ($PM_{2.5}$, $PM_{10}$, sebatian organik mudah meruap, suhu, kewujudan kulat, humiditi relatif) dan implikasinya terhadap kesihatan respiratori dalam kalangan kanak-kanak prasekolah malaya di Selangor. **Metodologi:** Kajian keratan rentas perbandingante lah dijalankan ke atas kanak-kanak prasekolah yang sihat di Puchong (n=135), sebagai kawasan kajian dan di Hulu Langat (n=135) sebagai kawasan perbandingan. Kanak-kanak prasekolah dalam kajian ini dipilih berdasarkan beberapa kriteria inklusif seperti; mereka yang berumur antara 5 dan 6 tahun, sihat, mereka yang telah berada di sekolah sekurang-kurangnya 6 bulan dan Melayu. Simptom respiratori telah diperolehi menggunakan borang soal selidik yang diadaptasi daripada American Thoracic Society. Pemantauan kualiti udara dalaman telah dijalankan menggunakan peralatan berikut;DustTrak Aerosol untuk partikel terampai,pbbRAE 3000 untuk sebatian organik mudah meruap, Model 8554 plus Trak Q untuk suhu dan humiditi relatif, Model 8386 Plus TSI VelociCalc untuk velositi udara; Pbi DuoSAS Super 360 dan Agar-agar Dekstrous Sabroud untuk persampelan dan identifikasian kulat, Spirometer Chestgraph HI-101 untuk ujian fungsi paru-paru. **Hasil:**Analisis statistik menunjukkan pencemar udara dalaman secara signifikannya lebih tinggi bagi $PM_{2.5}$, $PM_{10}$ dan kulat dalam kajian ini, kecuali humiditi relatif yang didapati lebih tinggi dalam kawasan perbandingan ($p = 0.049$). Selain itu, paras pencemar dalaman di kediaman kanak-kanak prasekolah dalam kajian ini adalah lebih tinggi secara

signifikan bagi sebatian organik meruap, suhu, kulat, $PM_{2.5}$, dan $PM_{10,}$ kecuali humidity relatif berbanding kumpulan perbandingan. Terdapat perbezaan yang signifikan dalam $FEV_1$/FVC% (p = 0.001) dan $FEV_1$% (p = 0.008) ramalan bagi kumpulan kajian dan perbandingan. Perkaitan yang signifikan didapati antara pencemar udara dalaman $PM_{2.5,}$ ($\chi^2$= 15.008, p=<0.001), $PM_{10}$ ($\chi^2$= 8.816, p=0.003) dan batuk. Pendedahan terhadap pencemar $PM_{10}$ ($\chi^2$= 6.842, p=0.009) dan sebatian organik meruap ($\chi^2$= 12.153, p=<0.001) adalah berkaitan secara signifikan dengan peratusan FVC. Sebatian organik meruap adalah secara signifikan berkaitan dengan peratus $FEV_1$ ($\chi^2$= 14.382, p=<0.001). Kulat yang diasingkan dari prasekolah dalam kawasan kajian dan perbandingan meliputi; *Candida albican, Aspergilus niger, Mikrosporium kanis, Penisilium spp.* Regresi logistik telah digunakan untuk menentukan faktor utama yang mempengaruhi simptom respiratori dan abnormaliti fungsi paru-paru selepas pengawalan kesemua faktor pembauran. Hasil analisis mendapati risiko abnormaliti $FEV_1$% meningkat secara signifikan dengan peningkatan paras $PM_{10}$ (AOR=2.1, 95% CI= 2.509-8.221), sebatian organik meruap (AOR= 5.3, 95% CI= 1.912-14.835) dan humiditi relatif (AOR=14.3, 95% CI= 1.451-14.306). **Kesimpulan:** Kajian ini mendapati pendedahan pencemar udara dalaman yang tinggi boleh meningkatkan simptom respiratori dan penurunan fungsi paru-paru dalam kalangan kanak-kanak prasekolah di kawasan terdedah. Adalah disarankan bahawa bangunan prasekolah perlulah ditempatkan di kawasan yang kurang terdedah daripada sumber luar pencemar udara dalaman. Pertumbuhan kulat telah banyak didapati di prasekolah yang mempunyai material dalaman bangunan yang lembap. Justeru itu, material bangunan yang rosak akibat kelembapan perlulah diganti bagi mengelakkan pertumbuhan kulat.

**Kata kunci***: Kanak-kanak prasekolah; kualiti udara tertutup; simptom respiratori; kulat*.

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My love and gratitude goes to my husband who was my pillar of support through my master's programme. Your love, support and encouragement kept me going. My gratitude goes to my lovely children king David and Doreen for your prayers. May God keep you all safe for me in Jesus name.

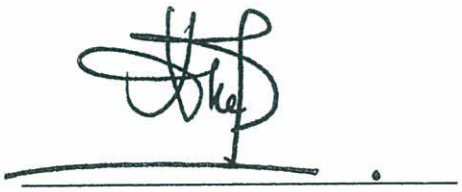
I certify that a Thesis Examination Committee has met on 8 December 2017 to conduct the final examination of Onwusereaka Cynthia Oluchi on her thesis entitled "Indoor Air Quality and Respiratory Health Implication among Malay Pre-School Children in Puchong and Hulu-Langat, Selangor, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

**Suhaili binti Abu Bakar @ Jamaludin, PhD**
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

**Abdah binti Md Akim, PhD**
Associate Professor
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Internal Examiner)

**Mohd Talib Latif, PhD**
Associate Professor
Universiti Kebangsaan Malaysia
Malaysia
(External Examiner)



**NOR AINI AB. SHUKOR, PhD**
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 29 January 2018

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

**Juliana binti Jalaludin, PhD**
Associate Professor
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

**Titi Rahmawati binti Hamedon, PhD**
Senoir Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

**ROBIAH BINTI YUNUS, PhD**
Professor and Dean
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**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF APPENDICES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| ATS | American Thoracic Society |
| ASHRAE | American Society of Heating, Refrigerating and Air Conditioning Engineers |
| DOSH | Department of Occupational Safety and Health |
| EEHS | European Environment and Health Strategy |
| IAQ | Indoor Air Quality |
| ICOP | Industrial Code of Practice |
| ISAAC | International Study of Asthma and Allergies in Children |
| ppm | Part per million |
| ppb | Part per billion |
| PM | Particulate Matter |
| $PM_{0.1}$ | Particulate Matter less or equal to 0.1 |
| $PM_{2.5}$ | Particulate Matter less or equal to 2.5 |
| $PM_{10}$ | Particulate Matter less or equal to 10 |
| VOCs | Volatile Organic Compounds |
| SDA | Sabouraud Dextrouse Agar |
| SPSS | Statistical Package for Social Sciences |
| USEPA | United State Environmental Protection Agency |
| WHO | World Health Organisation |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Indoor air quality (IAQ) refers to the nature of air that circulates throughout the space where we live (USEPA 2010). It refers to the air that we breathe during the time we spend indoors. Indoor air is made up of physical, biological, and chemical components. Indoor temperature and humidity can affect the comfort of occupants. Indoor air quality also refers to the characteristic of the indoor air inside a building (USEPA 2010). Indoor environments are considered to be protective, at the same time they can become contaminated with particles which can cause more serious risks than those related to outdoor exposures when the concentration of indoor air pollutants exceeded the recommended maximum limits. Approximately 19% deaths in children under the age of 5 were attributed to respiratory infections (World Health Organization 2010).

Indoor air quality (IAQ) has recently become a concern. There is an increasing concern regarding the effects of indoor air quality (IAQ) to health because people spend more of their time indoors than outdoors. The slow exchange of air indoors has resulted to accumulation of indoor air pollutants to a substantial level. From frequent observations, it has estimated that a quarter of the population in the world has been exposed to pollutants which can be harmful to health (Canha et al., 2010).

Indoor air pollutant level is higher than outdoor air pollutant level (Godoi et al., 2009; Jo and Seo, 2005; Kotzias et al., 2009; Pegas et al., 2010; Yang et al., 2009). Children are more exposed to indoor air pollutants compared to the adult. This is resulted from the immaturity of their immune system and growing process (Mendell et al., 2005). In recent years, there has been an increase in the prevalence of asthma and allergy among children. Currently, researchers focused more in school environments as a second source besides the home environments of children. This is because children spend most of their time either in school or at home (Anna and Elwira 2015; Branco et al., 2014; Santamouris et al., 2008).

Indoor air quality monitoring have being conducted in recent studies. This studies measured the indoor level of particulates (Ayuni et al., 2014; Anis et al 2015; Asrul et al., 2016;Anna and Elwira, 2015), presence of mold (Ayuni et al., 2014; Andrew et al., 2015), relative humidity and thermal comfort (Jing et al., 2012; Asrul et al., 2016; Andrew et al., 2015).

Studies have shown a consistent association between prolonged exposure to indoor air pollutants and increase in respiratory symptoms which reduces the lung function of children (Nazariah et al., 2013; Salleh et al., 2013; Nur Azwani et al., 2015; Nurul Fariza et al., 2010). Barnett et al. (2005) found that the risk of developing respiratory symptoms such as cough, wheeze, asthma, respiratory infections, headache and tiredness is higher for occupants living in moisture damaged buildings. All damp surfaces in buildings including concrete, wood, plastics, bricks, painted surfaces or metal may become colonized by microbes from the air. The colonizing microbes are bacteria, fungi and algae. Human activities like talking, sneezing, coughing, walking, washing and toilet flushing can generate airborne biological particulate matter. Spores from pets, carpets, dust and furniture can be released into the air. (Maeir et al., 2006).

Studies have shown that the presence of indoor air pollutants in the environment has caused a greater impact on the health of occupants' especially preschool age who are still growing. There has been an increase in the rate of respiratory symptoms as a result of exposure to indoor pollutants (Noor Hisyam & Juliana, 2014)

Indoor air comprises of biological components such as mold. Mold includes airborne particles which are of biological origin. Mold can enter into human respiratory tract through inhalation and also by skin contact. Studies have shown consistent associations between indoor mold and respiratory or allergic health effects in infants, children and adults (Institute of medicine, 2005 and World health Organization, 2009).

Many recent studies have reported the association between health symptoms and the physible growth of mold as a result from accumulation of water in school building and moisture damage in the school structures (Aydogbu et al., 2005; Hussin et al., 2011; Meklin et al., 2010). There has not been a standardized guideline for indoor mold and dampness in indoor environment (Karvala 2012 and WHO 2009). Previous studies related to the measurement of microbial agents have not shown much consistent association between microbiological agents and health symptoms. A water damaged building caused by mold and moisture have reported significant fungi growth in indoor environments (Kavala 2012). There is no generally accepted environmental sampling method which can be used in assessing the exposure to environmental contaminants including mold growth and other indoor environmental contaminants (ACGIH, 2009 & Frankel et al., 2012). Fungi depends on temperature and humidity to grow suitably in indoor environment.

National Institute for Occupational Safety and Health (NIOSH, 2011), has reported that in the last decades microbial contaminants are the main cause of poor air quality. The report also found that, approximately 5% of more than 500 indoor air quality (IAQ) from investigation and the remaining 95% was a result of poor ventilation, contamination in building and the rest are not known (NIOSH, 2011).

Disease of the lungs often manifest by one or more symptoms that can be easily recognized. Thus the presence of particular symptoms can confirm the presence of diseases in the upper and lower airways. Upper respiratory symptoms include (URS), runny and stuffy nose, sinusitis, sore throat, cold, fever, burning or red eyes. Lower respiratory symptoms include wheezing, wet cough and dry cough, phlegm, shortness of breath and chest discomfort or pain. These respiratory diseases are caused by bacteria and mold. These symptoms developed as a result of exposure to indoor air pollutants (Dockery et al. 2010).

## 1.2 Problem Statement

Children living in the industrial area have different indoor air exposure rate compared to children living in the suburban area. Exposure to industrial emission and automobile exhaust can cause acute respiratory diseases in children. Particulate matter has been associated with respiratory infections in children between the ages of 0-4 years. Exposure to pollutants like gases and particulate matter which are released from combustion of fossil fuel can cause a reduction in the lung function of children. Studies have shown that 1% mortality rate among children has been attributed to exposure to indoor particulate matter (Franklin 2007). Malaysia statistics data by DOE (2014) has reported that 70% to 75% of air pollution are attributed from traffic vehicles emissions (Noor Hisyam & Juliana, 2014; Nur Azwani et al., 2015; Salleh et al., 2013; Lee et al., 2012).

The presence of respiratory symptoms have being linked to the exposure to indoor air pollutants. Local studies have reported a high prevalence of respiratory symptoms like cough and phlegm among preschool children who are exposed compared to indoor air pollutants compared to those who are not exposed (Yahaya and Jalaludin, 2014; Nurul Anis et al., 2013; Nazariah et al., 2013; Ayuni et al., 2014; Nur Fazhilah et al. 2012). A report by World Health Organization (2005) has shown that approximately 2.7% of diseases occurred globally are due to the effects of poor indoor air quality

Preschool children spend most of their time indoors at home and schools. They attend classes in the morning approximately 4-5 hours, will be fetched by their parents or guardian and some of them will spend the remaining hours of the day at home. As a result of these, children are highly exposed to indoor air pollutants. Children are the main subject in this study because they easily respond to exposure to indoor air pollutants. A study has shown that from 1982 to 2013, there has being an increase from 2.5 to 7.1 million in the number of children suffering from asthma. In Malaysia 10% of children had been diagnosed with asthma. Furthermore, nearly 80 to 90% of asthmatic cases in Malaysia were children. There is no conclusive evidence showing that there are more asthmatic children in Malaysia now than before (Junaidah et al., 2010).

Susceptibility to mold related diseases occurs mainly in immune compromised persons. The person may develop chronic illnesses, such as lung diseases (CDC, 2005). Jacob et al. (2008) found that there was a significant association between exposure to *Penicillium* spores and the incidence of respiratory tract infections. Pollutants in the indoor air such as particulate matter, bioaerosol and other chemical components expose children to different respiratory health diseases and symptoms. Exposures to air pollutants are manifested through respiratory symptoms such as coughing, wheezing, sneezing, breathlessness, phlegm and shortness of breath.

Preschool indoor air quality and settings should be assessed in order to reduce indoor air pollutants and spread of respiratory symptoms. Local studies have found that preschool settings and characteristics of the surrounding environment can increase asthmatic symptoms, respiratory symptoms and allergies. (Marzuki et al. 2010; Nurul Anis et al. 2014; Ayuni et al., 2014; Yahaya et al., 2014; Salleh et al., 2013).

The aim of this study was to evaluate the indoor air quality and its' health implication on Malay preschool children living in the selected locations.

## 1.3 Conceptual frameworks

The aim of this study is to determine the association between indoor air pollutants and respiratory health among Malay preschool children in Puchong and Hulu Langat, Selangor, Malaysia. Locations used in this study were selected based on their level of exposure where Puchong represented the polluted area (Industrial) and Hulu Langat represented the less polluted area (Suburban). Exposure to pollutants was assessed by measuring the concentration of indoor pollutants such as VOCs, $PM_{2.5}$, $PM_{10}$, mold, relative humidity and temperature. The main route of exposure to indoor air pollutants in this study is by inhalation. Home exposure to pollutants was also assessed. The presence of respiratory symptoms (cough, phlegm, wheeze, chest tightness) was assessed using a questionnaire. Lung function of respondents was also assessed. Figure 1.1 below shows the study variables in this study.

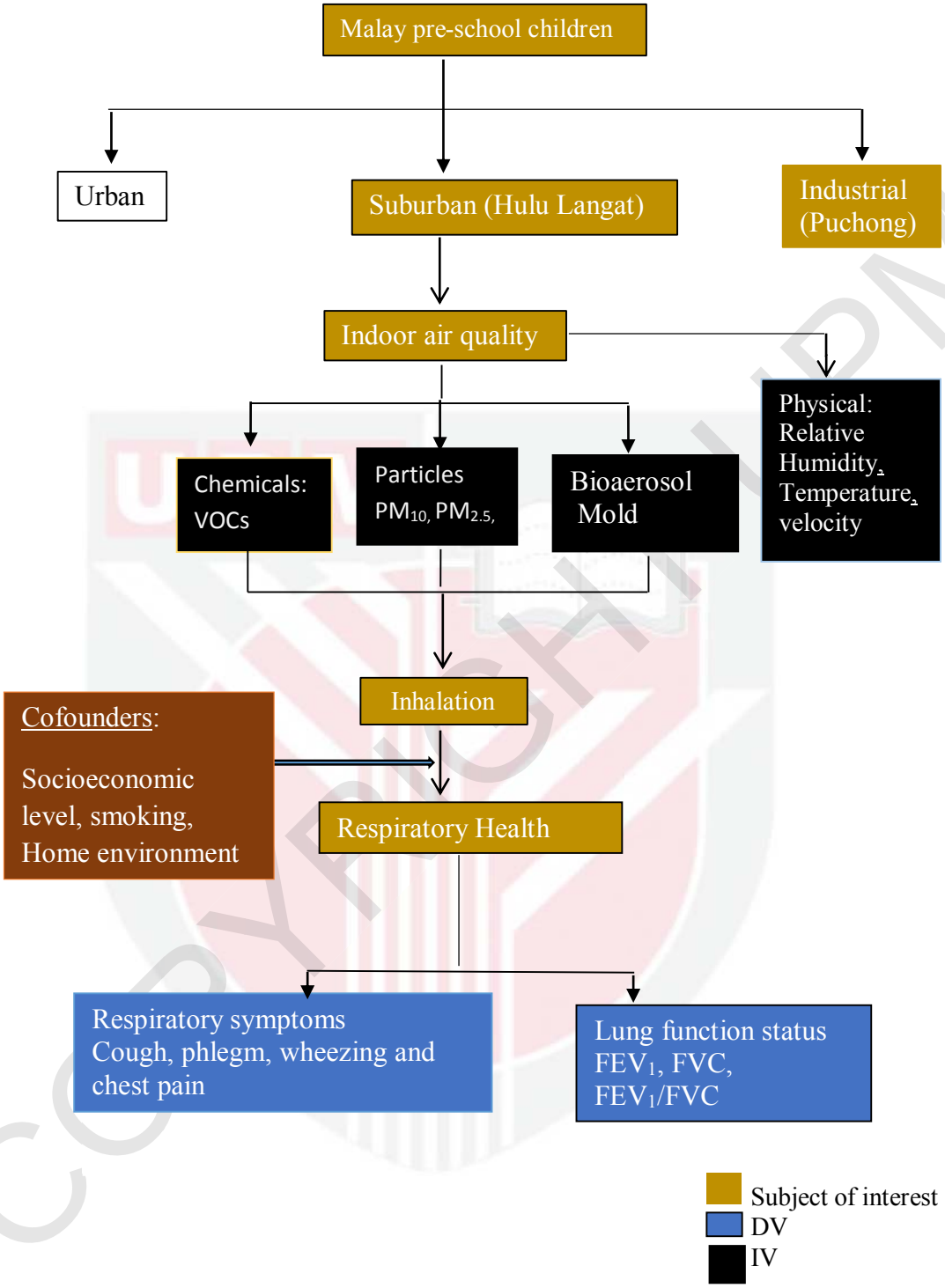


**Figure 1.1 : Conceptual Frameworks**

## 1.4 Study Justification

The purpose of this study is to determine the respiratory health implications due to exposure to indoor pollutants. This study will relate exposure to indoor air pollutants and the respiratory implication among preschool children in the different study locations.

Children are known to be the most susceptible groups (British Lung Foundation, 2014). Approximately 19% deaths in children under the age of 5 were attributed to respiratory infections (World Health Organization 2010).There have not been many studies carried out on preschool aged children compared to adults.

Rate of asthma, allergy and other health implications have been increasing in children which are caused by exposure to environmental factors instead of genetic influence. This study will help to provide information on exposures and prevention of these health implications. Respiratory symptoms can develop into full blown asthma for those who are prone to or those, who have family history of asthma. Unhealthy lungs may also lead to cough or cold which can affect the quality of life and missing school days. Medical treatment can be expensive and therefore it is better to identify health problems earlier by conducting indoor air monitoring study.

Previous studies conducted in Malaysia has shown that the presence of particulate matter ($PM_{10}$, $PM_{2.5}$) can directly cause an influence on the severity of asthma among school children who reside in the different locations of urban, industrial, and rural areas of Selangor and Kuala Lumpur. Exposure to indoor air pollutants can increase the prevalence of respiratory symptoms, which can affect the lung function of children. Indoor monitoring is important to reduce the level of exposure to children. prolonged exposure can lead to adverse health effects (Marzuki et al., 2010; Salleh et al., 2013; Yahaya et al., 2013; Ayuni et al., 2014; Nurul Anis et al., 2013; Ithnin et al., 2013; Nur Azwani et al., 2015; Tezara et al., 2014).

This study is more reliable since the effects from exposure to indoor air pollutants and respiratory symptoms are conducted among preschool children, this is because smoking is rarely found in children. They are not exposed to occupational pollutants, they have a more stable residence unlike the adults and also because of the nature of their immune system which is still maturing (Branco et al., 2014; Santamouris et al., 2008).

The locations (Puchong and Hulu- Langat) used for this study was selected due to the activities that have been carried out which can increase the possibility of indoor pollutants in preschools located around the areas. Development and construction of amenities, roads and houses has led to increase in the level of atmospheric pollution.

Mold is harmful to human health. It can cause damages on building materials and exposure to mold can also cause health effects. Malaysia is a tropical country with warm and humid climate. There are still limited studies which has related the presence of indoor mold in school environments especially in tropical countries. So far, studies carried out assessed the cause of allergens in settled dust instead of assessing allergen through air sampling (Hussin et al., 2011).

Previous studies (International Study of Asthma and Allergy in Childhood, 2015; European Environment and Health Strategy, 2003) have found an increase in the rate of asthma which is more prominent in the lower middle income countries (Asher et al., 2006). There has been a significant increase in the rate of asthma among children from 3-10% in the year 1990 to 2001 in studies which has been previously conducted in Malaysia. Wheezing symptom has also being found to increase from the rate of 5-8% in children (Quah et al., 2005).

Studies have reported that the exposure to mold in damp buildings is associated with the risk of experiencing health problem, in relation to no clear standard for the concentrations of microorganisms. A study conducted in Singapore on mold exposure has shown an increase in level of allergens in schools compared to homes (Zhang et al., 2006). Therefore, this study will help to provide more information on the existing knowledge on microbial contaminants in the indoor environment.

## 1.5 Study Variable

### 1.5.1 Dependent variable

The dependent variables in this study are respiratory symptoms which includes wheezing, cough, phlegm, chest tightness and lung function status.

### 1.5.2 Independent variable

The independent variable are particulate matter (PM), volatile organic compounds (VOCs) and mold. Physical parameters for Indoor Air Quality status (IAQ) such as temperature, humidity and air velocity were assessed.

## 1.6 Research Objectives

### 1.6.1 General objective

To determine the association between exposures to indoor air pollutants and respiratory health implications among preschool children in selected areas.

### 1.6.2 Specific objective

1) To determine the socio demographic status of preschool children in study areas.
2) To determine the indoor air quality of the preschools in study and comparative area.
3) To identify the different types of mold present in the selected preschools.
4) To compare lung functions (FVC, $FEV_1$, $FEV_1$/FVC) of respondents in the study and comparative area.
5) To compare the presence of respiratory symptoms between the children in the study and comparative area.
6) To determine the association between indoor air pollutants and respiratory health symptoms among preschool children in the study locations.
7) To determine the association between the indoor air pollutants with lung function (FVC, $FEV_1$, $FEV_1$/FVC) among the respondents in the study areas.
8) To identify the main factors that influence indoor air pollutants and respiratory symptoms among study respondents after controlling all the confounders.

## 1.7 Research Hypothesis

1) There is a significant difference in the level of exposure to indoor air pollutants between the study and comparative group.
2) There is a significant difference between the lung functions of the respondents in study group and the comparative group.
3) There is a significant difference between the respiratory symptoms of respondents in the study and the comparative group.
4) There is a significant association between exposure to indoor air pollutants and respiratory symptoms in preschools children in the study and comparative group.
5) There is a significant association between the indoor air pollutants with lung function (FVC, $FEV_1$, $FEV_1$/FVC) among respondents.
6) There is a significant association between the indoor concentration of $PM_{2.5}$, $PM_{10}$, VOC, temperature, relative humidity with respiratory symptoms among study respondents after controlling all the confounders.
7) There is a significant association between the indoor concentration of $PM_{2.5}$, $PM_{10}$, VOC, temperature, relative humidity with lung function among study respondents after controlling all the confounders.

## 1.8 Definition of Variables

### 1.8.1 Conceptual definition

**a) Indoor air quality**

Indoor air quality refers to the air quality of buildings and structures as it relates to the health and comfort of building occupants. The component of indoor air determines the quality of indoor environments in relation to the comfort and wellbeing of occupants. Indoor environment comprises of physical components such as humidity, temperature, velocity; biological components which include virus, fungi, bacteria, spores: and chemical components which include volatile organic compounds, carbon dioxide, formaldehyde, smoke from combustion (Environmental Protection Agency 2015).

**b) Mold**

Mold are group of organisms that belong to the kingdom of fungi and are filamentous in nature. Mold produces airborne spores. These particles are from biological origin, and are usually suspended in the air. They can also be referred to as organic dust. Bioaerosol particles vary in different sizes from below 1 µm to 100 µm in aerodynamic diameter. Mold has being shown to be a major source of indoor air pollution that can cause allergic reactions when they are inhaled by children. Since the presence of mold in the indoor environment is related to various human health symptoms and the indoor environment is a means of exposure, indoor mold has become a concern (Sanchez-Monedero et al., 2008).

**c) Volatile Organic Compounds**

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals; some have short- term while some have long- term adverse health effects. Concentrations of VOCs are usually higher indoors than outdoors. These chemical are emitted from household products such as detergents used for cleaning, paints, plastics (Environmental Protection Agency 2013).

**d) Respiratory Symptoms.**

Respiratory symptoms are symptoms which are experienced after exposure to indoor air pollutants and can last up to 7-10 days. They usually begin 1-3days after the exposure to air pollutants and can last up to 7 to 10 days. These signs include chronic cough, wheezing, shortness of breath and red itchy eyes. (Eccles et al., 2007).

**e) Particulate Matter**

These are complex mixture of small particles and liquid droplets. Particulates have different aerodynamic diameters. $PM_{2.5}$ are referred to as inhalable fine particles. They are coarse in nature with the aerodynamic diameter 2.5um. They are commonly found in smoke and haze. The can cause impaired vision, it can release harmful substances

into the air. When inhaled these particles can penetrate deep into the lung tissues and cause health problems. (USEPA, 2012).

$PM_{10}$ are particles with aerodynamic diameter of 10 micrometers or less. This particle causes a greater health risk among other particulate matter because it can cause damage to the lung tissue and respiratory implications when they are inhaled. It can even go as far down the bloodstream of humans. $PM_{10}$ is known to cause serious health impairment such as decrease in lung function, increase of respiratory symptoms, lung diseases and asthma severity. This particle is produced from activities like grinding and also from roads (USEPA, 2012).

**f) Forced Expiratory Volume in 1 second ($FEV_1$)**

This is the maximum volume of air exhaled in the first second which is as a result of forced expiration and from a position of full inspiration. It is expressed in liters. This test is used in the diagnoses of obstructive lung diseases such as asthma and chronic obstructive pulmonary disease (COPD). There is reduction in $FEV_1$ if there are any forms of obstruction in air flow. Forced Expiratory Volume was performed based on American Thoracic Society standard.

**g) Forced Vital Capacity (FVC)**

This refers to the volume of air that can be forcefully exhaled from the lungs after a maximum inspiration. This is the total amount of air that is exhaled during FEV test. Measuring how well the children can forcefully exhale can be used to detect the presence of any chronic obstructive pulmonary diseases (COPD). It is expressed in liter. There is reduction in FVC if there is restriction in the lung volume or air flow capacity. Forced Vital Capacity was carried out based on the standard set by American Thoracic Society.

**h) $FEV_1$% Predicted**

This is expressed based on the normal value as a percentage of the Forced Expiratory Volume in one second. $FEV_1$% Predicted = ($FEV_1$ measured/ $FEV_1$ Predicted) × 100

**i) FVC% Predicted**

This is expressed based on the normal value as a percentage of the Forced Vital Capacity. FVC% Predicted = (FVC measured/ FVC Predicted) × 100

**h) Wheezing**

This is a whistling sound which is made while inhaling and exhaling. This could be as a result of inflammation in the lungs. Wheezing could be associated with breathlessness and occurs days and nights (Bass 2009).

**i) Chronic Cough**
Cough occurs naturally with the removal mucus when the throat is irritated. Cough becomes chronic when it is consistent and lasts for at least 4days in a week and occurs consecutively for 4 months in a year. Cough occurs when air is released forcefully from the lung. It could be triggered by cold or infection of the sinus (Pubmed article, 2013)

**j) Chest Tightness**
This is a continuous occurrence of cough or phlegm. It causes a sharp pain and ache in the chest. This occurs consecutively for a period of 3 months in a year. It can signify the presence of some diseases in the body (Chen 2014).

**k) Chronic Phlegm**
This occurs when there is persistent release of mucus which usually coughs up from the chest and occurs for at least 4days in a week and occurs consecutively for 3 months in a year (Phlegm 2007).

## 1.9 Operational Definition

**a) Particulate Matter ($PM_{2.5}$ and$PM_{10}$)**
Indoor air quality assessment was carried out by measuring the indoor environmental level of $PM_{2.5}$ and $PM_{10}$. Indoor assessment of particulate matter was measured using TSI DustTrak$^{TM}$ DRX Aerosol Monitor 8534. This instrument detects aerosol concentration between the ranges of 0.001 to 150 mg/m$^3$. The aerosol particles are isolated in the optic chamber using the sheath air system (USEPA, 2012).

**b) Volatile Organic Compounds (VOCs)**
Volatile Organic Compound is one of the indoor parameter which influences the growth of bioaerosol in indoor environment. In this study, concentration of Volatile Organic Compound was measured using ppbRAE Volatile Organic Compound (VOC) Monitor (Model PGM-7240) which is a sensitive photo-ionization Detector (PID) for real-time monitoring of volatile organic compounds (VOCs) at part per billion (ppb) levels. Data was downloaded using the proRAE Remote software (USEPA, 2013).

**c) Indoor mold**
Measurement of mold was conducted using DuoSAS Super 360 microbiological air sampler by collecting air samples into petri dishes containing agar medium, 200 volumes of air sample for 2 minutes was used during sampling. The petri dishes was sealed with parafilm for transportation to the laboratory. The samples was incubated and analysis was carried out. The media that was used is Sabaroud Dextrose Agar (SDA) for investigating total fungi. The colonies was identified through their specific colour, turbidity or other characteristics that appear when cultured on selective media (Sanchez-Monedero et al., 2008).

**d) Temperature and Relative Humidity**

This was measured using TSI Q-Trak plus Indoor Air Quality Monitor 8554. This equipment has a sensor type thermistor and measures the ranges of 0 to $50^0$C. The sensor is made up of type thin-film capacity which can detect 5 to 95% relative humidity. It uses the principle of detection of a wet bulb and dry bulb to compares the humidity ratio and absolute humidity to measure the level of RH in indoor environment (USEPA, 2013).

**e) Respiratory symptoms**

Respiratory symptoms of respondents in this study was determined using a questionnaire on respiratory health symptoms adapted from American Thoracic Society (ATS). Examples of respiratory symptoms are coughing, wheezing, phlegm (American Thoracic Society).

**f) Forced Vital Capacity (FVC)**

Lung function test was assessed based on the American Thoracic Society (ATS) standard to determine the forced vital capacity level of the respondents using a spirometer. This is expressed in liters at body temperature. (American Thoracic Society 2005).

**g) Forced expiratory volume ($FEV_1$)**

This was assessed based on the ATS standard 1994 to determine the forced expiratory volume level of the respondents using a spirometer. Forced vital capacity is expressed in liters (American Thoracic Society 2005)

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