



**UNIVERSITI PUTRA MALAYSIA**

***ASSOCIATION BETWEEN INDOOR PM<sub>2.5</sub> AND NO<sub>2</sub> WITH AIRWAY  
INFLAMMATION AMONG PRESCHOOL CHILDREN AT INDUSTRIAL  
AND SUB-URBAN AREAS***

**NOOR HISYAM NOOR HASSIM**

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**NOOR HISYAM BIN NOOR HASSIM**

**DEPARTMENT OF ENVIRONMENTAL AND OCCUPATIONAL HEALTH  
FACULTY OF MEDICINE AND HEALTH SCIENCES  
UNIVERSITI PUTRA MALAYSIA  
SERDANG, SELANGOR**

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INFLAMMATION AMONG PRESCHOOL  
CHILDREN AT INDUSTRIAL AND  
SUB-URBAN AREAS.**

I declare that the thesis is my original work and that all sources which have been used are fully acknowledged.



NOOR HISYAM BIN NOOR HASSIM

MATRIC NO: 158775

25<sup>th</sup> MAY 2014

**NOOR HISYAM BIN NOOR HASSIM**

**This thesis submitted in fulfilment of the requirement for the degree of Bachelor Science  
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Sciences, University Putra Malaysia**

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## ABSTRACT

### ASSOCIATION BETWEEN INDOOR PM<sub>2.5</sub> AND NO<sub>2</sub> WITH AIRWAY INFLAMMATION AMONG PRESCHOOL CHILDREN AT INDUSTRIAL AND SUB-URBAN AREAS.

Noor Hisyam Noor Hassim

**Introduction:** Indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) have been known to pose great risks to the human respiratory system. A slight airway inflammatory response in the adult might produce a potentially significant obstruction in the airway of a preschool child. The main objective of this study is to determine the association between indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) and airway inflammation among preschool children. **Methodology:** A cross sectional comparative study was conducted among healthy preschool children selected from 3 preschools in industrial (n=62) and 3 preschools in sub-urban (n=62) areas. Questionnaires were used to determine reported respiratory symptoms among respondents. Indoor PM<sub>2.5</sub> and NO<sub>2</sub> exposure in classes were measured using Dustrak DRX Aerosol Monitor and LaMotte Air Sampler. Meanwhile, Fractional exhaled Nitric Oxide (FeNO) was measured using NIOX MINO device. **Results:** There were significant differences ( $p < 0.05$ ) in measurements of indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) between both study areas. Concentration of indoor PM<sub>2.5</sub> [75.0 (47.0)  $\mu\text{g}/\text{m}^3$ ] and NO<sub>2</sub> [0.14 (0.14) ppm] in preschools at industrial area were significantly higher than the preschools at sub-urban area ( $Z = -8.517$ ,  $p = 0.001$ ). A significant difference ( $p < 0.05$ ) was found in measurements between the two areas. Indoor PM<sub>2.5</sub> and NO<sub>2</sub> were found to be significantly associated with the concentration levels of Fractional exhaled Nitric Oxide (FeNO) measured in both areas ( $p < 0.05$ ). **Conclusion:** Preschool children in industrial area are highly exposed to indoor air pollutants as compared to those in the sub-urban area. Exposure to indoor PM<sub>2.5</sub> and NO<sub>2</sub> were associated with concentration levels of Fractional exhaled Nitric Oxide in both areas. Therefore, it was suggested that greater exposure to PM<sub>2.5</sub> and NO<sub>2</sub> may increase the chances of airway inflammation occurrences among those exposed.

**Keywords:** FeNO, indoor air pollutants, NIOX MINO, respiratory symptoms, and preschool

## ABSTRAK

### HUBUNGKAIT ANTARA PM<sub>2.5</sub> DAN NO<sub>2</sub> DALAMAN DENGAN RADANG PARU-PARU DALAM KALANGAN KANAK-KANAK TADIKA DI KAWASAN INDUSTRI DAN PINGGIR BANDAR.

Noor Hisyam Noor Hassim

**Pengenalan:** Bahan pencemar udara dalaman (PM<sub>2.5</sub> dan NO<sub>2</sub>) boleh memberi kesan yang buruk kepada sistem pernafasan manusia. Respons radang yang sedikit pada saluran udara pernafasan orang dewasa mungkin menghasilkan kesan obstruktif yang ketara pada saluran udara pernafasan kanak-kanak prasekolah. Objektif utama kajian ini adalah untuk menentukan hubungan antara bahan pencemar udara dalaman (PM<sub>2.5</sub> dan NO<sub>2</sub>) dan keradangan saluran pernafasan udara dalam kalangan kanak-kanak prasekolah. **Metodologi:** Satu kajian keratan rentas perbandingan telah dijalankan dalam kalangan kanak-kanak prasekolah yang sihat yang dipilih dari 3 buah tabika di kawasan industri (n=62) dan 3 buah tabika (n = 62) di kawasan pinggir bandar. Borang soal selidik telah digunakan untuk menentukan laporan simptom pernafasan dalam kalangan responden. Pendedahan PM<sub>2.5</sub> dan NO<sub>2</sub> dalam persekitaran kelas diukur dengan menggunakan 'Dustrak DRX Aerosol Monitor' dan 'Lamotte Air Sampler'. Sementara itu, pecahan hembusan nitrik oksida (FeNO) disukat dengan menggunakan alat peranti NIOX MINO. **Hasil Kajian:** Terdapat perbezaan yang signifikan ( $p < 0.05$ ) dalam ukuran bahan pencemar udara dalaman (PM<sub>2.5</sub> dan NO<sub>2</sub>) di antara kedua-dua kawasan kajian. Paras PM<sub>2.5</sub> [75.0 (47.0)  $\mu\text{g}/\text{m}^3$ ] dan NO<sub>2</sub> [0.14 (0.14) ppm] dalaman di prasekolah kawasan perindustrian adalah lebih tinggi daripada paras di prasekolah kawasan pinggir bandar ( $Z = -8.517$ ,  $p = 0.001$ ). Ini menunjukkan perbezaan yang signifikan ( $p < 0.05$ ) dalam ukuran antara kedua-dua kawasan. PM<sub>2.5</sub> dan NO<sub>2</sub> dalaman juga didapati mempunyai perkaitan yang signifikan dengan paras pecahan hembusan nitrik oksida (FeNO) yang diukur pada kanak-kanak prasekolah di kedua-dua kawasan tersebut ( $p < 0.05$ ). **Kesimpulan:** Kanak-kanak prasekolah di kawasan industri terdedah kepada pencemaran udara dalaman dengan paras yang sangat tinggi berbanding dengan mereka yang berada di kawasan pinggir bandar. Pendedahan kepada PM<sub>2.5</sub> dan NO<sub>2</sub> dalaman juga dikaitkan dengan paras pecahan hembusan nitrik oksida (FeNO) oleh kanak-kanak prasekolah di kedua-dua kawasan. Oleh itu, adalah dicadangkan bahawa pendedahan yang lebih tinggi terhadap PM<sub>2.5</sub> dan NO<sub>2</sub> boleh meningkatkan peluang untuk terjadinya radang saluran udara pernafasan dalam kalangan mereka yang terdedah.

**Kata kunci:** FeNO, pencemar udara dalaman, NIOX MINO, simptom pernafasan, dan tabika

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## LIST OF ABBREVIATIONS

|                   |  |
|-------------------|--|
| ATS               | American Thoracic Society  |
| DOE               | Department of Environment  |
| DOSH              | Department of Occupational Safety and Health                       |
| ERS               | European Respiratory Society                                       |
| ICOP              | Industrial Code of Practice on Indoor Air Quality                  |
| IAQ               | Indoor Air Quality   |
| ppm               | Part per million   |
| ppb               | Part per billion   |
| PM                | Particulate Matter   |
| PM <sub>2.5</sub> | Particulate Matter less or equal to 2.5 um in aerodynamic diameter |
| CO <sub>2</sub>   | Carbon dioxide   |
| CO                | Carbon Monoxide  |
| MAAQS             | Malaysian Ambient Air Quality Standard                             |
| SPSS              | Statistical Packages for Social Sciences                           |
| USEPA             | United States Environmental Protection Agency                      |
| WHO               | World Health Organization  |

## CHAPTER 1

### INTRODUCTION

#### 1.1 Background

Epidemiological and toxicological studies have been conducted worldwide in order to indicate the association between air pollution and its effects on human respiratory health (Samet & Krewski, 2007). As we spend most of our time indoors, it can be much polluted with pollution levels that are higher than the outdoors especially in an environment of poor ventilation filled with things such as consumer products, gas appliances, cigarettes, and furniture (Hoskins, 2011).

In developing countries, an approximately of 2 million premature deaths is caused by the indoor air pollution in which half of it are due to pneumonia in children under 5 years of age.

Meanwhile, an estimation of 1.3 million deaths worldwide per year is caused by the outdoor pollution (WHO, 2011)

The quality of indoor air can be affected by numerous sources of indoor air pollutants. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution (U.S. EPA, 2013).

Many studies have been done to associate the adverse health effects in children with the exposure towards certain air pollutants where it can be either acute or chronic health effects (Schwartz, 2004). Common health problems that are usually associated with poor indoor air quality include allergic reactions, respiratory problem, sinusitis, bronchitis, and pneumonia (DOSH, 2010). In addition, there are also studies that relate airway inflammation as an indicator and feature for allergic rhinitis, asthma, and chronic obstructive pulmonary disease (Kevin *et al.*, 2009; Peter & Tari, 2006; Sutherland & Richard, 2003).

Within the last two decades, exposure to air pollutants in the indoor environments has been recognised as potential significance for child's health (Kirk *et al.*, 2000). In similar environments, the air pollutants health impact is much higher for children than for adults (WHO, 2005). Even though there is no definitive proof exists, due to more diverse activities as well as immune system and bodies that are less mature, the preschool students are assumed to be more vulnerable towards reduced IAQ than elementary or middle school students (Chungsik *et al.*, 2011).

## 1.2 Problem Statement

Preschool is mainly the first place for social activities among children where they spend around 5-7 hours per day for 5 days in a week. While some extra hours may depends on the time that they arrive and the time they leave the preschool, they may be exposed to diverse pollutants that might cause increases in the risk of allergies and asthma.

Numerous studies have found associations between selected air pollutants and adverse health effects in children in which it include childhood hospital admission, school absences, physician visits for upper and lower respiratory illness, deficits in lung function growth rates, bronchitis and chronic cough, and increased infant mortality (Barnett *et al.*, 2005). Health effects from indoor air pollutants may be experienced soon after exposure (acute) or possibly years later (chronic). Immediate effects or also known as acute effects may become evident after a single

exposure or repeated exposure. These include irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue. Such immediate effects are usually short-term and treatable. If it can be identified, sometimes the treatment is simply eliminating the person's exposure to the source of the pollution. Symptoms of some diseases, including asthma, hypersensitivity pneumonitis, and humidifier fever, may also appear soon after exposure to certain types of indoor air pollutants. Meanwhile, long-term effects or also known as chronic effects may become evident either after years of exposure or only after long or repeated periods of exposure. These effects, which include some respiratory diseases, heart disease, and cancer, can be severely debilitating or fatal. Even if the symptoms are not noticeable, it is advisable to try to improve the indoor air quality in home (U.S. EPA, 2013). Local studies also found that poor indoor air quality is associated with the prevalence of respiratory symptoms among the preschool children.

### 1.3 Study Justification

Previous study conducted in Balakong by Nur Azwani, *et al.* (2013) found that the concentration levels of indoor PM<sub>2.5</sub> at the preschools within the area are highly above the international standard guidelines set by the World Health Organization and the U.S Environmental Protection Agency. Another study conducted by Nazariah, *et al.* (2013) also found that the indoor concentration levels of PM<sub>2.5</sub> are significantly higher in primary schools located in urban area as compared to rural primary schools. Therefore, children are really at high risk due to the exposure that they have.

Children are more sensitive than adults towards exposure to air quality as their bodies are still in developing process which puts them in a susceptible group of a population. The effect of environmental may interrupt the growth of their lung function and immune systems (Gordon, 2004). They breathe more air in proportion to their weight than adults, and in the case of very young children, they spend proportionally more time indoors (Schwartz, 2004). Due to higher heart rate than adults, every substance that is absorbed into the blood of a child body will permeate tissue faster (Flynn *et al.*, 2000). Since children have narrower airways than adults do, irritation caused by air pollution that would produce only a small response in an adult can result in potentially significant obstruction in the airways of a young child (WHO, 2008).

### 1.3 Study Justification

The purpose of this study is to determine the airway inflammation among preschool children in preschools located in industrial area and sub-urban area towards exposure to  $PM_{2.5}$  and  $NO_2$ . This study will also compare the concentration levels of those indoor air pollutants between the two studied areas as well as how does it affect the airway inflammation among preschoolers.

This study can be counted as one of the primary prevention as it focuses more on early disease prevention in which the study subjects chosen are the preschool children. As have been mentioned in the problem statement section, preschool children are considered as one of the

susceptible groups prior to exposure towards any air pollution. Due to their bodies and organs that are still in a developing process as well as their immune system that are still weak, they are highly susceptible to any airborne diseases and air pollutants especially the ones that are related with air pollution such as PM<sub>2.5</sub> and NO<sub>2</sub>.

Preschool children are advantageous to be studied especially when the study conducted is related with respiratory symptoms and air pollution. This is because they are unlikely to smoke cigarettes regularly or even smoke, they have no serious exposure to occupational pollutants, they have stable residential history, and their respiratory system seems to be more sensitive to air pollution.

The preschool children usually live within the same area to their attended preschools, and they attend it five days a week from 8 a.m. to 12 p.m. which is within 4-5 hours depending on the time that their parents will be taking them back home. Since they only rely on their parents for their transportation, they are virtually area bounded during the day which limits the exposure experienced by them towards that particular residential area's pollution profile.

Many researchers have found that the concentration of indoor pollutants is much higher than the outdoors as well as how well the outdoor pollutants' concentration can penetrate through and affect the indoor environment. Therefore, the selection of research location is based on the

indoor and outdoor activities that may contribute to the indoor pollutant concentrations in the preschools. Moreover, there are very limited numbers of studies that have been conducted relate the indoor air pollutant with the health impacts of preschool children in Malaysia.

The selection of preschools in industrial area as a studied group are due to the fact that the emissions from the industries within the area will affect the ambient air pollution in which it will also contribute to the concentration of the indoor air pollutants of the preschools. Thus, it will affect the preschoolers' respiratory health. Meanwhile, preschools in sub-urban area are chosen as the comparative group.

This study will indirectly help to increase the level of awareness of the community about the risk of exposure towards the indoor air pollutants that are experienced by the preschoolers. Parents will be informed about the risk of adverse health effects that may affect their young children due to the exposure with certain concentration of indoor air pollutants, mainly in this study refers to  $PM_{2.5}$  and  $NO_2$ . Ways and recommendations on how to minimize the exposure and improve the indoor air quality will be educated to the parents and teachers. The outcome of this study will also be addressed to the preschools management and the public especially those parents who are sending their children to the preschools within the study location.

## 1.4 Conceptual Framework

As shown in the figure 1.1, there are many types of indoor air pollutants in air, such as  $PM_{10}$ ,  $PM_{2.5}$ ,  $PM_1$ ,  $NO_2$ , and  $SO_2$ . However, this study only focuses on  $PM_{2.5}$  and  $NO_2$  that exists within the industrial and the sub-urban areas. These pollutants may pose significant health threats to the two groups of population; it's either the workers or the public population. This study will be focusing on the public population where it consists of susceptible groups which may received the greatest impacts due to the exposure of the pollutants through inhalation. These susceptible groups consist of pregnant women, preschool children, and elderly people.

Apparently, this study will be focusing on the effect of the exposure of the pollutants towards the preschool children only. Due to the exposures, it may or may not cause them to develop certain kinds of respiratory symptoms or illnesses. However, the main focus will be on the airway inflammation which is the main characteristic of some respiratory diseases such as asthma, allergic rhinitis, chronic obstructive pulmonary disease (COPD), and respiratory infection.

There are four contributing factors that have been identified which may contribute to the concentration levels of the indoor air pollutants in this study. It includes air velocity, location of the preschools, outdoor pollution, and temperature. Meanwhile, the confounders of this study

which may affect the outcome of airway inflammation among the study subjects are their age, gender, nutritional status, smoking, and socioeconomic status (SES).

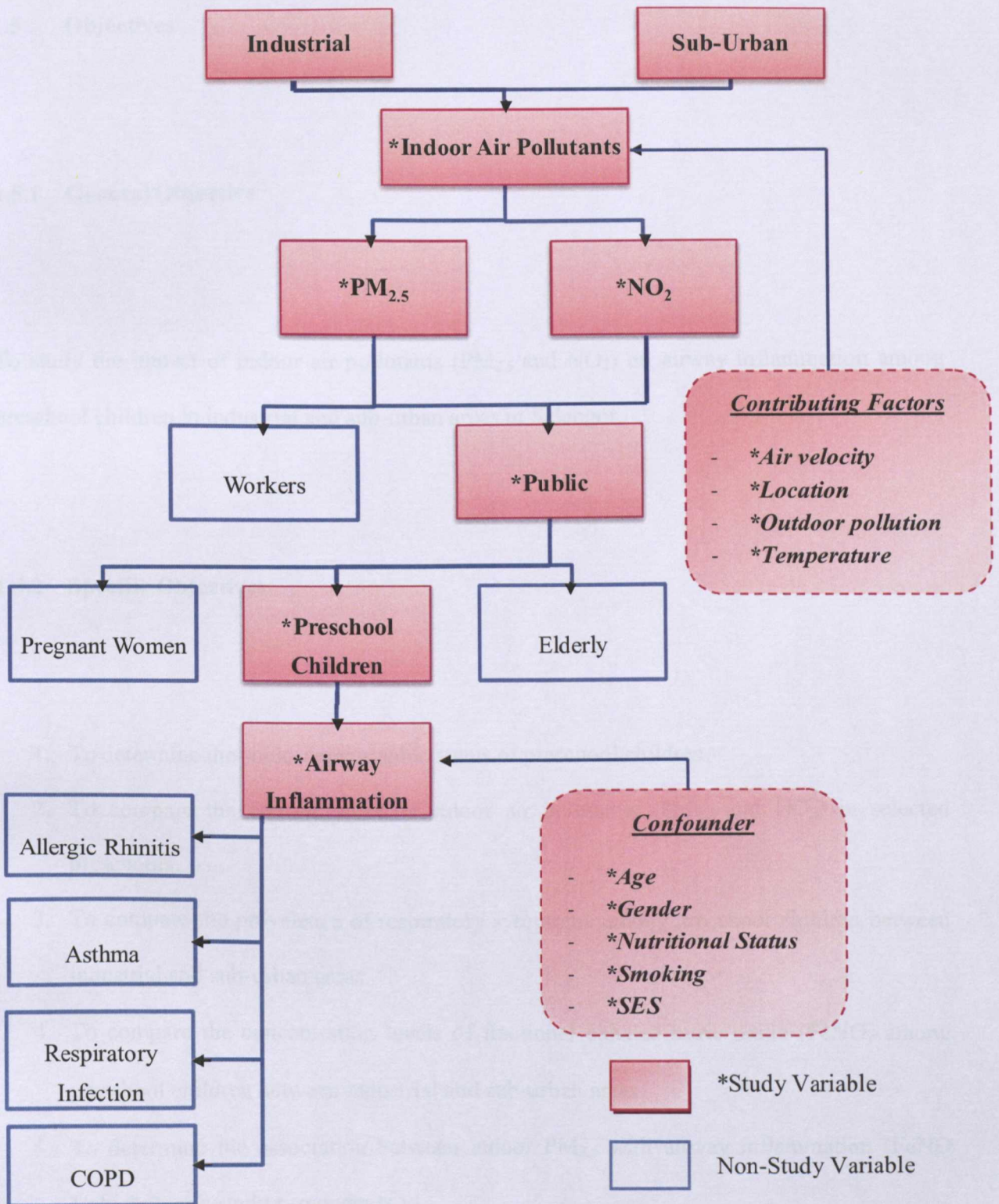


Figure 1.1: Conceptual Framework

## 1.5 Objectives

### 1.5.1 General Objective

To study the impact of indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) on airway inflammation among preschool children in industrial and sub-urban areas in Selangor.

### 1.5.2 Specific Objectives

1. To determine the socio-demographic status of preschool children.
2. To compare the concentration of indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) in selected preschools.
3. To compare the prevalence of respiratory symptoms among preschool children between industrial and sub-urban areas.
4. To compare the concentration levels of fractional exhaled nitric oxide (FeNO) among preschool children between industrial and sub-urban areas.
5. To determine the association between indoor PM<sub>2.5</sub> with airway inflammation (FeNO Value) among study respondents.

6. To determine the association between indoor  $\text{NO}_2$  with airway inflammation (FeNO Value) among study respondents.

## 1.6 Hypotheses

1. The indoor air pollutant concentrations ( $\text{PM}_{2.5}$  and  $\text{NO}_2$ ) are significantly higher in the industrial area's preschools as compared to the sub-urban area's preschools.
2. The prevalence of respiratory symptoms among preschool children is significantly higher among those in the industrial area than those in the sub-urban area.
3. The concentration levels of fractional exhaled nitric oxide (FeNO) of the preschool children in the industrial area are significantly higher than the preschool children in the sub-urban area.
4. There is a significant association between indoor  $\text{PM}_{2.5}$  with airway inflammation (FeNO Value) among study respondents.
5. There is a significant association between indoor  $\text{NO}_2$  with airway inflammation (FeNO Value) among study respondents.

## 1.7 Study Variables

The independent variables of this study are exposure to  $PM_{2.5}$  and  $NO_2$  while the dependent variable is the airway inflammation among preschool children in both preschools located in industrial and sub-urban areas.

## 1.8 Definition of Variables

### 1.8.1 Conceptual Definition

#### a) Particulate Matter $_{2.5}$ ( $PM_{2.5}$ )

$PM_{2.5}$  is particles with an aerodynamic diameter of 2.5 microns or less, also known as fine fraction particles. It can remain in the atmosphere for days to weeks and travel through the atmosphere hundreds to thousands of kilometres (U.S. EPA, 2012).

## **b) Nitrogen Dioxide (NO<sub>2</sub>)**

NO<sub>2</sub> is one of a group of highly reactive gasses known as "oxides of nitrogen," or "nitrogen oxides (NO<sub>x</sub>). It forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment (U.S. EPA, 2013)

## **c) Airway Inflammation**

Airway inflammation is defined by infiltration of the airway by inflammatory cells including eosinophils, mast cell, monocytes, lymphocytes, active complement fragments (C3a and C5a), and neutrophils, which contribute to elevated levels of inflammatory mediators and procontractile stimulants (Khan, 2013).

## **d) Fractional Exhaled Nitric Oxide (FeNO)**

Fractional exhaled nitric oxide is considered as a non-invasive marker of airway inflammation (Olin *et al.*, 2010; Flamant-Hulin *et al.*, 2010). It refers to the concentration levels of nitric oxide (NO) that are released from epithelial cells of the bronchial wall (Van Den Toorn *et al.*, 2001).

### 1.8.2 Operational Definition

#### a) Particulate Matter <sub>2.5</sub> (PM<sub>2.5</sub>)

The presence of PM<sub>2.5</sub> was measured using TSI DustTrak™ DRX Aerosol Monitor 8523. It can simultaneously measure both mass and size fraction concentrations corresponding to PM<sub>1</sub>, PM<sub>2.5</sub>, and PM<sub>10</sub>. It applies light-scattering laser photometer that gives real-time aerosol mass readings. It uses a sheath air system that isolates the aerosol in the optics chamber to keep the optics clean for improved reliability and low maintenance. The concentration of PM<sub>2.5</sub> was measured in  $\mu\text{g}/\text{m}^3$ .

#### b) Nitrogen Dioxide (NO<sub>2</sub>)

The presence of NO<sub>2</sub> was assessed using LaMotte Portable Air Sampling Pump. The sampling pump was used along with Nitrogen Dioxide in Air Test Kit in which the portable vacuum pump drew precise volumes of air through an absorbing solution in a special bubbling tube (impinger) at a constant flow rate between 0 and 2.0 litres per minute. After few treatments with Nitrogen Dioxide Reagents, the resulting colour reaction was measured in an Octet Comparator for results in parts per million (ppm).

### **c) Airway Inflammation**

Airway inflammation was identified using NIOX MINO<sup>®</sup> which is a device designed to measure the fractional exhaled nitric oxide (FeNO) that acts as a marker or indicator for the airway inflammation. Airway inflammation acts as an indicator or a feature for other respiratory problems such as asthma, chronic obstructive pulmonary disease (COPD), and respiratory infection.

### **d) Fractional Exhaled Nitric Oxide (FeNO)**

Fractional exhaled nitric oxide (FeNO) was measured using NIOX MINO<sup>®</sup>. It is a device designed to measure the airway inflammation through the measurement of concentration levels of nitric oxide (NO) in an exhaled breath (FeNO) of the user. In this study, the respondents fully exhaled for 6 seconds for the NIOX MINO<sup>®</sup> to measure the concentration levels of NO in parts per billion (ppb) of their exhaled breath. The concentration levels of FeNO obtained were then compared with American Thoracic Society (ATS) guideline in clinical interpretation of FeNO.

### **e) Industrial Area**

Industrial area refers designated area as approved or gazetted by the local authority for the purpose of siting industrial, manufacturing or processing plants, factories or facilities (DOE, 2007). It also refers to area that has presence of warehouses, and distribution centres as well as manufacturing establishment (Bale, 1974). Any preschool located within 5km radius of this area

will be considered as preschool within the industrial area. Therefore, three preschools located within the 5km radius of Puchong Industrial Park, Selangor, were selected.

#### **f) Sub-Urban Area**

Sub-urban area refers to refer either to an outlying residential area of a city or town or to a separate municipality, borough, or unincorporated area outside a town or city (Rusk, 2010). It is also refers to the smaller urban areas that surround cities (National Geographic, 2013). Semenyih and Serdang are located adjacent to the city of Kuala Lumpur. Therefore, three preschools located within these areas were selected as preschools in the sub-urban area.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Indoor Air Quality (IAQ)

Indoor air quality acts as one of the most important role in our life as we spend most of our times indoor compared to outdoor. Outdoor pollution, ventilation equipment, furnishings, as well as human activities affect the indoor air quality. In industrialised countries, people spend over 80% of their time inside home, school, and office (Wiley, 1991) while the young children spend 60-80% of their time indoors on average school day, and they may be heavily exposed to indoor air pollutants (Gomzi, 1999). There are many situations in day care which may expose individuals to contaminants (WHO, 2010).

The sources of indoor air pollutants are widely range and among the common ones are environmental tobacco smoke (ETS) that is emitted due to the burning of tobacco products,

various chemical substances such as formaldehyde emitted from furnishings, volatile organic compounds emitted from the use and application of solvents, and ozone emitted from photocopiers and laser printers. Therefore, good indoor air quality is a need for a healthy indoor environment as poor indoor air quality can cause many types of short-term and long-term health implications (DOSH, 2010).

## 2.1 Indoor Air Pollutants and Respiratory Health Effects

Globally, indoor exposure to air pollutants causes very serious damage to human health especially in developing countries. Even so, public health awareness on indoor air pollution has slacked behind that on outdoor air pollution. Indoor air is very important because people spend a substantial proportion of their time in buildings. In residences, day-care centres, retirement homes and other special environments, indoor air pollution affects population groups that are particularly vulnerable owing to their health status or age (WHO, 2010).

Common indoor air pollutants that have already been known or suspected for its health effects on the prevalence of respiratory symptoms in children and adults include particulate matter of three size fractions ( $PM_{10}$ ,  $PM_{2.5-10}$ , and  $PM_{2.5}$ ), sulphur dioxide ( $SO_2$ ), nitrogen dioxide ( $NO_2$ ), formaldehyde (HCHO), and carbon monoxide (CO) (Yeatts *et al.*, 2012). Sources for these pollutants could be from heating and cooking activities, tobacco smoke, and

auto, truck, or bus exhaust from attached garages, nearby roads, or parking areas (U.S EPA, 2013).

Occurrences of high level of air pollution in industrial and urbanized areas have made people to focus their attention to the quality of air that they breathe and relate it with environmental health (Burroughs & Hansen, 2004).

## **2.2 Children Respiratory System and Deposition of Air Pollutants**

The respiratory system is made up of the organs and tissues that help our human breathing processes. It is responsible in any gas interchanges process of a human, and it consists of the nose, pharynx, larynx, trachea, bronchi, and lungs. Respiratory tract can be divided into two, which are the upper and the lower respiratory tract. The upper respiratory tract is made up of nose, nasal cavity and sinuses (ethmoid, frontal, maxillary, and sphenoid). Meanwhile, the lower respiratory tract is made up of larynx, trachea, lungs, airways (bronchi and bronchioles), and air sacs (alveoli). It is a series of organs responsible for taking in oxygen and expelling carbon dioxide. These processes supply human body with adequate amount of oxygen for the cells and remove any waste product of the body cells in the form of gases and droplets. The lungs are a pair of cone-shaped organs made up of spongy, pinkish-gray tissue and they are

located inside the thorax as well as covering most of the space in the chest (Sherwood, 2007).  
 (Refer Figure 2.1)

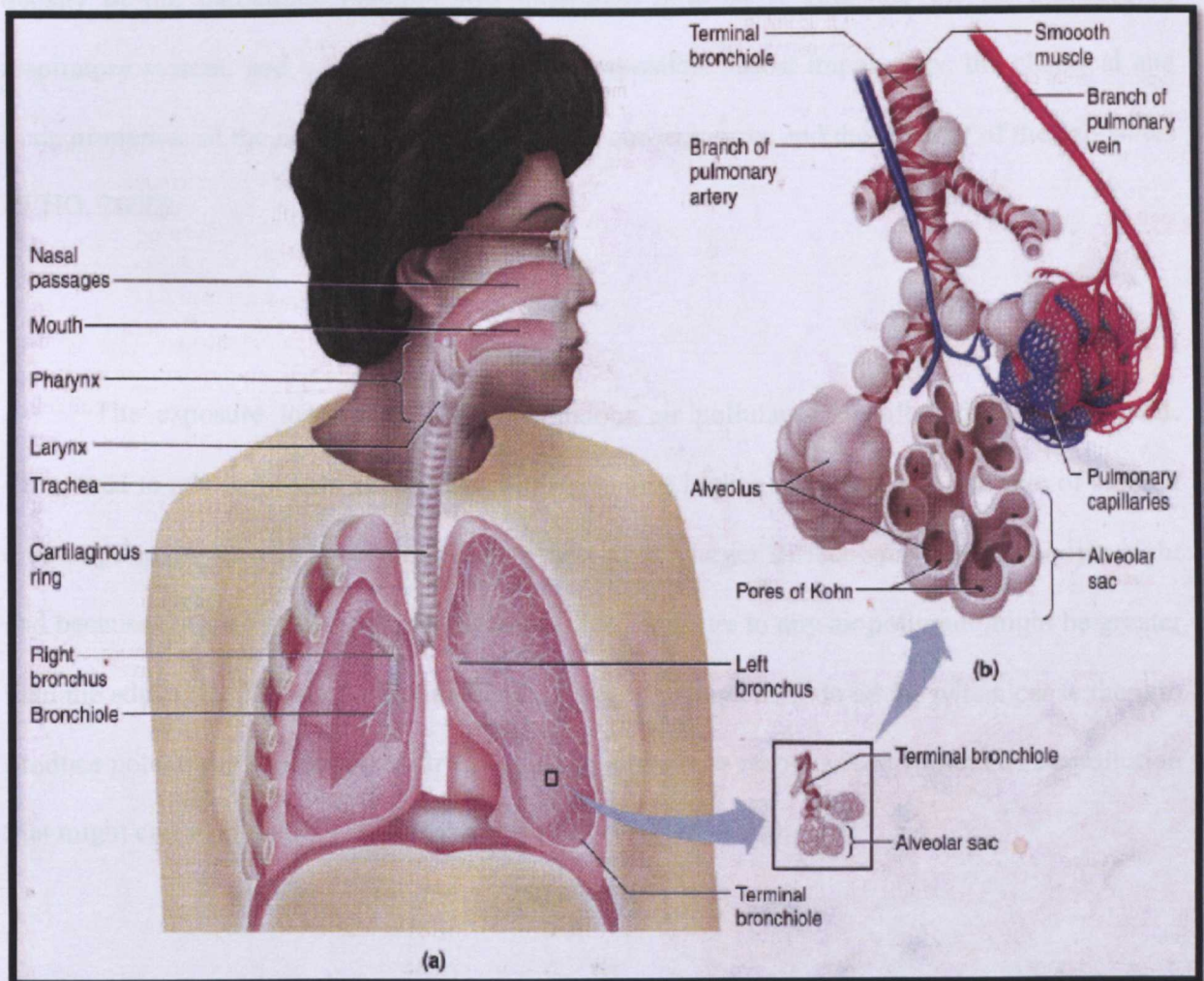


Figure 2.1: Human Respiratory System

(Source: Sherwood, L., The Respiratory System, In: Human Physiology, Thomson Brooks/Cole, United Kingdom, 453, 6<sup>th</sup> Ed, (2007))

In of exposure to air pollutants, inhalation is the most important route of entry. Each time these particles are in the air, the chance of inhaling them are always there. The size, shape, and density of the particulate material will determine how far it gets into the air passages of respiratory system, and what it does once it is deposited. Most importantly, the chemical and toxic properties of the material will determine the consequences and the severity of the exposures (WHO, 2008).

The exposure towards outdoor and indoor air pollutants are often difficult to avoid. Compared to adults, infants and young children have a higher metabolic rate and rate of oxygen consumption per unit body weight because they have a larger surface area per unit body weight and because they are growing rapidly. Hence, their exposure to any air pollutant might be greater than the adults. Besides that, children have narrower airways than do adults which cause them to produce potentially significant obstruction in the airways as response to irritation of air pollution that might cause only slight response in the adults (WHO, 2008).

The deposition of particulate pollutants into the lungs is necessary before particles can travel through the mucus into the lung tissue. Three mechanisms are involved in the process of particulate's deposition, which are diffusion, sedimentation, and impaction. Deposition by diffusion is caused by Brownian motion, and it is the mechanism for small particles ( $<0.5\mu\text{m}$ ) due to collision with air molecules. The particle may move across the streamline and deposit upon contact with the airway wall. Meanwhile, sedimentation is caused by the dominating

gravitational force acting on the inhaled particles (sized  $\geq 0.5 \mu\text{m}$ ) over the air resistance which then caused the particle to deposit on the lower surface of the airway. Impaction is where the large-sized particles ( $>1 \mu\text{m}$ ) with great momentum that simply do not follow the curvature of the air stream due to inertia and deposit on the airway wall (Hussain *et al.*, 2011).

Particulate matters (PM) are divided into three classes based on its size; there are coarse, fine, and ultrafine particles. Firstly, coarse particulate matter consists of particles with a diameter between 2.5 and 10 micrometers and deposit efficiently along the airways while particles larger than 10 micrometers are generally not inhalable into the lungs. Secondly, fine particulate matter consists of particles with a diameter of less than 2.5 micrometers and can be inhaled deeply into the lungs and may reach terminal bronchioles and alveoli. Lastly, the smallest of its classes, the ultrafine particles consist of particles with a diameter of smaller than 0.1 micrometers and have widespread deposition within the respiratory tract (U.S. EPA, 2012). Particle size is the determinant factor in the deposition of particles in the lung. Fine particles can remain suspended in the atmosphere for longer periods and transported over longer distances than large particles. It is also believed that fine particles have stronger respiratory effects in children than large particles (WHO, 2008) (Figure 2.2).

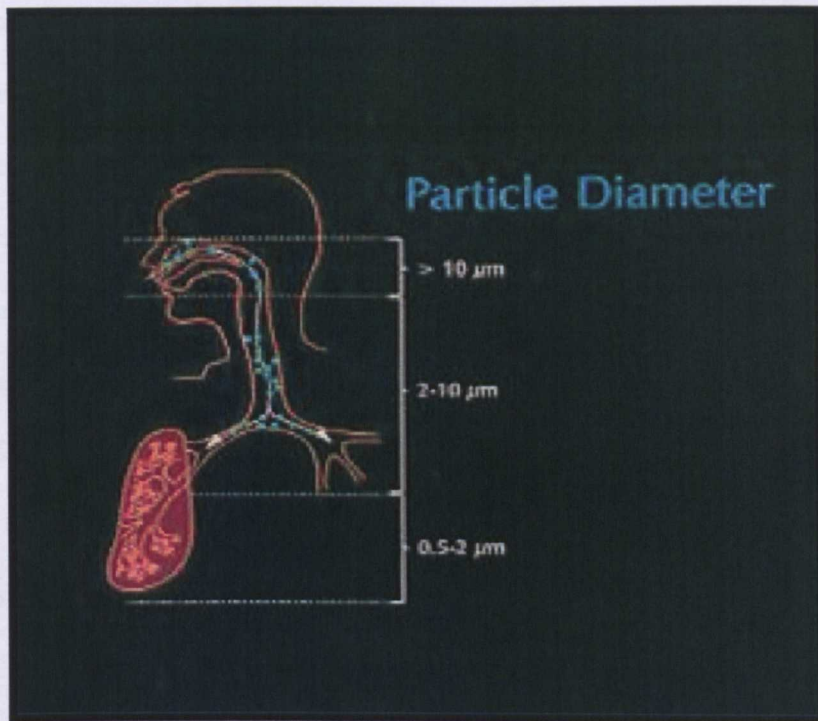


Figure 2.2: Particles deposition in the lungs according to its diameter size.

(Source: Children's Health and the Environment, Indoor Air Pollution, WHO, 2008)

### 2.3 $\text{PM}_{2.5}$ and Respiratory Health Effects

$\text{PM}_{2.5}$  is also referred as fine particles; it has a diameter of 2.5 micrometers or smaller. The sources of these particulates can be divided into two groups which are natural source and anthropogenic source (man-made). However, anthropogenic source is the main concern for the production of  $\text{PM}_{2.5}$  in our environment. The examples of anthropogenic sources that release  $\text{PM}_{2.5}$  are motor vehicles, diesel locomotives, coal- and oil-fired power plants, open burning,

woodstoves and fireplaces, and some industrial processes. It also present in smoke and haze. These particles come in various sizes and shapes and can be made up of hundreds of different chemicals. There are two types of particles which are primary and secondary particles. Primary particles are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Meanwhile, secondary particles are others form in complicated reactions in the atmosphere of chemicals such as sulphur dioxides and nitrogen oxides that are emitted from power plants, industries, and automobiles. Because of their small size (less than one-seventh the average width of a human hair), fine particles can lodge deeply into the lungs and are believed to pose the largest health risks (U.S. EPA, 2013).

#### The Effects of PM<sub>2.5</sub>

Due to the small size of PM<sub>2.5</sub> particles, it can evade our human body's natural defense mechanisms and penetrate deep into the lung tissue. The particles will be transported into the lower pulmonary system and will be deposited there. It may then either being retained or cleared from the respiratory system. Clearance of the deposited particles at the upper and middle regions of the respiratory tract in a healthy person occurs within less than a day, while clearance from the pulmonary region where gas exchange process occurs might take weeks to months. This means that the PM<sub>2.5</sub> particles are in contact with sensitive tissues for longer times than the particles that are trapped in the upper and middle regions of the respiratory tract due to its slow clearance rate mechanism (Godish, 1997). Many studies have been conducted to associate these fine particles (PM<sub>2.5</sub>) with airway inflammation of study subjects.

A study done by Frank Schaumann, *et al.*, (2004) found that PM<sub>2.5</sub> triggered distinct airway inflammation in healthy subjects with a selective influx of monocytes and increased generation of oxidant radicals. Another study also supported that these particles of air pollutant plays its role in increased lung inflammation of children, especially those with asthma (Fischer *et al.*, 2002). In addition, other study published in 2008 also found that increased in the concentration levels of PM<sub>2.5</sub> was associated with increased airway inflammation as well as decreased lung function of school children (Barraza-Villareal *et al.*, 2008). The most recent studies conducted locally also found that the high concentration levels PM<sub>2.5</sub> affect the airway inflammation as well as the respiratory health of the preschool children (Nazariah *et al.*, 2013; Nur Azwani & Juliana, 2013).

#### **2.4 NO<sub>2</sub> and Respiratory Health Effects**

In ambient air, there are seven oxides of nitrogen that may be found. However, nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) are the two principal nitrogen oxides associated with combustion sources. NO<sub>2</sub> is formed through the oxidation of nitric oxide in air. It is colourless to brown in its liquid form and its boiling point is 21.15°C. In normal ambient conditions, its low partial pressure (908mmHg at 25°C) prevents condensation so that it exists in the air in its gaseous form. In that form, it is volatile, reddish-brown colour and heavier than air with pungent odour. It reacts with water and is soluble in sulphuric and nitric acids (Debbie *et al.*, 2009).

The oxides of nitrogen are formed mainly during the combustion process through various combinations of oxygen and nitrogen at high temperatures. Usually, 90-95% of the nitrogen oxides are emitted as nitric oxide and only 5-10% as nitrogen dioxide. However, in ambient conditions, nitric oxide is rapidly oxidized in air to form nitrogen dioxide by available oxidants such as oxygen, ozone, and VOCs. This rapid oxidation velocity is such that it is nitrogen dioxide that is usually considered as a primary pollutant. On the other hand, this oxidation process is much slower in indoor air condition (Arashidani *et al.*, 1996). The sources NO<sub>2</sub> are divided into two, outdoor and indoor sources. The outdoor sources include mobile sources of diesel- and petrol-powered vehicles of road traffic and stationary source of industrial combustion. In contrast, the indoor sources include tobacco smoke, fuel burning stoves that use wood, kerosene, natural gas or propane, and fuel-burning heating system that use wood, oil, or natural gas. The outdoor nitrogen dioxide from both natural and anthropogenic sources also influences the indoor nitrogen dioxide levels (Levy *et al.*, 1998).

As a free radical, nitrogen dioxide has the potential to deplete tissue antioxidant defences and cause injury and inflammation in a variety of in vitro test system (B Halliwell *et al.*, 1992). An experimental study on animals in 2002 conducted by Persinger RL, *et al.*, also supports that exposure to nitrogen dioxide will cause a range of biological effects including changes in lung metabolism, structure, function, inflammation, and host defence against infectious pulmonary disease. Another experimental study on animals has also supported the previous study mentioned; it has examined the acute effects of nitrogen dioxide on airway eosinophilic inflammation and bronchial hyperreactivity (Hussain, *et al.*, 2004).

Besides, there are numbers of epidemiological studies that have been conducted to associate the NO<sub>2</sub> exposure with airway diseases. In a study conducted by Gauderman *et al.*, (2009), NO<sub>2</sub> concentrations have been associated with cough, wheeze, and shortness of breath in children. It is also being associated with exacerbations of asthma in which it is associated with emergency room visits, wheezing, and medication use among children with asthma (Lipsett *et al.*, 1997; Gauderman *et al.*, 2005). Airway inflammation and bronchial hyperresponsiveness which act as the characteristics of asthma has been found to increase dramatically worldwide, particularly within industrial societies (Eder *et al.*, 2006). Local study also revealed that NO<sub>2</sub> is highly correlated with the tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) which act as the proinflammatory mediators that are released when there are interaction of alveolar macrophages (lung) with atmospheric particles of the airway inflammation mechanism (Nazariah *et al.*, 2013). A strong association has also been found long years ago between asthma prevalence and NO<sub>2</sub> levels (Studnicka *et al.*, 1997).

## **2.5 FeNO as an Indicator of an Airway Inflammation**

Fractional exhaled nitric oxide (FeNO) act as a suitable marker for predicting response to inhaled corticosteroids as well as to monitor the anti-inflammatory effect of the lungs (Alving & Malinovschi, 2010). There is also a strong interest in using FeNO as a guide in treating asthma, based on the premise that FeNO reflects airway inflammation. In fact, FeNO assessment

produces some advantages including the good correlation with symptoms in asthma and risk of exacerbations (Giuliana *et al.*, 2013).

Endogenous nitric oxide is identified as a key signalling molecule in a whole host of biological functions (Yates *et al.*, 2001). In the lungs, NO is an important mediator of inflammatory response and involved in the regulation of vasodilatation, neurotransmission, and cell-mediated immunity. The production of endogenous NO is due to the activation of an inducible isoform of NO synthase (Rahman & Macnee, 1998). It can be induced by certain inflammatory cytokines, and this activation is seemed to be responsible for an increased production of NO in the exhaled air (FeNO) of subjects with asthma, rhinitis, and atopy, particularly those with airway inflammation condition (Cibella *et al.*, 2008). Therefore, FeNO is considered to a reliable non-invasive marker of airway inflammation. (Refer Figure 2.3)

Many types of air pollutants such as particulate matter (PM), nitrogen dioxide (NO<sub>2</sub>), or Ozone (O<sub>3</sub>) may induce inflammation in lower respiratory system (Bernstein *et al.*, 2004). Studies have found that FeNO is a good indicator in comparing patients with asthma and those healthy controls as well as to be superior to lung function testing for predicting steroid-naive asthma (Deykin *et al.*, 2002; Malmberg *et al.*, 2003). Recently, there are a lot of studies that have implemented and supported FeNO as one of their markers in studying subjects with airway inflammation diseases, especially those with asthma (Yoon *et al.*, 2012; Zhang *et al.*, 2012; Flamant-Hulin *et al.*, 2010).

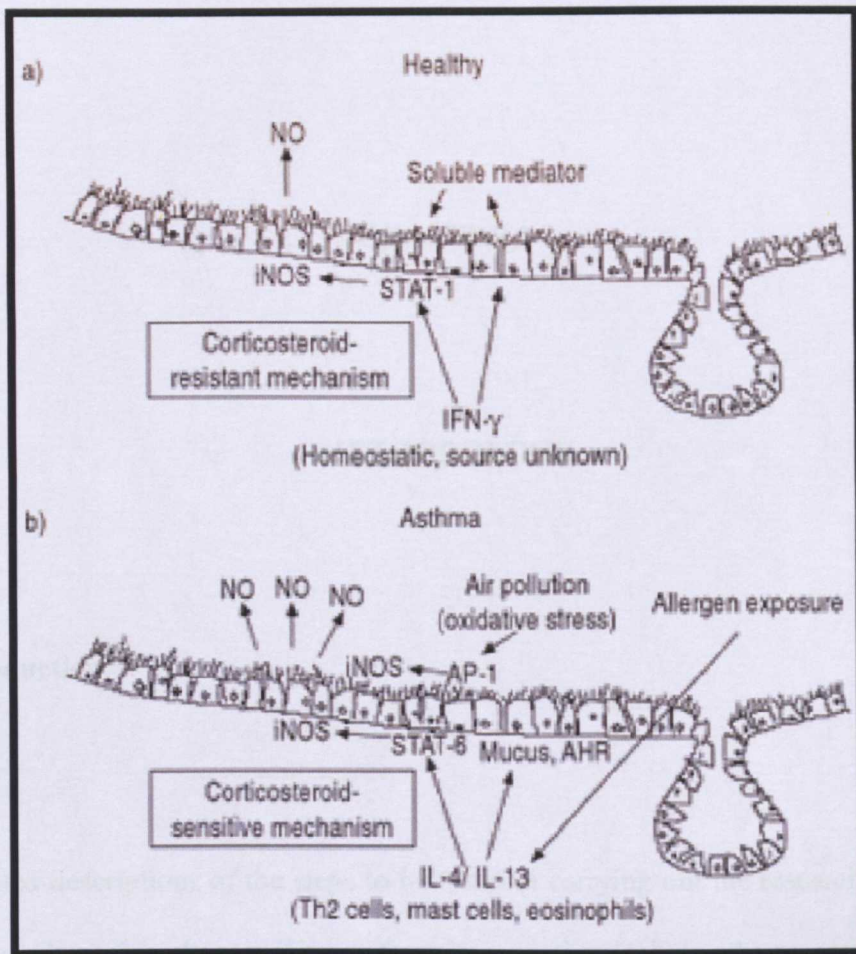


Figure 2.3: Regulation of inducible nitric oxide synthase (iNOS) expression in the bronchial epithelium in a) a healthy subject and b) an asthmatic subject.

(Source: Alving & Malinowski, 2010)

## CHAPTER 3

### METHODOLOGY

#### 3.1 Introduction

Detailed descriptions of the steps to be taken in carrying out the research project will be informed throughout this chapter. The methodology section includes the research design, study location, study population, sampling frame, study sample, sample unit, sample size calculation, sampling method, instrumentation, statistical analysis that will be used, quality control, and study ethics.

### **3.2 Study Design**

This research was a cross-sectional comparative type of study, with the aim to determine the airway inflammation among preschool children in preschools located in industrial area and sub-urban area towards exposure to PM<sub>2.5</sub> and NO<sub>2</sub>. The preschools were chosen by simple random sampling from the lists given by KEMAS state office. All the students from selected preschools were included in the study (universal sampling). Three preschools from Puchong represented industrial area, and 3 preschools (2 from Semenyih and 1 from Serdang) represented sub-urban area.

### **3.3 Study Location**

The study location chosen was according to the surrounding environment that might have contributed to the air pollution status in the preschools. Therefore, three preschools in Puchong, Selangor (industrial) and another three preschools in Semenyih and Serdang, Selangor (sub-urban) were randomly selected. (Figure 3.1, Figure 3.2, & Figure 3.3)

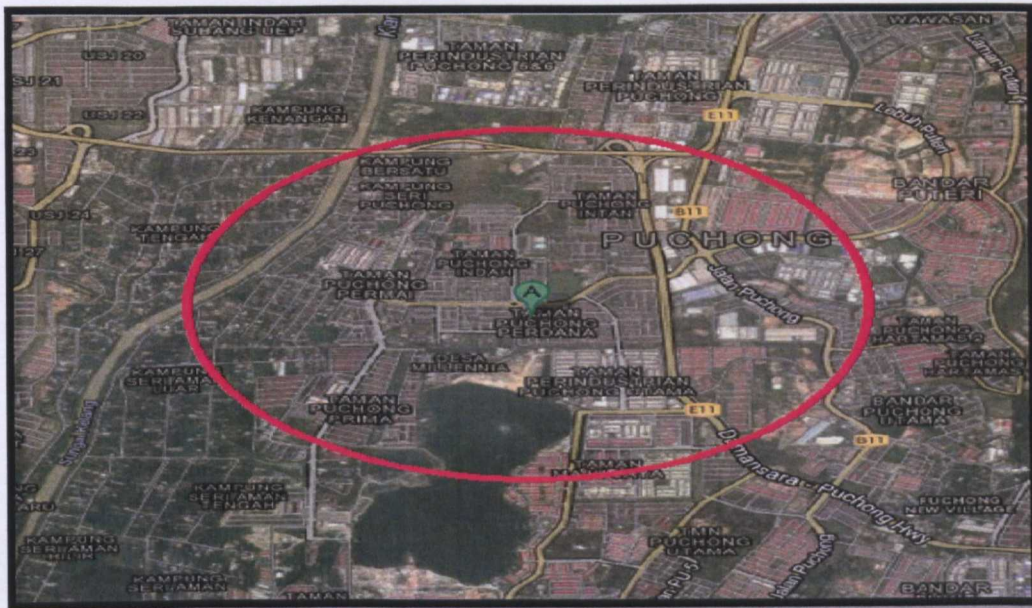


Figure 3.1: Area location map of the studied group in Puchong, Selangor.



Figure 3.2: Area location map of the comparative group in Semenyih, Selangor.

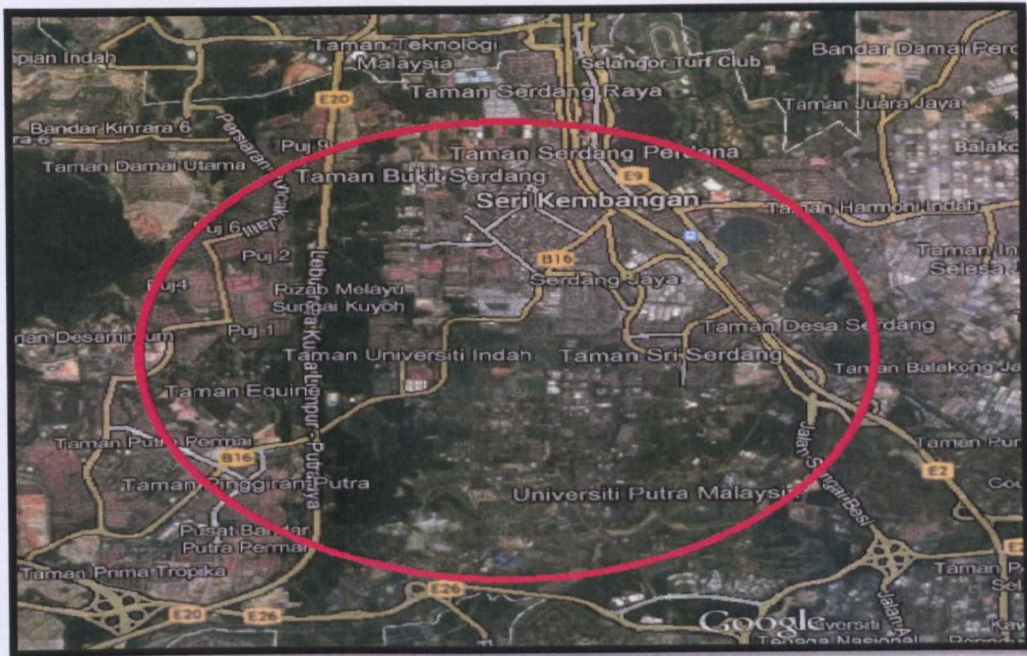


Figure 3.3: Area location map of the comparative group in Serdang, Selangor.

### 3.4 Sampling

#### 3.4.1 Study Population

A total of 240 preschool children aged 5-6 years old who attended the selected 6 preschools located in Puchong, Semenyih and Serdang were included in this study. Study population for the exposed group selected was among those Malay male and female preschool children attended the preschools in Puchong area, while the population for the comparative group

selected was among Malay male and female preschool children attended preschools in Semenyih and Serdang.

### **3.4.2 Sampling Frame**

The sampling frame was all male and female preschool children who attending the selected preschools, aged between 5- 6 years old. The name lists were obtained from the teachers and it only included among those with no evidence of asthma.

### **3.4.3 Study Sample**

Study samples were selected among male and female preschool children attending the selected preschools who fulfilled the inclusive criteria. The exposed group was the preschool children who were currently attending the preschools located in Puchong, while the comparative group was the preschool children who were currently attending the preschools located in Semenyih and Serdang.

### 3.4.4 Sample Unit

Male and female preschool children aged 5-6 years old, free from asthma, and Malay ethnic.

### 3.4.5 Sample Size

The sample size determination of this study was based on Lemeshow *et al.* (1990) formula for group comparison study using the combined (or pooled) standard deviation ( $\sigma^2$ ) for the two groups as follows:

$$n = \frac{2 \times 2 \sigma^2 [Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}]^2}{\mu_1 - \mu_2}$$

Where;

$n$  = Sample size

$\sigma^2$  = Estimated standard deviation (assumed to be equal to each group)

$\mu_1$  = Estimated mean (larger)

$\mu_2$  = Estimated mean (smaller)

$Z_{1-\alpha}$  = Standard error associated with confidential interval, 95% CI = 1.96

$Z_{1-\beta}$  = Standard error associated with power, 80% of power = 0.84

According to Malmberg, *et al.* (2003),

$$\mu_1 = 2.6 \quad (\text{FeNO level among probable asthma preschool children})$$

$$\mu_2 = 0.0 \quad (\text{FeNO level among healthy preschool children})$$

$$\text{Thus, } n = \frac{4(3.4)^2[1.96+0.84]^2}{(2.6-0)^2}$$

$$n = 54$$

Based on the formula, 54 respondents were needed for each exposed and comparative group which gave a total of 108 respondents. However, for the strength of analysis of the study and taking into account of non-responsive respondents, the number of respondents was increased by 10%. Hence, the total numbers of samples included in this study were 124 samples. A total of 62 preschool children from the selected preschools in Puchong (industrial area), and another 62 preschool children from the selected preschools in Semenyih and Serdang (sub-urban areas) will be selected.

### 3.4.6 Sampling Method

The sampling methods applied in this study were simple random sampling (for selection of preschools) and universal sampling (for selection of preschool children). Several inclusive

criteria were established where only those who matched and fulfilled these criteria were selected for each location. For FeNO analysis however, simple random sampling was used to choose 30 preschool children from the industrial area as the exposed group, and 30 preschool children from the sub-urban area preschools as the comparative group.

#### 3.4.6.1 Inclusive Criteria

- i. Preschool children aged 5-6 years old.
  - Both male and female.
  - From the selected preschools of both exposed and comparative groups.
  
- ii. Malay ethnic.
  - To homogenized the respondents so that no confounding genetic factors influenced the results' validity.
  
- iii. Free from asthma.
  - To ensure that current exposure that affect their lungs are not influenced by their medical history status.

### 3.4.6.2 Exclusive Criteria

- i. Parents of the preschool children who did not give their consent.
- ii. Preschool children who was absent during the three times visit to the preschool.

## 3.5 Instrumentations

### 3.5.1 Questionnaires

The questionnaire used in this study was a modified questionnaire adapted from the American Thoracic Society, 'Questionnaire ATS-DLD-78-C', and a part of the questionnaire was from the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire. It consisted of seven parts, namely Part 1 – Socio-demographic background, Part 2 – Respiratory Symptoms and Asthma, Part 3 – Allergy (Nose and Skin) Symptoms, Part 4 – Childhood Experience, Part 5 – Current Home Environment, Part 6 – Current Eating Habit of the Children, and Part 7 – Current Health Symptoms.

### 3.5.2 Measurement of Indoor PM<sub>2.5</sub> in Preschool

The DustTrak™ II Aerosol Monitor 8532 is a handheld battery-operated, data-logging, light-scattering laser photometer that gives you real-time aerosol mass readings. It uses a sheath air system that isolates the aerosol in the optics chamber to keep the optics clean for improved reliability and low maintenance. It is suitable for clean office settings as well as harsh industrial workplaces, construction and environmental sites, and other outdoor applications. The DustTrak II Aerosol Monitor measures aerosol contaminants such as dust, smoke, fumes, and mists. It measures aerosol concentrations corresponding to PM<sub>1</sub>, PM<sub>2.5</sub>, Respirable, or PM<sub>10</sub> size fractions in concentration range of 0.001 to 150 mg/m<sup>3</sup>.

The DustTrak II Aerosol Monitor was used to measure PM<sub>2.5</sub> concentration levels in the indoor and outdoor environment of the preschools selected. The flow rate of the instrument was set at 1.7 liter per minute (L/min) to measure the PM<sub>2.5</sub> concentration levels for 4 hours inside the preschool during class hours, and another measurement of 30 minutes at the outside of the preschool's building for the concentration level of PM<sub>2.5</sub> at the outdoor environment. As for analysis, TRAKPRO™ Data Analysis Software was used.



Figure 3.4: TSI DustTrak™ DRX Aerosol Monitor 8523

(Source: TSI Website)

### 3.5.3 TSI Velocicalc Plus Model 8386

The TSI Velocicalc Plus Model 8386 simultaneously measures and data logs several ventilation parameters using a single probe with multiple sensors. The ventilation meter measures temperature, velocity and pressure. It also features automatic calculation of flow rate and automatic conversion between actual and standard velocity readings. Its features also includes direct calculation of dew point and wet bulb temperature, heat flow calculations, sampling and statistic functions, variable time constant, single point and continuous data logging, telescoping and articulate probe with etched length marks and easy to read with the back-lit display. It measures wide velocity range of 0 to 10 000 ft/min (0-50 m/s) using the thermal sensor or a Pitot tube.



### 3.5.4 Measurement of Indoor NO<sub>2</sub> in Preschool

LaMotte's Model BD Air Sampling Pump features durability and simplicity of use. The diaphragm vacuum pump draws the air sample through absorbing reagent in impinger at a constant rate between 0 and 2.0 liters per minute. An integral flow meter regulates the air flow rate to control the amount of air sampled. It operates up to 48 hours on a single set of four, size "C" batteries.

The sampling pump was used to measure the concentration of NO<sub>2</sub> at the indoor and the outdoor environment of the preschools selected. The measurement of the indoor NO<sub>2</sub> was done for 4 hours, whereas the measurement of the outdoor NO<sub>2</sub> was done for 30 minutes. It was used along with Nitrogen Dioxide in Air Test Kit in which the portable vacuum pump draws precise volumes of air through an absorbing solution in a special bubbling tube (impinger) at a constant flow rate between 0 and 2.0 litres per minute. After few treatments with Nitrogen Dioxide Reagents, the resulting colour reaction was measured in an Octet Comparator for results in parts per million (ppm).

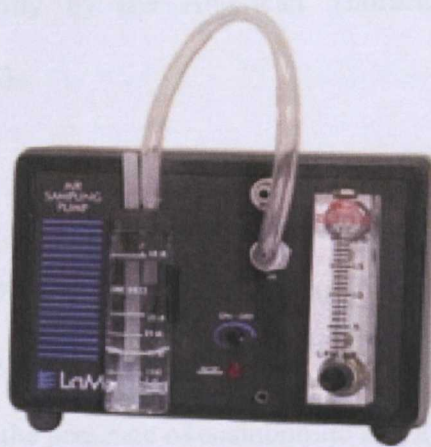


Figure 3.6: LaMotte Portable Air Sampling Pump

(Source: LaMotte Website)

### 3.5.5 Assessment of Airway Inflammation

NIOX MINO<sup>®</sup> Airway Inflammation Monitor is the first point-of-care medical device for measuring fractional exhaled nitric oxide (FeNO), thus offering personalized asthma management. It enables healthcare providers to obtain an accurate, quantitative measure of airway inflammation to more effectively diagnose and manage asthma by measuring Fractional Exhaled Nitric Oxide (FeNO) in human breath. The level of Nitric Oxide is elevated when eosinophilic airway inflammation is present and decreases as a response to anti-inflammatory treatment. The FENO concentration in expired breath can be measured by NIOX MINO<sup>®</sup> with assurance that such measurements are repeatable and according to recommendations for NO

measurement established jointly by the American Thoracic Society and the European Respiratory Society (ATS/ERS)

Measurement of FeNO by this device is a quantitative, non-invasive, simple and safe method to measure the FeNO concentration in patients with asthma-like airway symptoms in order to establish and monitor the presence of eosinophilic airway inflammation. It is suitable for children, approximately 4 - 17 years, and adults 18 years and older.

The respondents were required to breathe into the mouthpiece attached to the recording device (NIOX MINO). They were asked not to eat, drink or participate in heavy exercise during the hour before testing. Testing began with the respondent stood up quietly and comfortably. First, the respondent's nose was clipped, and the respondent was required to fully expelled air from the lungs by doing a full exhalation, after which the respondent inserted the mouthpiece of the NIOX system and inhaled NO-free air calmly to total lung capacity over a period of 2-3 seconds. The respondent was then exhaled steadily for 6 seconds, maintaining a constant air speed in which the machine will emit a continuous humming sound if the respondent breathed correctly. All of the respondents were provided with a mouthpiece (disposable) each. As a measure of preventing error in maintaining constant air speed while exhaling the air, a visual display on how strong the respondent is exhaling during the testing was displayed at the screen of a computer and shown to them so that they can control the speed of the air being exhaled.

The results were then compared with the ATS guidelines which strongly recommends that FeNO less than 25 ppb (<20 ppb in children) indicates that eosinophilic inflammation and responsiveness to corticosteroids are less likely, FeNO greater than 50 ppb (>35 ppb in children) indicates that eosinophilic inflammation and, in symptomatic patients, responsiveness to corticosteroids are likely, and FeNO values between 25 ppb and 50 ppb (20-35 ppb in children) should be interpreted cautiously and with reference to the clinical context.



Figure 3.7: NIOX MINO<sup>®</sup> Airway Inflammation Monitor

(Source: NIOX MINO Website)

### 3.6 Statistical Analysis

#### 3.6.1 To determine the socio-demographic status of preschool children.

Statistical analysis: Descriptive analysis

[Mean and standard deviation (SD), Median and interquartile range (IQR);

Categorical data - Frequency and percentage (%)]

#### 3.6.2 To compare the concentration of indoor air pollutants ( $PM_{2.5}$ and $NO_2$ ) in selected preschools.

##### Statistical analysis

Parametric : Mean and standard deviation (SD), Chi-Square Test

Non-Parametric : Median and interquartile range (IQR), Chi-Square Test

**3.6.3 To compare the prevalence of respiratory symptoms among preschool children between industrial and sub-urban areas.**

Statistical Analysis

Descriptive data : Frequency (Number) and Percentage (%)

Categorical data : Chi-Square Test

**3.6.4 To compare the concentration levels of fractional exhaled nitric oxide (FeNO) among preschool children between industrial and sub-urban areas.**

Statistical Analysis

Parametric : Independent Sample T-test

Non-Parametric : Mann-Whitney Test

**3.6.5 To determine the association between indoor PM<sub>2.5</sub> with airway inflammation (FeNO Value) among study respondents.**

Statistical Analysis

Parametric : Pearson Correlation Test

Non-Parametric : Spearman Rho's Test

**3.6.6 To determine the association between indoor NO<sub>2</sub> with airway inflammation (FeNO Value) among study respondents.**

Statistical Analysis

Parametric : Pearson Correlation Test

Non-Parametric : Spearman Rho's Test

**3.6.7 To identify which indoor air pollutants (NO<sub>2</sub> & PM<sub>2.5</sub>) that influence the airway inflammation (FeNO Value) the most among study respondents.**

Statistical Analysis

Categorical data : Multiple Logistic Regression

Continuous data : Multiple Linear Regression

### 3.7 Quality Control

To ensure that data collection was reliable and valid, quality control on the instruments and procedures during the data collection process were conducted. The purpose was to avoid bias and human error. Therefore, there were quality controls for the questionnaires, FeNO test, TSI DustTrak™ DRX Aerosol Monitor 8523, TSI Velocicalc Plus Model 8386, LaMotte Portable Air Sampling Pump, and NIOX MINO Airway Inflammation Monitor. Pre-test of the questionnaires was performed on 10% of the total respondents, and the results of the pre-test were tested using Cronbach's Alpha Test to ensure its reliability. This was done to ensure that all of the respondents understand the questions given, and to increase the quality of the questionnaire of this study. As for the TSI DustTrak™ DRX Aerosol Monitor 8523, TSI Velocicalc Plus Model 8386, and LaMotte Portable Air Sampling Pump, the equipments were calibrated beforehand according to the manufacturer's specifications, while the NIOX MINO Airway Inflammation Monitor was ensured that it was still within the expired date and functioned properly according to the manufacturer's specifications.

### 3.8 Study Ethics

Ethical approval for this study was obtained from the Research Ethic Committee of Universiti Putra Malaysia. Written consent forms were given and explained to the parents prior to obtaining their permission for taking their children as respondents in this study. This study was also conducted on voluntary basis where all respondents will be given briefings on the conduct of the experiment and they get to choose whether they want to participate or not. All of the information obtained from this study was kept confidential.

## CHAPTER 4

### RESULTS

A total set of 240 questionnaires were distributed to the preschools that were selected to be involved in this study in both areas. Even so, only 144 sets were returned back and only 124 of which were completely filled in and were acceptable. This produced a response rate of 60%.

#### 4.1 Respondents' Socio-demographic Status

There were 10 children (16.1%) aged 5 years old and 52 (83.9%) aged 6 years old in the exposed group, while there were 20 (32.3%) aged 5 years old and 42 (67.7%) aged 6 years old in the comparative group. The chi square test result showed age was significantly different between the exposed and comparative groups ( $p=0.037$ ). Percentages of boys were higher in both study groups (58.1% in exposed group and 53.2% in comparative group). The household income was categorized into low and middle based on the Mean Monthly Household Income for Income

Groups Year 2012 for 'bumiputera' data obtained from the Department Of Statistics Malaysia. The results showed majority of the respondents were in the middle group for both study groups with 80.6% in the exposed group and 82.3% in comparative group. Gender and household income among the exposed and comparative groups were not significantly different. (Refer Table 4.1)

**Table 4.1 Socio-demographic Characteristics of Respondents**

| Variables               | Exposed Group | Comparative Group | p             |
|-------------------------|---------------|-------------------|---------------|
|                         | (n=62)        | (n=62)            |               |
|                         | Number (%)    | Number (%)        |               |
| <b>Age (years)</b>      |               |                   |               |
| 5                       | 10 (16.1)     | 20 (32.3)         | <b>0.037*</b> |
| 6                       | 52 (83.9)     | 42 (67.7)         |               |
| <b>Gender</b>           |               |                   |               |
| Boys                    | 36 (58.1)     | 33 (53.2)         | 0.589         |
| Girls                   | 26 (41.9)     | 29 (46.8)         |               |
| <b>Ethnic</b>           |               |                   |               |
| Malay                   | 62 (100)      | 62 (100)          | -             |
| <b>Household Income</b> |               |                   |               |
| Low ( $\leq$ 686)       | 12 (19.4)     | 11 (17.7)         | 0.818         |
| Middle (1,687 - 10,665) | 50 (80.6)     | 51 (82.3)         |               |

\*Significant at  $p < 0.05$ , Chi-Square Test, N = 124

Table 4.2 shows the categories of educational level among the respondents' parents in both exposed and comparative groups. The categories consisted of none until higher education. The highest educational level among the two study groups was PhD level (included in the higher education), whereas the lowest education level obtained was none. The parents' educational level was divided into educational level of father and educational level of mother. It can be seen that the highest percentage for the educational level of fathers in the exposed group and comparative group are secondary education with 77.4% and 67.7% respectively. Similarly, the highest percentage in the educational level of mothers for both the exposed group and comparative group are secondary education with 74.2% and 54.8% respectively. The chi square test results showed no statistical significant differences between both educational level of fathers and mothers in both the study groups.

**Table 4.2 Parents' Educational Level among Respondents**

| Variables                          | Exposed group | Comparative group | p     |
|------------------------------------|---------------|-------------------|-------|
|                                    | (n=62)        | (n=62)            |       |
|                                    | Number (%)    | Number (%)        |       |
| <b>Educational Level of Father</b> |               |                   |       |
| None                               | 2 (3.2)       | 2 (3.2)           | 0.659 |
| Primary education                  | 2 (3.2)       | 3 (4.8)           |       |
| Secondary education                | 48 (77.4)     | 42 (67.7)         |       |
| Higher education                   | 10 (16.1)     | 15 (24.2)         |       |
| <b>Educational Level of Mother</b> |               |                   |       |
| None                               | 0 (0.0)       | 1 (1.6)           | 0.131 |
| Primary School                     | 2 (3.2)       | 3 (4.8)           |       |
| Secondary education                | 46 (74.2)     | 34 (54.8)         |       |
| Higher education                   | 14 (22.6)     | 24 (38.7)         |       |

\*Significant at  $p < 0.05$ , Chi-Square Test, N = 124

## 4.2 Respondents' Home Exposure

Table 4.3 shows the respondents' exposure towards indoor air pollutant sources in homes among the two study groups. The possible sources are fuel for cooking, indoor smoking, mosquito repellent and pets. The fuel for cooking used was divided into gas and others. The findings indicate that most of the respondents for both study groups were exposed to cooking gas (75.8% in exposed group and 72.6% in comparative group). 59.7% of the respondents were exposed to indoor smoking in the exposed group and 64.5% in the comparative group. Exposure to mosquito repellents shows that 83.9% of respondents from the exposed group were exposed while there were 74.2% in comparative group also have had the same exposure. Majority of the respondents did not have pets in their house (80.6% in exposed group and 79.0% in comparative group). Descriptive analysis and Chi Square tests were conducted for all the variables; however, none of them were found to be significantly different between both the groups.

**Table 4.3 Indoor Air Pollutant Sources in Homes between Two Study Groups**

| Variables               | Exposed group | Comparative group | $\chi^2$ | P     |
|-------------------------|---------------|-------------------|----------|-------|
|                         | (n=62)        | (n=62)            |          |       |
|                         | Number (%)    | Number (%)        |          |       |
| <b>Fuel For Cooking</b> |               |                   |          |       |
| Gas                     | 47 (75.8)     | 45 (72.6)         | 0.168    | 0.681 |
| Others                  | 15 (24.2)     | 17 (27.4)         |          |       |
| <b>Indoor Smoking</b>   |               |                   |          |       |
| Yes                     | 37 (59.7)     | 40 (64.5)         | 1.009    | 0.799 |
| No                      | 25 (40.3)     | 22 (35.5)         |          |       |
| <b>Mosquito Coil</b>    |               |                   |          |       |
| Yes                     | 52 (83.9)     | 46 (74.2)         | 1.752    | 0.186 |
| No                      | 10 (16.1)     | 16 (25.8)         |          |       |
| <b>Pets</b>             |               |                   |          |       |
| Yes                     | 12 (19.4)     | 13 (21.0)         | 0.050    | 0.823 |
| No                      | 50 (80.6)     | 49 (79.0)         |          |       |

\*Significant at  $p < 0.05$ , Chi Square Test, N = 124

### 4.3 Concentration of Indoor Air Pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) in Selected Preschools

Table 4.4 shows the comparison of indoor PM<sub>2.5</sub> measured in  $\mu\text{g}/\text{m}^3$  with indoor NO<sub>2</sub> measured in ppm between two study groups. Normality test was conducted in the first place in order to assess whether the data of indoor PM<sub>2.5</sub> and indoor NO<sub>2</sub> were normally distributed within the classrooms of the preschools selected. It was found that the data for both indoor PM<sub>2.5</sub> and NO<sub>2</sub> were not normally distributed, and thus, non-parametric test (Mann-Whitney U Test) was conducted to compare the indoor PM<sub>2.5</sub> and NO<sub>2</sub> concentrations between the two study groups.

Statistical analysis shows that the median (interquartile range) concentration of the indoor PM<sub>2.5</sub> of the exposed group was higher [75.00(47.00)] than the median (interquartile range) of the comparative group [65.0(84.00)]. Mann-Whitney U Test result found a significant difference between the concentrations of indoor PM<sub>2.5</sub> in both study groups ( $Z=-4.727$ ,  $p=0.001$ ).

Correspondingly, the median (interquartile range) concentration of the indoor NO<sub>2</sub> in exposed group was higher [0.14(0.13)] as compared to comparative group [0.01(0.01)]. Mann-Whitney U Test result found that the difference in concentrations of indoor NO<sub>2</sub> between both study groups is statistically significant ( $Z=-8.517$ ,  $p=0.001$ ).

**Table 4.4 Comparison of Indoor PM<sub>2.5</sub> and NO<sub>2</sub> in Preschools between Two Study Groups**

| Variables                              | Exposed group    | Comparative group | Z      | p             |
|--|------------------|-------------------|--------|---------------|
|  | (n=3 preschools) | (n=3 preschools)  |        |               |
|  | Median (IQR)     | Median (IQR)      |        |               |
| PM <sub>2.5</sub> (µg/m <sup>3</sup> ) | 75.00 (47.00)    | 65.0 (84.00)      | -4.727 | <b>0.001*</b> |
| NO <sub>2</sub> (ppm)                  | 0.14 (0.13)      | 0.01 (0.01)       | -8.517 | <b>0.001*</b> |

\*Significant at p<0.05, Mann-Whitney U Test, N = 124

#### 4.4 Prevalence of Respiratory Health Symptoms among Study Respondents

Table 4.5 shows the comparison of respiratory symptoms among respondents between the two study groups which were assessed using standardized questionnaire adapted from ATS-DLC-78-C WHO and International Study of Asthma and Allergies in childhood (ISAAC). The respiratory symptoms included were cough, chest tightness, phlegm and wheezing where parents were required to answer it for their child. For cough, the findings showed that majority of the preschool children reported that they did not have it (71.0% in the exposed group and 88.7% in the comparative group). However, those who were reported of having cough were higher in the exposed group (29.0%) compared to the comparative group (11.3%). Chest tightness was not common among the respondents of the two study groups (0.0% in exposed group and 3.2% in comparative group). Another symptom, Phlegm, was found to be reportedly higher in the

exposed group (16.1%) compared to the comparative group (4.8%). Wheezing was also reported to be higher in the exposed group (27.4%) than in the comparative group (16.1%).

Normality test was conducted for each of the respiratory symptoms, and it was found that the data for all of the symptoms were not normally distributed. Therefore, non-parametric test (Chi Square) was conducted. Based on the statistical test result, it showed that the prevalence of the respiratory symptoms was higher among the exposed group for cough ( $p=0.014$ ,  $PR=3.214$ ,  $95\% CI=1.232-8.385$ ) and phlegm ( $p=0.040$ ,  $PR=0.040$ ,  $95\% CI=0.987-14.487$ ) than the comparative group.

**Table 4.5 Comparison of Respiratory Symptoms among Respondents**

| Variables              | Exposed group | Comparative group | $\chi^2$ | p             | PR    | 95%<br>CI        |
|------------------------|---------------|-------------------|----------|---------------|-------|------------------|
|                        | (n=62)        | (n=62)            |          |               |       |                  |
|                        | Number (%)    | Number (%)        |          |               |       |                  |
| <b>Cough</b>           |               |                   |          |               |       |                  |
| Yes                    | 18 (29.0)     | 7 (11.3)          | 6.062    | <b>0.014*</b> | 3.214 | 1.232-<br>8.385  |
| No                     | 44 (71.0)     | 55 (88.7)         |          |               |       |                  |
| <b>Chest Tightness</b> |               |                   |          |               |       |                  |
| Yes                    | 0 (0.0)       | 2 (3.2)           | 2.033    | 0.559         | 0.492 | 0.043-<br>5.568  |
| No                     | 62 (100.0)    | 60 (96.8)         |          |               |       |                  |
| <b>Phlegm</b>          |               |                   |          |               |       |                  |
| Yes                    | 10 (16.1)     | 3 (4.8)           | 4.211    | <b>0.040*</b> | 3.782 | 0.987-<br>14.487 |
| No                     | 52 (83.9)     | 59 (95.2)         |          |               |       |                  |
| <b>Wheezing</b>        |               |                   |          |               |       |                  |
| Yes                    | 17 (27.4)     | 10 (16.1)         | 2.320    | 0.128         | 0.509 | 0.212-<br>1.224  |
| No                     | 45 (72.6)     | 52 (83.9)         |          |               |       |                  |

\*Significant at  $p < 0.05$ , Chi Square Test, 95% CI = 95% Confidence Interval, N = 124

#### 4.5 Comparison of FeNO Levels among Respondents

Table 4.6 shows the comparison of FeNO level among respondents in the exposed and the comparative groups. Normality test was conducted between FeNO level and study groups. It was found that the data was not normally distributed. Hence, Mann-Whitney U Test was done, and the result showed a significant difference between the FeNO level with the study groups (exposed and comparative) with p-value of 0.001.

**Table 4.6 Comparison of FeNO Level among Respondents between Two Study Groups**

| Variables  | Exposed group | Comparative group | Z      | p      |
|------------|---------------|-------------------|--------|--------|
|            | (n=30)        | (n=30)            |        |        |
|            | Median (IQR)  | Median (IQR)      |        |        |
| FeNO (ppb) | 11.0 (3)      | 8.0 (84.00)       | -3.240 | 0.001* |

\*Significant at  $p < 0.05$ , Mann Whitney U Test, N = 60

#### 4.6 Association between Indoor Air Pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) and Airway Inflammation (FeNO Value) among Study Respondents

Table 4.7 shows the association between indoor PM<sub>2.5</sub> and indoor NO<sub>2</sub> with airway inflammation (FeNO values) among exposed and comparative groups. Firstly, correlation test of Spearman's Rho was conducted for indoor PM<sub>2.5</sub> with airway inflammations according to each study group, there were no significant association found between both of them [indoor PM<sub>2.5</sub> (p=0.796)]. Indoor NO<sub>2</sub> level for the exposed and the comparative groups were constant. Therefore, no values of correlations were calculated. However, when correlation test of Spearman's Rho was conducted for both indoor PM<sub>2.5</sub> and NO<sub>2</sub> with combined FeNO values, the statistical results found that there were significant associations between concentrations of the indoor PM<sub>2.5</sub> (p=0.013) and NO<sub>2</sub> (p=0.001) with the airway inflammations (FeNO values).

**Table 4.7 Association between Indoor Air Pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) and Airway Inflammation (FeNO Value) among Study Respondents**

| Variables                                 | Exposed group |         | Comparative group |         | Total    |               |
|---|---------------|---------|-------------------|---------|----------|---------------|
|   | FeNO (ppb)    |         | FeNO (ppb)        |         | (n = 60) |               |
|   | (n = 30)      |         | (n = 30)          |         |          |               |
|   | r value       | p value | r value           | p value | r value  | p value       |
| PM <sub>2.5</sub><br>(µg/m <sup>3</sup> ) | -0.049        | 0.796   | -0.182            | 0.335   | 0.319    | <b>0.013*</b> |
| NO <sub>2</sub><br>(ppm)                  | -             | -       | -                 | -       | 0.422    | <b>0.001*</b> |

\*significant at p<0.05, Spearman's Rho Test, N = 60

No statistics value for NO<sub>2</sub> at exposed and comparative groups because the NO<sub>2</sub> levels are constant

#### 4.7 Association between Home Indoor Air Pollutant Sources and Airway Inflammation (FeNO Values) among Study Respondents

Table 4.8 shows the association between home indoor air pollutant sources and airway inflammation (FeNO values) among respondents of the exposed and comparative groups. The FeNO values were categorized based on median value (9 ppb). Values that were higher than or equal to median ( $\geq$  ppb) were categorized as high while the value lower than the median were categorized as low. The home indoor air pollutant sources included were fuel for cooking, indoor smoking, mosquito repellent, and pets. Those who were exposed to indoor air pollutants, specifically, sources of cooking gas were found to have high FeNO (58.1%) values while those exposed to other types of cooking fuel were found to have lower FeNO values (64.7%). 53.3% and 50% of the respondents were found to have high FeNO values when they were exposed to indoor smoking, and 56.9% were found to have high FeNO values when they were exposed to mosquito repellent as opposed by the 77.8% who have lower FeNO values when they were not exposed to it. As for pets as the source of exposure at home, 50% were found to have high FeNO values when they were exposed to it and the other 50% were low.

Chi-Square Test reveals that there were no significant association between the exposures towards home indoor air pollutant sources with the airway inflammation (FeNO Values) among the study respondents.

**Table 4.8 Association between Home Indoor Air Pollutant Sources and Airway Inflammation (FeNO Value) among Study Respondents**

| Variables                 | FeNO (ppb)        |              | $\chi^2$ | P                  |
|---------------------------|-------------------|--------------|----------|--------------------|
|                           | High ( $\geq 9$ ) | Low ( $<9$ ) |          |                    |
|                           | N (%)             | N (%)        |          |                    |
| <b>Fuel for cooking</b>   |                   |              |          |                    |
| Gas                       | 25 (58.1)         | 18 (41.9)    | 2.546    | 0.111              |
| Others                    | 6 (35.3)          | 11 (64.7)    |          |                    |
| <b>Indoor smoking</b>     |                   |              |          |                    |
| Yes                       | 16 (53.3)         | 14 (46.7)    | 0.067    | 0.796              |
| No                        | 15(50.0)          | 15 (50.0)    |          |                    |
| <b>Mosquito repellent</b> |                   |              |          |                    |
| Yes                       | 29 (56.9)         | 22 (43.1)    | 3.676    | 0.076 <sup>b</sup> |
| No                        | 2 (22.2)          | 7 (77.8)     |          |                    |
| <b>Pets</b>               |                   |              |          |                    |
| Yes                       | 5 (50.0)          | 5 (50.0)     | 0.013    | 1.000 <sup>b</sup> |
| No                        | 26 (52.0)         | 24 (48.0)    |          |                    |

\*significant at  $p < 0.05$ , Chi Square Test, N = 60

**b = Fisher's Exact Test (one or more cells has an expected frequency of five or less)**

## CHAPTER 5

### DISCUSSION

#### 5.1 Respondents' Socio-demographic Status

Based on Table 4.1, socio-demographic characteristics of respondents, the results showed significant difference ( $p$ -value=0.037) in age of the respondents between the exposed and the comparative groups. The preschool children who aged 6 years old (83.9%) were higher than the exposed group (67.7%). This was caused by the low response rate where the parents of the 6 years old preschool children were the majority within the total 124 returned questionnaires. However, there were no significant differences found in gender, ethnic, and household income of the respondents. There was not much difference in the percentage of the gender as the percentages of boys and girls between both study groups were nearly the same. The same goes for the household income where majority of the respondents' parents were in the middle group (RM 1,687 - 10665).

Furthermore, the parents' educational levels among the respondents were also assessed using the questionnaires. Based on the statistical analyses done, there were no significant differences in the parents' educational level among those preschool children between the exposed group and the comparative group. Majority of the fathers' educational level among the respondents within both of the study groups were secondary education (exposed=77.4%, comparative=67.7%). The educational level of the mother of respondents were also secondary education for both of the study groups (exposed=74.2%, comparative=54.8%).

## **5.2 Respondents' Home Exposure**

Indoor air pollutant sources in homes assessed in this study were type of fuel used for cooking, presence of indoor smoking, usage of mosquito repellent, and pets. Statistical analyses results showed no significant differences in indoor air pollutant sources in homes between the exposed group and the comparative group. Cooking gas is the type of fuel that was being used by majority of the respondents' parents at homes between the two study groups. Nearly equal amount of respondents were being exposed to indoor smoking at home between the exposed and the comparative group. Most of the respondents were exposed to mosquito repellent at homes between the two study groups, and only few of them have pets at their homes.

### 5.3 Concentration of Indoor Air Pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) in Selected Preschools

There was a significant difference in the concentration of indoor PM<sub>2.5</sub> and NO<sub>2</sub> inside the classrooms of selected preschools between the exposed (industrial area) and the comparative (sub-urban area) groups, suggested that the preschools' locations might had influenced or contributed to the concentration of the particulates and gases.

The measured data showed the mean concentration of indoor PM<sub>2.5</sub> and NO<sub>2</sub> at the preschools of the studied area were higher (91.69 µg/m<sup>3</sup> and 0.14 ppm respectively) than the preschools at the comparative area (73.32 µg/m<sup>3</sup> and 0.01 ppm respectively). Since there was no national standard established for indoor PM<sub>2.5</sub>, the concentration of indoor PM<sub>2.5</sub> in this study refers to the international standard set by the U.S Environmental Protection Agency (2012) for 24-hour (35 µg/m<sup>3</sup>) and annual (15 µg/m<sup>3</sup>) as well as the WHO Air Quality Guidelines (2005) standard for 24-hour (25 µg/m<sup>3</sup>) and annual average (10 µg/m<sup>3</sup>). Meanwhile the concentration of indoor NO<sub>2</sub> in this study refers to the Malaysian Ambient Air Quality Standard (MAAQS) for 1 hour (0.13 ppm). These findings clearly indicated that the preschool children in the exposed group were highly exposed towards high concentration of indoor PM<sub>2.5</sub> and NO<sub>2</sub> which exceed all the standards mentioned. These also support the hypothesis that indoor air pollutant concentrations (PM<sub>2.5</sub> and NO<sub>2</sub>) are significantly higher in the industrial area's preschools as compared to the sub-urban area's preschools.

High indoor PM<sub>2.5</sub> with mean a concentration of 82.6±7.9 µg/m<sup>3</sup> in preschools located in industrial area was also found in a study conducted by Nur Azwani *et al.*, (2013). Likewise, another study conducted by Nazariah *et al.*, (2013) showed that the indoor PM<sub>2.5</sub> concentration in primary schools located in urban area was significantly higher (median=48.96, IQR=12.55) than the rural area (median=27.71, IQR=1572). Recent study done by Ayuni *et al.*, (2014) also found that the concentrations of indoor PM<sub>2.5</sub> and NO<sub>2</sub> in primary schools located in industrial area (79 µg/m<sup>3</sup> and 3.73 ppm respectively) were higher than the comparative area (49 µg/m<sup>3</sup> and 0.14 ppm respectively). All these studies support the findings and the hypothesis of this study where the locations of preschools or schools contributed the concentrations of the indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>).

#### **5.4 Prevalence of Respiratory Health Symptoms among Study Respondents**

The prevalence of respiratory health symptoms among each of the preschool children between the two study groups were assessed using a set of standardised questionnaire adapted from both American Thoracic Society 'Questionnaire ATS-DLC-78-C WHO' and International Study of Asthma and Allergies in childhood (ISAAC) questionnaires. Parents were required to fill in the questionnaires for their child. Asthma and respiratory health symptoms were detected through the returned questionnaires.

There were significant differences in the prevalence of cough and phlegm among the two study groups (industrial and sub-urban areas), suggested that location of the preschools might have influenced or contributed to the prevalence of both respiratory symptoms (cough and phlegm) among the respondents.

Based on the returned questionnaires, it showed that the preschool children who were in the studied area were reported of having more cases [18 (29%)] of cough than those who were in the comparative area [7 (11.3%)]. Statistical analysis showed the prevalence of cough in the preschool children who attended preschools located at the studied area were significantly higher than those who attended preschools in the comparative area ( $p$ -value=0.014, PR=3.214, 95% CI=1.232-8.385). They were 3.2 times more likely to get cough compared to those in the comparative area's preschools. Another respiratory health symptom, phlegm, was also reportedly higher in the preschool children who attended preschools at the studied area [10 (16.1%)] than the preschool children attended preschools at the comparative area [3 (4.8%)]. The results of statistical analysis indicated that the prevalence of the preschool children who have phlegm were higher in those who were in the studied area rather than those in the comparative area ( $p$ -value=0.040, PR=3.782, 95% CI=0.987-14.487). They were 3.7 times more likely to get phlegm than the comparative area's preschool children. Hence, all the findings mentioned support the hypothesis that the prevalence of respiratory health symptoms is significantly higher among those in the industrial area than those in the sub-urban area.

Heavy road traffics, industrial emissions, and the Klang Valley Mass Rapid Transit (MRT) constructions as the outdoor pollutants might have contributed to the high prevalence of the respiratory health symptoms among the preschool children at the exposed area. A study done in Emilia-Romagna, an administrative region of Northern Italy, found that cough and phlegm were the most frequent symptoms reported and the prevalence of the respiratory symptoms were higher in the urban-industrial area than the rural area (Ranzi *et al.*, 2004). Local study conducted by Nur Fazhilah *et al.* (2012) found that the prevalence of respiratory symptoms especially cough and phlegm were higher among exposed preschool children living near industrial area in Kajang compared to the non-exposed preschool children. This study was also supported with several local studies conducted by Arasyi *et al.*, (2013), Nurul *et al.*, (2013), Nazariah *et al.*, (2013) and Ayuni *et al.*, (2014), which found that the prevalence of respiratory symptoms reported were higher among those exposed than those who were not exposed. All of the studies mentioned support the findings and the hypothesis in which the locations of preschools or schools contributed to the prevalence of the respiratory health symptoms reported.

## **5.5 Comparison of FeNO Levels among Respondents**

For fractional exhaled nitric oxide (FeNO) analysis, sub-sample was done whereby only 60 students (exposed group=30, comparative group=30) were included. The 60 preschool children participated in this analysis were ensured that they were free from asthma (exclusion

criteria: asthma diagnosed by medical doctor). Aerocrine NIOX MINO Airway Inflammation Monitor was used in analysing the FeNO levels (parts per billion) among them.

Based on the results of the FeNO levels, there were significant differences in the FeNO levels (ppb) among the preschool children between the exposed group (industrial area) and the comparative group (sub-urban) with p-value of 0.01, suggested that location of the preschools might have influenced the FeNO levels among study respondents. The mean for FeNO values among those who were in the exposed area (11.43 ppb) was higher than those in the comparative area (8.17 ppb). These could be due to the higher degree of exposure experienced by those in the exposed area as compared to those in the comparative area (Ayuni *et al.* 2014). Thus, the findings support the hypothesis that the FeNO levels of the preschool children in industrial area are significantly higher than the preschool children in the sub-urban area.

#### **5.6 Association between Indoor Air Pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) and Airway Inflammation (FeNO Value) among Study Respondents**

Correlation tests were conducted to determine the association of the indoor PM<sub>2.5</sub> and NO<sub>2</sub> with airway inflammation among each group. The statistical results showed that there were no significant association of the indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) and airway inflammation among the industrial and the sub-urban areas. There was no value of correlation for NO<sub>2</sub> when

the measurement data was separated between the exposed and the comparative groups. This might be due to the constant values of NO<sub>2</sub> in each study group, small sample size of the NO<sub>2</sub> measurement data with FeNO samples, low NO<sub>2</sub> readings as well as lack in variability of the data.

Next, another correlation test was done in order to determine the association between indoor PM<sub>2.5</sub> and NO<sub>2</sub> with airway inflammation (FeNO Value) of total 60 respondents (all study respondents). The statistical results showed significant association between indoor PM<sub>2.5</sub> (p-value=0.013) and NO<sub>2</sub> (p-value=0.001) with airway inflammation of the combined study groups.

PM<sub>2.5</sub> and NO<sub>2</sub> both were found to be significantly associated with airway inflammation in two separate international studies conducted by Frank *et al.*, (2004) and Persinger *et al.*, (2002). Recent local study done by Nur Aida *et al.*, (2014), also supported that there was a significant association between indoor NO<sub>2</sub> with the airway inflammation among study respondents. These findings supported the study hypothesis that there are significant associations between indoor air pollutants (PM<sub>2.5</sub> and NO<sub>2</sub>) with airway inflammation among study respondents.

## **5.7 Association between Home Indoor Air Pollutant Sources and Airway Inflammation (FeNO Value) among Study Respondents**

According to the American Thoracic Society Guidelines (2011), FeNO value of greater than 35 ppb in children indicated that airway inflammation is likely to occur, less than 20 ppb is considered low with occurrence of airway inflammation were less likely, and 20-35ppb is considered as intermediate where the occurrence of airway inflammation might be possible but mild.

However, in assessing the association between home indoor air pollutant sources and airway inflammation (FeNO value), this study found that all of the FeNO values of the study respondents did not exceed 25 ppb. Only 1 out of total 60 respondents was found to have intermediate value of 22 ppb. Therefore, in order to compare those who had high and low FeNO values between the two study groups, statistical analysis was conducted and median (9 ppb) was used as the cutoff point. Those who were found to have FeNO values of higher than or equal to 9 ppb were categorized as high while those who have FeNO values of lower than 9 ppb were categorized as low. All of the parameters were assessed and based on the statistical results, there were no significant association between the home indoor air pollutant sources and the airway inflammation.

## STUDY LIMITATIONS

Limitations in this study include some information bias as the parents or guardian may not recall some of the actual experiences of their children as they fill in the questionnaire although only those fully filled questionnaires are accepted, selection bias for the FeNO analysis as the age is unable to be controlled due to the low response rate and the preschool children are selected based on voluntary basis.

Due to the fluctuated temperature ( $>30^{\circ}$  Celsius) as early in the morning which causes the NIOX MINO device to destabilize and occurrences of heavy haze within the duration of data collection, the process of collecting data and FeNO samples was very much interrupted which caused the sample size of the FeNO samples to be smaller than expected.

Lastly, the cross sectional study design of this study only focuses on the association between variables, and it cannot establish the cause and effect relationships, which can be done by using cohort, case-control, or experimental study design.

## CONCLUSION

In summary, this study confirms that the preschool children who attended the preschools at the industrial area were exposed to high amount of indoor air pollutants ( $PM_{2.5}$  and  $NO_2$ ) as compared to those in the sub-urban area. The prevalence of respiratory symptoms reported (cough and phlegm) and the FeNO levels were significantly higher among those in the industrial area than those in the sub-urban area. The indoor  $PM_{2.5}$  and  $NO_2$  were significantly associated with airway inflammation (FeNO levels). Thus, this study supports the claims that FeNO can be suggested as a non-invasive biomarker for airway inflammation in preschool children aged 5-6 years old.

Results obtained from the statistical analyses that were used to test the entire hypothesis of this study proved that:

1. The indoor air pollutant concentrations ( $PM_{2.5}$  and  $NO_2$ ) are significantly higher in the industrial area preschools as compared to the sub-urban area preschools.
2. The prevalence of respiratory symptoms among preschool children is significantly higher among those in the industrial area than those in the sub-urban area.

3. The concentration levels of fractional exhaled nitric oxide (FeNO) of the preschool children in the industrial area are significantly higher than the preschool children in the sub-urban area.
4. There is a significant association between indoor PM<sub>2.5</sub> with airway inflammation (FeNO value) among study respondents.
5. There is a significant association between indoor NO<sub>2</sub> with airway inflammation (FeNO value) among study respondents.

### **RECOMMENDATIONS**

As recommendations, more studies on the association of the FeNO levels between different locations or areas among preschool children should be conducted as there was still lack of related studies at the moment. It was also suggested that measurements on the exposure towards preschool children or children (aged less than 7 years old) for a longer period of time or continuously at home should be done as well to further determine the causal factors (individual or environmental) that may affect the FeNO value among them. Repetition of FeNO measurements (before and after class session) could also be conducted in the future to reveal the impact of acute indoor air exposure inside the classrooms of the preschool or school towards the airway inflammation (FeNO value) of the children.

Also, physical barrier (door) should be installed to separate the classroom with the kitchen as this could help in reducing the exposure of the indoor air pollutants especially  $PM_{2.5}$  and  $NO_2$ , towards the preschool children. In addition, an installation of an air-conditioning system inside the classroom would be much better as this will prevent most of the outdoor air pollutants from entering the indoor environment of the class.

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## APPENDIX I

### UPPER AIRWAY CLEARANCE



PELAYSAT TIRIBALAN NARI GANESHA (PENYELIDIKAN DAN INOVASI)  
OFFICE OF THE RESEARCH AND INNOVATION (PENYELIDIKAN DAN INOVASI)

Dr. Nur Hafizah  
Date: 18 January 2024

Dr. Zulhazmi  
Department of Environmental & Occupational Health  
Faculty of Health Sciences  
Universiti Putra Malaysia  
Serampok, Perak

Dear Madam,

RESEARCH PROJECT ASSOCIATION BETWEEN INDOOR PM<sub>2.5</sub> AND NO<sub>2</sub> WITH  
LEVELS OF AIR POLLUTION IN RURAL FRESHWATER CHILDREN IN INDUSTRIAL  
AND URBAN AREAS

PROJECT LEADER: DR. HUSNA NUR HASBIM  
PROJECT NUMBER: 2023-2024

**APPENDIX 1:**  
**UPM ETHICAL CLEARANCE**

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The information contained herein is confidential and should not be disclosed to any third party without the prior written consent of the University of Putra Malaysia.

**DECLARATION OF ETHICAL CLEARANCE**

I, the undersigned, have read and understood the contents of the research proposal and have approved it for ethical clearance. I confirm that the research has been conducted in accordance with the ethical standards and guidelines of the University of Putra Malaysia.

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JKEUPM Ref No. : FPSK\_November(13)51

- a) Members of the JKEUPM who reviewed the documents:  
 - Prof. Dr. Lim Thiam Aun
- b) Date of approval: 30/12/2013

Endorsed at JKEUPM Meeting on 10/1/2014, attended by:

| NAME  | DESIGNATION  | GENDER | TICK IF PRESENT |
|---|--|--------|-----------------|
| Prof. Dr. Norlijah Othman                       | Paediatrics & Dean, Faculty of Medicine and Health Sciences  | Female |                 |
| Prof. Dr. Zamberi Sekawi                        | Medical Microbiologist & Deputy Dean of Research and Internationalization, Faculty of Medicine and Health Sciences   | Male   | √               |
| Prof. Dato' Dr. Lye Munn Sann                   | Medical Statistician, Dept of Community Health, Faculty of Medicine and Health Sciences                              | Male   | √               |
| Prof. Dr. Tengku Aizan Abd Hamid                | Gerontologist & Director, Institute of Gerontology   | Female |                 |
| Prof. Dr. Lekhraj Rampal                        | Medical Statistician, Dept of Community Health, Faculty of Medicine and Health Sciences                              | Male   | √               |
| Prof. Dr. Elizabeth George                      | Pathologist, Dept of Pathology, Faculty of Medicine and Health Sciences  | Female | √               |
| Prof. Dr. Lim Thiam Aun                         | Anesthesiologist, Dept of Surgery, Faculty of Medicine and Health Sciences   | Male   | √               |
| Prof. Dr. Wan Omar Abdullah                     | Medical Parasitologist, Dept of Medical Microbiology and Parasitology, Faculty of Medicine and Health Sciences       | Male   |                 |
| Prof. Dr. Patimah Ismail                        | Professor of Biomedicine, Dept of Biomedical Sciences, Faculty of Medicine and Health Sciences                       | Female | √               |
| Prof. Dr. Johnson Stanslas                      | Pharmacologist, Dept of Medicine, Faculty of Medicine and Health Sciences  | Male   | √               |
| Assoc. Prof. Dr. Mansor Abu Talib               | Assoc. Professor of Guidance and Counselling, Dept of Human Development and Family Studies, Faculty of Human Ecology | Male   |                 |
| Assoc. Prof. Dr. Azmawani Abd. Rahman           | Operations and Technology Management / Deputy Dean of Research and Graduate Studies                                  | Female | √               |
| Assoc. Prof. Dr. Noritah Omar (Lay Person)      | Assoc. Professor of English Language, Dept of English Language, Faculty of Communication and Modern Languages        | Female | √               |
| Dr. Rojanah Kahar (Lay Person)                  | Senior Lecturer of Dept of Human Development and Family Studies, Faculty of Human Ecology                            | Female | √               |
| Tan Sri Dato' Napsiah Omar (Independent Member) | Chairman, National Population and Family Development Board   | Female | √               |

**APPENDIX 2:**  
**EXPLANATION LETTER AND CONSENT FORM**



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

## BORANG B2: PENERANGAN DAN PERSETUJUAN IBUBAPA/PENJAGA

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

### 1. TAJUK KAJIAN:

Hubungan Antara  $PM_{2.5}$  Dan  $NO_2$  Dalam Dengan Keradangan Saluran Udara Pernafasan Dalam Kalangan Kanak-kanak Prasekolah Di Kawasan Perindustrian dan Sub-Bandar.

### 2. PENGENALAN:

Kajian epidemiologi dan toksikologi telah dijalankan di seluruh dunia untuk menunjukkan hubungan antara pencemaran udara dan kesannya terhadap kesihatan pernafasan manusia (Samet J., & Krewski D., 2007). Apabila kita menghabiskan sebahagian besar masa kita di dalam bangunan, persekitaran dalaman bangunan itu boleh menjadi lebih tercemar dengan tahap pencemaran yang lebih tinggi berbanding luar terutamanya dalam keadaan pengudaraan kurang sihat yang dipenuhi dengan barang-barang seperti produk pengguna, peralatan gas, rokok, dan perabot (Hoskins, 2011). Dalam tempoh dua dekad yang lalu, pendedahan kepada pencemaran udara dalam persekitaran dalaman telah diiktiraf sebagai berpotensi untuk memberi kesan yang tinggi terhadap kesihatan kanak-kanak (Kirk R Smith, et al., 2000). Dalam persekitaran yang sama, kesan kesihatan terhadap pencemaran udara untuk kanak-kanak adalah lebih tinggi daripada orang dewasa (WHO, 2005). Oleh itu, tujuan kajian ini dijalankan adalah untuk mengkaji kesan pencemaran udara dalaman terhadap keradangan saluran pernafasan dalam kalangan kanak-kanak prasekolah di kawasan perindustrian dan sub-bandar di Selangor.

### 3. APAKAH YANG PERLU ANDA LAKUKAN?

Anda sebagai ibu/bapa/penjaga kepada anak anda dikehendaki untuk menandatangani borang penyertaan responden dan menyatakan minat anda untuk menyertai kajian ini. Ianya boleh dilakukan setelah anda membaca dan memahami isi kandungan penerangan ini. Borang penyertaan responden haruslah dikembalikan kepada pengkaji sebelum temubual dan ujian yang akan dijalankan.

#### 4. SIAPAKAH YANG TIDAK PATUT MENYERTAI KAJIAN INI?

Individu yang berumur kurang dari 5 tahun atau lebih dari 6 tahun tidak patut menyertai kajian ini.

#### 5. APAKAH FAEDAH KAJIAN INI:

##### (a) KEPADA ANAK/JAGAAN SAYA SEBAGAI RESPONDEN?

Kajian ini dapat menjelaskan sama ada status udara dalaman boleh mengakibatkan masalah kepada fungsi paru-paru atau tidak kepada kanak-kanak prasekolah. Sekiranya kepekatan pencemar udara dalaman adalah tinggi dan memberi kesan kepada responden, tindakan selanjutnya boleh dilakukan berdasarkan hasil daripada maklumat kajian ini. Melalui kajian ini juga, anda akan dapat menentukan sama ada anak anda mengalami masalah dari segi sistem pernafasan ataupun tidak tanpa dikenakan sebarang bayaran.

##### b) KEPADA PENYELIDIK?

Penyelidik dapat meningkatkan kemahiran dalam mengendalikan alat-alat yang terlibat dalam persampelan kajian ini. Di samping itu, pengajaran pendidikan boleh disampaikan kepada ibu/bapa/penjaga dan responden agar mereka dapat memahami dengan lebih jelas tentang kajian yang dilakukan. Selain itu, data yang diperolehi daripada kajian ini dapat digunakan bagi melengkapkan projek ilmiah tahun akhir.

#### 6. APAKAH TERDAPAT SEBARANG RISIKO?

Kajian ini tidak melibatkan sebarang risiko.

#### 7. ADAKAH MAKLUMAT DAN IDENTITI ANAK/JAGAAN SAYA KEKAL RAHSIA?

Semua maklumat yang diperolehi dari temubual dan ujian-ujian yang dijalankan oleh pengkaji adalah dijamin sulit. Maklumat ini hanya akan digunakan untuk tujuan kajian ini sahaja.

#### 8. SIAPAKAH YANG SAYA HARUS HUBUNGI SEKIRANYA SAYA MEMPUNYAI SOALAN TAMBAHAN SEPANJANG PENYELIDIKAN INI?

Sekiranya anda mempunyai sebarang kemusykilan, anda boleh menghubungi pengkaji iaitu Noor Hisyam Bin Noor Hassim pada talian 010-2203326.

*Please initial here if you have read and understood the contents of this page* NH

## 9. PERSETUJUAN

Saya..... No Kad Pengenalan. ....  
 beralamat.....  
 .....dengan ini secara sukarela bersetuju membenarkan \*anak / jagaan saya  
 ..... menyertai **penyelidikan tersebut di atas \*(klinikal/percubaan ubat-  
 ubatan/rakaman video/kumpulan sasaran/temuduga/ soal selidik).**

Saya telah diberi penjelasan secara menyeluruh mengenai penyelidikan ini dari segi metodologi, risiko dan komplikasi (seperti 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.

**Saya 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)



JABATAN KESIHATAN PERSEKITARAN DAN PEXERMAN  
FAKULTI PERUBATAN DAN SAINS KESIHATAN  
UNIVERSITI PUTRA MALAYSIA

BUSINESS NAME STUDY

ASSOCIATION BETWEEN INDOOR PM<sub>2.5</sub> AND NO<sub>2</sub> WITH AIRWAY  
HYPERPLASIA AMONG PRESCHOOL CHILDREN  
IN INDUSTRIAL AND SUBURBAN AREAS  
IN SELANGOR

**APPENDIX 3:**  
**QUESTIONNAIRE**

NO. 100, JALAN TRUSMI, SEREMBAN, N.S.

NO. 100, JALAN TRUSMI

NO. 100, JALAN TRUSMI

NO. 100, JALAN TRUSMI

Terima kasih atas perhatian anda terhadap penyelidikan ini. Sila isi borang ini  
anda secepat mungkin untuk tujuan penyelidikan ini. Borang ini yang telah diisi  
anda diserahkan ke pejabat penyelidikan ini.

Penyaji maklumat yang dipaparkan dalam borang ini adalah berdasarkan data penyelidikan  
yang dijalankan oleh penyelidik ini.



**U P M**  
UNIVERSITI PUTRA MALAYSIA  
BERILMU BERBAKTI

JABATAN KESIHATAN PERSEKITARAN DAN PEKERJAAN  
FAKULTI PERUBATAN DAN SAINS KESIHATAN  
UNIVERSITI PUTRA MALAYSIA

**BORANG SOAL SELIDIK**

TAJUK:  
**ASSOCIATION BETWEEN INDOOR PM<sub>2.5</sub> AND NO<sub>2</sub> WITH AIRWAY  
INFLAMMATION AMONG PRESCHOOL CHILDREN  
IN INDUSTRIAL AND SUB-URBAN AREAS  
IN SELANGOR.**

ID RESPONDEN:

|  |  |  |  |
|--|--|--|--|
|  |  |  |  |
|--|--|--|--|

TARIKH SOAL SELIDIK:

|  |  |  |
|--|--|--|
|  |  |  |
|--|--|--|

SOAL SELIDIK DILENGKAPKAN OLEH:

Ibu kanak-kanak

Bapa kanak-kanak

Ibu dan bapa kanak-kanak

Terima kasih atas kesudian anda menyertai penyelidikan saintifik ini. Kerjasama dari anda adalah sangat penting dalam menjayakan kajian ini. Jawapan yang jujur dan tepat amat diperlukan untuk melaksanakan projek ini.

Kesemua maklumat yang diperolehi dalam kajian ini akan dirahsiakan dan hanyalah untuk tujuan kajian kesihatan sahaja.

|  |  |  |  |
|--|--|--|--|
|  |  |  |  |
|--|--|--|--|



12. Jumlah pendapatan isi rumah: RM \_\_\_\_\_/bulan

**BAHAGIAN 2: SIMPTOM RESPIRATORI DAN ASMA**

**A: BATUK**

- |  |     |       |
|--|-----|-------|
| 1. Adakah anak anda selalu mengalami batuk beserta selesema? | Ya  | Tidak |
|  | ( ) | ( )   |
| 2. Adakah anak anda selalu mengalami batuk sahaja?           | Ya  | Tidak |
|  | ( ) | ( )   |

**JIKA YA SOALAN 1 ATAU/DAN 2:**

- |   |       |       |
|---|-------|-------|
| 3. Adakah dia batuk pada keseluruhan 4 hari atau lebih dalam masa seminggu atau selama 3 bulan berturut-turut dalam masa setahun? | Ya    | Tidak |
|   | ( )   | ( )   |
| 4. Sudah berapa tahunkah anak anda mengalami batuk?   | _____ | tahun |

**B: KAHAK**

- |   |     |       |
|---|-----|-------|
| 1. Adakah anak anda selalu mengalami kesesakan nafas serta mengeluarkan kahak dan juga mengalami selesema ? | Ya  | Tidak |
|   | ( ) | ( )   |
| 2. Adakah anak anda selalu mengalami kesesakan nafas serta mengeluarkan kahak dan tanpa selesema ?          | Ya  | Tidak |
|   | ( ) | ( )   |

**JIKA YA SOALAN 1 ATAU/DAN 2:**

- |   |       |       |
|---|-------|-------|
| 3. Adakah anak anda mengeluarkan kahak pada keseluruhan hari (4 hari atau lebih dalam masa seminggu) atau selama 3 bulan berturut-turut dalam masa setahun? | Ya    | Tidak |
|   | ( )   | ( )   |
| 4. Jika ya (soalan di atas), sudah berapa lamakah masa ini berlaku?   | _____ | tahun |
| 5. Secara purata, berapa kalikah anak anda mendapat selesema dalam tempoh setahun?  | _____ | kali  |

**C: NAFAS BERBUNYI DI DADA**

- |  |     |       |
|--|-----|-------|
| 1. Pernahkah anak anda mengalami nafas berbunyi di dada pada bila-bila masa dalam 12 bulan yang lepas: | Ya  | Tidak |
| Semasa mengalami selesema?   | ( ) | ( )   |
| Semasa tidak mengalami selesema?   | ( ) | ( )   |
| Kerap pada waktu siang atau malam?   | ( ) | ( )   |

**JIKA YA SOALAN 1:**

- |  |       |                 |
|--|-------|-----------------|
| 2. Sudah berapa lamakah anak anda mengalami masalah ini ( dada berbunyi)                                     | _____ | Bulan/<br>Tahun |
| 3. Pernahkah anak anda mengalami serangan nafas berbunyi sehingga menyukarkan pernafasan?                    | Ya    | Tidak           |
|  | ( )   | ( )             |
| 4. Adakah anak anda mengalami masalah ini setelah anak anda melakukan aktiviti seperti senaman atau latihan? | Ya    | Tidak           |
|  | ( )   | ( )             |

# BORANG SOAL SELIDIK

## BAGIAN 3: SIMPTOM ALAHAN HIDUNG DAN KULIT

### D: SESAK NAFAS

1. Pernahkah anak anda mendapat serangan sesak nafas yang datang tiba-tiba ketika berehat dalam 12 bulan yang lepas? Ya    Tidak  
( )    ( )
2. Pernahkah anak anda mendapat serangan sesak nafas yang datang selepas melakukan aktiviti berat pada bila-bila masa dalam 12 bulan yang lepas? Ya    Tidak  
( )    ( )

#### **JIKA YA SOALAN 1 ATAU/DAN 2:**

3. Pernahkah anak anda terjaga kerana sesak nafas dalam 12 bulan yang lepas? Ya    Tidak  
( )    ( )
4. Pada 12 bulan yang lepas, adakah masalah kesesakan nafas anak anda berada di tahap yang serius, sehingga membataskan percakapan pada hanya satu atau dua patah perkataan sahaja diantara nafas? Ya    Tidak  
( )    ( )
5. Pada 12 bulan yang lepas, pernahkah dada anak anda berbunyi kuat selepas bersenam? Ya    Tidak  
( )    ( )

### E: ASMA

1. a. Pernahkah anak anda menghidap asma? Ya    Tidak  
( )    ( )

#### **JIKA YA SOALAN 1:**

2. Adakah asma itu dikesan oleh doktor? Ya    Tidak  
( )    ( )
3. Jika ya, berapakah umur anak anda ketika itu? \_\_\_\_\_ tahun
4. Berapakah umur anak anda apabila mendapat serangan asma pertama? \_\_\_\_\_ tahun
5. Berapakah umur anak anda ketika mendapat serangan yang terbaru? \_\_\_\_\_ tahun
6. Berapa kerapkah kanak-kanak ini mendapat serangan asma dalam tempoh setahun? \_\_\_\_\_ (kali)
7. Pernahkan anak anda mendapat serangan asma dalam 12 bulan yang lepas? Ya    Tidak  
( )    ( )
8. Bagaimanakah keadaan serangan yang dialami oleh pesakit? Sangat teruk    ( )  
Teruk    ( )  
Sederhana    ( )  
Tidak teruk    ( )
9. Adakah anak anda sekarang menggunakan apa-apa ubat untuk asma? (semburan- inhaler, ubat biji, dan sebagainya) Ya    Tidak  
( )    ( )

**BAHAGIAN 3: SIMPTOM ALAHAN HIDUNG DAN KULIT****A: SIMPTOM-SIMPTOM KULIT**

1. Pernahkah anak anda mengalami ruam-ruam gatal yang tidak konsisten pada sekurang-kurangnya dalam tempoh 6 bulan? Ya    Tidak  
( )   ( )  
**Jika anda menjawab 'TIDAK', sila terus ke soalan B.**
2. Adakah anak anda mengalami ruam-ruam gatal ini pada bila-bila masa dalam bulan yang lepas? Ya    Tidak  
( )   ( )  
**Jika anda menjawab 'TIDAK', sila terus ke soalan B.**
3. Adakah ruam-ruam gatal ini menyerang mana-mana bahagian ini?
- |                                     |     |       |
|-------------------------------------|-----|-------|
| lipatan siku                        | Ya  | Tidak |
| belakang lutut                      | ( ) | ( )   |
| pergelangan kaki                    | ( ) | ( )   |
| di bawah punggung                   | ( ) | ( )   |
| sekeliling leher, telinga atau mata | ( ) | ( )   |
4. Pada anak anda umur berapakah ruam-ruam gatal ini mula berlaku? ( ) Bawah 2 tahun  
( ) 2-4 tahun  
( ) 5 tahun atau lebih
5. Adakah ruam ini hilang sepenuhnya pada bila-bila masa dalam 12 bulan yang lepas? Ya    Tidak  
( )   ( )
6. Pada 12 bulan yang lepas, berapa kerapkah secara puratanya, tidur anak anda diganggu disebabkan oleh ruam-ruam gatal ini? ( ) Tidak pernah  
( ) Kurang dari satu malam seminggu  
( ) Satu atau lebih malam dalam seminggu
7. Pernahkah anak anda menghadapi penyakit kulit? Ya    Tidak  
( )   ( )

**B: SIMPTOM-SIMPTOM HIDUNG**

1. Pernahkah anak anda mempunyai masalah bersin, hidung berair, serta tersumbat apabila anda TIDAK menghadapi selsema ataupun demam? Ya    Tidak  
( )   ( )  
**Jika anda menjawab 'TIDAK', sila terus ke soalan C**
2. Dalam 12 bulan yang lepas, adakah anak anda mempunyai masalah bersin, ataupun hidung berair, serta tersumbat apabila anda TIDAK menghadapi selsema ataupun demam? Ya    Tidak  
( )   ( )

## BORANG SOAL SELIDIK

3. Dalam 12 bulan yang lepas, pernahkah masalah hidung anak anda ini disertai dengan mata berair yang gatal? **Ya Tidak**  
( ) ( )
4. Pada bilakah dalam 12 bulan yang lepas, masalah hidung ini terjadi?
- |              |           |               |
|--------------|-----------|---------------|
| Januari ( )  | Mei ( )   | September ( ) |
| Februari ( ) | Jun ( )   | Oktober ( )   |
| Mac ( )      | Julai ( ) | November ( )  |
| April ( )    | Ogos ( )  | Disember ( )  |
5. Dalam 12 bulan yang lepas, masalah hidung ini mengganggu aktiviti harian anak anda?
- ( ) Tidak sama sekali  
( ) Sedikit  
( ) Sederhana  
( ) Banyak

### C: ALAHAN

1. Berapa banyakkah jangkitan pada paru-paru yang anak anda alami semasa 3 bulan yang lepas?  
\_\_\_\_\_ (nombor)
2. Pernahkah anak anda menggunakan antibiotic untuk melawan jangkitan pada paru-paru semasa 12 bulan yang lepas?
- |                     |                   |                              |
|---------------------|-------------------|------------------------------|
| <b>Tidak pernah</b> | <b>Ya, sekali</b> | <b>Ya, lebih dari sekali</b> |
| ( )                 | ( )               | ( )                          |
3. Adakah anak anda mempunyai apa-apa penyakit yang memerlukan berjumpa dengan doctor?  
Jika ya, penyakit apa?  
\_\_\_\_\_ **Ya Tidak**  
( ) ( )
6. Adakah anak anda terlalu sensitif /alah kepada:
- |                     |           |              |
|---------------------|-----------|--------------|
| Kucing/anjing       | <b>Ya</b> | <b>Tidak</b> |
| Objek yang berkulat | ( )       | ( )          |
| Debunga             | ( )       | ( )          |
| Debu/habuk          | ( )       | ( )          |
7. Adakah anak anda mempunyai alahan kepada makanan?  
Jika ya, apa penyebab reaksi alahan itu?  
\_\_\_\_\_ **Ya Tidak**  
( ) ( )
8. Lain-lain alahan: \_\_\_\_\_

# BORANG SOAL SELIDIK

## D: PENYAKIT ALAHAN DI KALANGAN AHLI KELUARGA YANG LAIN

1. Bilangan jumlah adik beradik yang lebih tua, kesemuanya: \_\_\_\_\_
2. Jumlah adik-beradik yang lebih tua yang tinggal di rumah sekarang: \_\_\_\_\_
3. Jumlah adik beradik yang lebih muda, kesemuanya: \_\_\_\_\_
4. Jumlah adik-beradik yang lebih muda yang tinggal di rumah sekarang: \_\_\_\_\_
5. Adakah terdapat penyakit alahan di dalam keluarga? Tandakan X pada yang berkenaan walaupun simptom itu sudah tiada.

|                       | Bapa | Ibu | Adik-beradik |
|-----------------------|------|-----|--------------|
| Asma                  | ( )  | ( ) | ( )          |
| Alahan simptom hidung | ( )  | ( ) | ( )          |
| Alahan pada kulit     | ( )  | ( ) | ( )          |

## BAHAGIAN 4: TENTANG ZAMAN KANAK-KANAK

1. Adakah anak anda diberi susu ibu ketika kecil? Ya    Tidak  
Jika ya, sehingga umur berapa? \_\_\_\_\_ ( )    ( )
2. Adakah sesiapa di dalam keluarga yang merokok dari anak anda lahir sehingga berumur setahun? Ya    Tidak  
( )    ( )  
Bapa merokok ( )    ( )  
Ibu merokok ( )    ( )  
Ahli keluarga lain merokok ( )    ( )
3. Adakah anak anda dihantar ke tempat jagaan/nurseri? Ya    Tidak  
( )    ( )  
Jika ya, pada umur berapakah anak anda mula dihantar ke tempat jagaan/nurseri? \_\_\_\_\_

## BAHAGIAN 5: PERSEKITARAN RUMAH SEKARANG

1. Apakah jenis rumah yang didiami sekarang? Sila tandakan di kotak sebelah:  
Teres ( )  
Banglo ( )  
Apartment ( )  
Flat ( )  
Kampung/felda ( )  
Jenis-jenis lain ( )
2. Berapa buah bilikkah yang terdapat di dalam rumah sekarang? \_\_\_\_\_ buah
3. Berapakah anggaran keluasan tempat kediaman anda? \_\_\_\_\_
4. Berapa orangkah yang tinggal di dalam rumah ini? \_\_\_\_\_ orang

## BORANG SOAL SELIDIK

5. Lokasi rumah dari jalanraya :
- |                                |     |       |
|--------------------------------|-----|-------|
| < 100 meter dari jalanraya     | Ya  | Tidak |
| > 100-500 meter dari jalanraya | ( ) | ( )   |
| >500-1000 meter dari jalanraya | ( ) | ( )   |
| >1000 meter dari jalanraya     | ( ) | ( )   |
6. Apakah pendapat anda mengenai persekitaran rumah anda? ( ) Sangat berhabuk  
( ) Sederhana berhabuk  
( ) Kurang berhabuk
7. Bahan apakah yang digunakan dalam pembinaan rumah anda? ( )
- |                         |     |  |
|-------------------------|-----|--|
| Batu                    | ( ) |  |
| Konkrit                 | ( ) |  |
| Batu-bata               | ( ) |  |
| Kayu                    | ( ) |  |
| Bahan-bahan lain: _____ |     |  |
8. Adakah bahagian dalam rumah anda dicat dalam 12 bulan yang lepas? ( ) Ya ( ) Tidak
9. Adakah lantai rumah anda ditukar sejak 12 bulan yang lepas? ( ) Ya ( ) Tidak
10. Adakah terdapat binatang peliharaan didalam kediaman anda? ( ) Ya ( ) Tidak  
Jika ya, binatang jenis apakah ia? \_\_\_\_\_
11. Adakah mana-mana yang berikut dikenalpasti di tempat kediaman anda dalam 12 bulan yang lepas?
- 12.
- |   | Ya  | Tidak |
|---|-----|-------|
| Air bocor dan merosakkan dinding,lantai atau siling   | ( ) | ( )   |
| Buih atau luntur kuning pada pelapik plastik lantai ataupun luntur hitam pada lantai yang berkarpet | ( ) | ( )   |
| Kulat tumbuh di dinding,lantai, atau siling   | ( ) | ( )   |
| Bau kulat di mana-mana bilik (kecuali bilik bawah tanah)  | ( ) | ( )   |
| Bau-bau lain di dalam rumah.jika YA, nyatakan bau itu   | ( ) | ( )   |
| _____   |     |       |
13. Adakah masalah lembap/kerosakan air berlaku di tempat kediaman anda dalam 5 tahun yang lepas? ( ) Ya ( ) Tidak
14. Apakah alat yang anda gunakan untuk membersihkan debu dan kotoran didalam rumah anda?(boleh tanda melebihi 1)
- |              |     |  |
|--------------|-----|--|
| Penyapu      | ( ) |  |
| Penyapu lidi | ( ) |  |
| Vakum        | ( ) |  |
| Mop          | ( ) |  |
15. Adakah anda menguna karpet di rumah? ( ) Ya ( ) Tidak
- |                   |     |     |
|-------------------|-----|-----|
| Ruang tamu        | ( ) | ( ) |
| Bilik kanak-kanak | ( ) | ( ) |
16. Adakah terdapat asap rokok di dalam rumah? ( ) Ya
- |                                  |     |  |
|----------------------------------|-----|--|
| Ya, setiap hari                  | ( ) |  |
| Ya, biasanya 1-4 kali seminggu   | ( ) |  |
| Ya,kadang-kadang 1-3kali sebulan | ( ) |  |
| Tidak pernah                     | ( ) |  |

## BORANG SOAL SELIDIK

17. Ahli keluarga yang merokok:
- |                            | Ya  | Tidak |
|----------------------------|-----|-------|
| Bapa merokok               | ( ) | ( )   |
| Ibu merokok                | ( ) | ( )   |
| Ahli keluarga lain merokok | ( ) | ( )   |
- Anggaran berapa batang rokokkah yang dihisap oleh individu diatas di persekitaran dalam rumah sehari? \_\_\_\_\_ batang
18. Apakah bahan api yang diguna untuk memasak di dalam rumah anda?
- |              |     |     |
|--------------|-----|-----|
| Elektrik     | ( ) | ( ) |
| Minyak tanah | ( ) | ( ) |
| Kayu api     | ( ) | ( ) |
| Gas          | ( ) | ( ) |
| Arang        | ( ) | ( ) |
19. Berapa kali dalam sehari anda gunakan untuk memasak? \_\_\_\_\_kali
20. Semasa memasak, adakah anda membuka tingkap atau pintu untuk membenarkan pengaliran udara di dalam rumah? .
- |  | Ya  | Tidak |
|--|-----|-------|
|  | ( ) | ( )   |
21. Adakah anda menggunakan bahan tertentu untuk mengelakkan daripada serangan nyamuk?
- |  | Ya  | Tidak |
|--|-----|-------|
|  | ( ) | ( )   |
22. Jika **YA** untuk soalan 17, apakah jenis yang selalu digunakan?
- |                   |     |     |
|-------------------|-----|-----|
| Lingkar biasa     | ( ) | ( ) |
| Semburan aerosol  | ( ) | ( ) |
| Elektrik          | ( ) | ( ) |
| Lain-lain : _____ | ( ) | ( ) |
23. Berapa kerapkah penggunaan dalam masa seminggu? \_\_\_\_\_kali
24. Dimanakah ianya ditempatkan di dalam rumah?
- |                         |     |     |
|-------------------------|-----|-----|
| Di ruang tamu sahaja    | ( ) | ( ) |
| Di bilik                | ( ) | ( ) |
| Di bilik dan ruang tamu | ( ) | ( ) |
25. Apakah alat yang digunakan untuk menyejukkan udara dalam rumah?
- |                |     |     |
|----------------|-----|-----|
| Penyaman udara | ( ) | ( ) |
| Kipas          | ( ) | ( ) |

**BAHAGIAN 6: MAKLUMAT TENTANG TABIAT PEMAKANAN KANAK-KANAK SEKARANG**

| Adakah anak anda menggemari makanan yang lepas?                                      | Tidak pernah | Jarang sekali | Sekali seminggu | Lebih sekali seminggu | Hampir setiap hari |
|--|--------------|---------------|-----------------|-----------------------|--------------------|
| Berapa kerapkah anak anda makan daging?  | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda makan ikan?  | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda makan makanan laut?  | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda makan buah-buahan?   | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda makan ulam-ulaman?   | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda makan sayur yang dimasak?                                  | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda meminum susu?  | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda mengambil makanan tenusu? (yogurt, keju, mayonis dll)      | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda makan makanan segera? (burger, pizza, hotdog, nugget, dll) | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda minum jus buah-buahan?                                     | ( )          | ( )           | ( )             | ( )                   | ( )                |
| Berapa kerapkah anak anda minum air bergas?  | ( )          | ( )           | ( )             | ( )                   | ( )                |

2. Apakah jenis minyak masak yang sering digunakan di rumah anda?

- Mentega Ya ( ) Tidak ( ) Tidak tahu ( )
- Margerin ( ) ( ) ( )
- Minyak jagung ( )
- Minyak kelapa sawit ( )
- Minyak sayuran ( )
- Lain-lain ( )

**BAHAGIAN 7: SIMPTOM SEMASA**

Adakah anak anda mengalami simptom-simptom berikut dalam masa 3 bulan yang lepas?

|  | Ya, setiap hari | Ya, 1-4 kali seminggu | Ya, kadang-kadang 1-3 kali sebulan | Tidak pernah |
|--|-----------------|-----------------------|------------------------------------|--------------|
| 1. Ruam di tangan                          | ( )             | ( )                   | ( )                                | ( )          |
| 2. Ruam di muka/tekak                      | ( )             | ( )                   | ( )                                | ( )          |
| 3. Sakit kulit.<br>Jika ya, di mana? _____ | ( )             | ( )                   | ( )                                | ( )          |
| 4. Gatal-gatal di muka/tekak               | ( )             | ( )                   | ( )                                | ( )          |
| 5. Gatal-gatal di tangan                   | ( )             | ( )                   | ( )                                | ( )          |
| 6. Radang mata (merah, kering, gatal)      | ( )             | ( )                   | ( )                                | ( )          |
| 7. Bengkak kelopak mata                    | ( )             | ( )                   | ( )                                | ( )          |
| 8. Sakit kepala                            | ( )             | ( )                   | ( )                                | ( )          |
| 9. Loya                                    | ( )             | ( )                   | ( )                                | ( )          |
| 10. Hidung berair/selsema                  | ( )             | ( )                   | ( )                                | ( )          |
| 11. Hidung tersekat/tersumbat              | ( )             | ( )                   | ( )                                | ( )          |
| 12. Kering tekak                           | ( )             | ( )                   | ( )                                | ( )          |
| 13. Sakit tekak                            | ( )             | ( )                   | ( )                                | ( )          |
| 14. Radang batuk                           | ( )             | ( )                   | ( )                                | ( )          |
| 15. Susah bernafas                         | ( )             | ( )                   | ( )                                | ( )          |
| 16. Penat dan tak berdaya                  | ( )             | ( )                   | ( )                                | ( )          |

1. Adakah simptom-simptom ini bertambah baik bila balik dari sekolah? Ya    Tidak    Tidak tahu  
( )    ( )    ( )  
Jika YA, simptom yang mana?  
\_\_\_\_\_

2. Adakah simptom-simptom ini bertambah baik bila berjauhan dari tempat tinggal? Ya    Tidak    Tidak tahu  
( )    ( )    ( )  
Jika YA, simptom yang mana?  
\_\_\_\_\_

**APPENDIX 4:**

**WORK PLAN**



**APPENDIX 5:**

**RESEARCH PHOTOGRAPH**



Photograph 1: Preschool Children During Their Class Session



Photograph 2: NIOX MINO Visual Display on Computer Screen



Photograph 3: FeNO Measurement