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COMPOSITION, SOURCE APPORTIONMENT AND HEALTH RISK ASSESSMENT OF INDOOR PARTICULATE MATTER ($PM_{2.5}$) IN SELECTED MALAYSIA TRAINING INSTITUTES

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INTAN IDURA BINTI MOHAMAD ISA

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MASTER BY RESEARCH

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ABSTRACT

This study aimed to determine the composition, source apportionment and health risk assessment (HRA) of indoor particulate matter ($PM_{2.5}$) in selected Malaysia training institutes. $PM_{2.5}$ samples were collected from lecture halls, laboratories and lecturer offices in Institut Latihan Kementerian Kesihatan Malaysia Sungai Buloh (SB) and Institut Latihan Kementerian Kesihatan Malaysia Sultan Azlan Shah (SAS). Sampling were conducted over a period of eight hours sampling for five consecutive days with a total number of 30 samples. The samples were collected on 47 mm micro fiber glass filter paper (0.2 µm pore size, Whatman) using low volume air sampler (LVS) at 5 L min^{-1} flow rate. The composition of $PM_{2.5}$ for water-soluble ionic species (WSIS) and trace metals were determined using ion chromatography (IC) and inductively coupled plasma-mass spectrometry (ICP-MS), respectively. Source apportionment of $PM_{2.5}$ was determined using the combination of Principal Component Analysis and Multiple Linear Regression (PCA-MLR) receptor model. HRA was conducted to evaluate the potential health hazard to adolescent and adult groups in the institutes. The result showed that the mean of $PM_{2.5}$ at SB (51.39 ± 29.95 µg m^{-3}) was higher than SAS (45.83 ± 20.47 µg m^{-3}). However, most of WSIS and trace metals were found higher at SAS compared to SB. PCA-MLR results identified four factors, where the main sources of $PM_{2.5}$ in SB and SAS were biomass burning (48%) and building material / crustal origin (81%), respectively. The adult group has higher hazard index (HI) and incremental lifetime carcinogenic risk (ILCR) values than adolescent group for both institutes. In conclusion, these two institutes have moderate level of air quality, but they have the potential to develop adverse health effects. As an implication, this study has provided a holistic view of indoor air quality, hence the effective control strategies need to be implemented to enhance indoor air quality for the comfort of all building occupants.

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KOMPOSISI, PENCIRIAN SUMBER DAN PENILAIAN RISIKO KESIHATAN KE ATAS ZARAHAN TERAMPAI ($PM_{2.5}$) DALAMAN DI INSTITUSI LATIHAN MALAYSIA TERPILIH

ABSTRAK

Kajian ini bertujuan untuk menentukan komposisi, pembahagian sumber dan penilaian risiko kesihatan (HRA) bahan zarah dalaman ($PM_{2.5}$) di institusi latihan terpilih di Malaysia. Sampel $PM_{2.5}$ dikumpulkan dari dewan kuliah, makmal dan pejabat pensyarah di Institut Latihan Kementerian Kesihatan Malaysia Sungai Buloh (SB) dan Institut Latihan Kementerian Kesihatan Malaysia Sultan Azlan Shah (SAS). Persampelan dilakukan dalam jangka masa lapan jam selama lima hari berturut-turut dengan jumlah 30 sampel. Sampel dikumpulkan pada kertas turas bergentian mikro kaca 47 mm (saiz liang 0.2 µm, Whatman) menggunakan pensampel udara berisipadu rendah (LVS) dengan kadar aliran 5 L min^{-1}. Komposisi $PM_{2.5}$ bagi spesies ionik larut air (WSIS) dan logam surih masing-masing ditentukan menggunakan kromatografi ion (IC) dan plasma gandingan aruhan-spektrometer jisim (ICP-MS). Pembahagian sumber $PM_{2.5}$ ditentukan dengan menggunakan gabungan model reseptor Analisis Komponen Utama dan Regresi Linear Berganda (PCA-MLR). HRA dijalankan untuk menilai potensi bahaya kesihatan kepada kumpulan remaja dan dewasa di institusi tersebut. Hasil kajian menunjukkan purata $PM_{2.5}$ di SB (51.39 ± 29.95 µg m-3) adalah lebih tinggi daripada SAS (45.83 ± 20.47 µg m-3). Walau bagaimanapun, kebanyakan WSIS dan logam surih didapati lebih tinggi di SAS berbanding SB. Hasil PCA-MLR mengenal pasti empat faktor, di mana sumber utama $PM_{2.5}$ di SB dan SAS masing-masing adalah pembakaran biomas (48%) dan bahan binaan / kerak asal (81%). Kumpulan dewasa mempunyai nilai indeks bahaya (HI) dan peningkatan risiko karsinogenik seumur hidup (ILCR) yang lebih tinggi berbanding kumpulan remaja bagi kedua-dua institusi tersebut. Kesimpulannya, kedua-dua institusi ini mempunyai tahap kualiti udara yang sederhana, tetapi mereka mungkin terdedah kepada kesan buruk terhadap kesihatan. Sebagai implikasi, kajian ini dapat memberikan gambaran holistik terhadap kualiti udara dalaman, oleh itu strategi kawalan yang efektif perlu dilaksanakan untuk meningkatkan kualiti udara dalaman bagi keselesaan semua penghuni bangunan.

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LIST OF ABBREVIATIONS

ADD	Average Daily Dose
ANOVA	Analysis of Variance
APCS	Absolute Principal Component Scores
AT	Averaging Time
ATSDR	Agency for Toxic Substances and Disease Registry
BRI	Building-Related Illness
BW	Body Weight
CA	Cluster Analysis
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CR	Cancer Risk
CSF	Cancer Slope Factor
DOSH	Department Safety and Health
ED	Exposure Duration
EF	Enrichment Factor
e.g.	For Example
et al	(et alia): and others

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FESEM	Field Emission Scanning Electron Microscopy
HI	Hazard Index
HQ	Hazard Quotient
HRA	Health Risk Assessment
IAQ	Indoor Air Quality
IC	Ion Chromatography
ICP-MS	Inductively Coupled Plasma- Mass Spectrometry
i.e	(id est): it is
ILCR	Incremental Lifetime Cancer Risk
ILKKM	Institusi Latihan Kementerian Kesihatan Malaysia
IR	Inhalation Rate
MDL	Method Detection Limit
NAAQS	National Ambient Air Quality Standard
PCA	Principal Component Analysis
PM	Particulate Matter
$PM_{2.5}$	Particles with an aerodynamic diameter less than and equal 10µm
PM_{10}	Particles with an aerodynamic diameter below than 10µm
QA/QC	Quality Assurance/Quality Standard
RH	Relative Humidity (%)
R_fD	Reference Dose
SBS	Sick Building Syndrome

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SPSS	Statistical Package for Social Science
SRM	Standard Reference Material
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation
WSIS	Water-Soluble Ionic Species

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H	Conference Attended
I	Article Accepted
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CHAPTER 1

INTRODUCTION

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1.1 Overview

This chapter provides the important basic information and the concept of this research. This chapter explain about the background of the research, the problem statement, research objectives, the significance of the study, thesis outline for each chapter and describe the conceptual framework of the study.

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1.2 Research Background

Indoor air quality (IAQ) always been topic of discussion in the 21st century. This is mainly due to most of people spend a longer time in indoor environment and have been exposed to indoor pollutants that will cause health problems (Saraga, Pateraki, Papadopoulos, Vasilakos, & Maggos, 2011). IAQ refers to the nature of the conditioned (heat/cool) air that circulates throughout space or area where peoples work and live. IAQ is the one of the important components in environment workplace that will be important for international codes of practices (NIOSH, 2015). The selected indoor air quality parameters and their acceptable limits is proposed by the Industrial Code of Practise on Indoor Air Quality (ICOP) (2010) that was published by the Department of Occupational Safety and Health, Malaysia (DOSH). Each IAQ parameter shall be ensured to comply with acceptable limits in order to maintain a good IAQ.

Poor IAQ may cause sick building syndrome (SBS) which affects occupant's health and well-being. SBS may also contributes to reduced productivity and absenteeism in the workplace as well (S. K. Wang et al., 2017). These problems seem to be related to the new building that has inadequate ventilation and a very effective barrier against the infiltration of air along with materials containing solvents, adhesives and other chemicals which were released into the indoor air. They are also associated with older buildings that have issues with moisture and mold related (Straus, 2009). Other factors such as indoor temperatures, relative humidity, and ventilation levels can also affect how individuals respond to the indoor environment (NIOSH, 2010).

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Academic buildings are important for lecturers and students, and it is slightly different than those commercial buildings in terms of the types of usage and the activities performed by occupants. The density of occupants in academic building are higher than offices as an academic building was fully occupied during the academic semester (Clements-Croome et al., 2008). The students and lecturer movement in and out of the building will lead the outdoor dust brought into the classroom. Improper ventilation system with poor maintenance will brings in small particulate matter into indoor environment (Braniš, Řezáčová, & Domasová, 2005). School and university students will stay longer in the internal environments compared with individuals at work (Ashmore & Dimitroulopoulou, 2009; Chithra & Shiva Nagendra, 2012; Raysoni et al., 2013). A poor IAQ in a university building can affect productivity as well as the health problems to occupants (Zhong et al., 2014) and has a correlation with student's performance as well (Mohai, Kweon, Lee, & Ard, 2011).

Air pollutants are absorbed into the indoor particulate matter and will settle as indoor dust (Latif et al., 2014). Indoor air pollutants may come from various sources depending on the activity of the occupants, the building location, internal sources such as interior building emission and external sources, e.g., fuel combustion (Mohamad, Latif, & Khan, 2016; Yang Razali et al., 2015). External contaminants have been recognized as a major source of indoor pollutants through air, water and soil penetration (Srivastava & Jain, 2007). The production of air pollutants in indoor and outdoor sources can directly affect the environment and health. Many previous epidemiological studies have suggested the association between the inhalation of air pollutants and increased mortality and morbidity (J.L. et al., 2011).

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1.3 Problem Statement

As a result of changes in the life and work habits, people now live in industrialized countries and spent more than 90% of the time in the building in their daily life (Hermann Fromme, 2012). It was shown that the number of airborne particles in the indoor environment can change accordingly to space but also in terms of time. In addition to the current situation where the outside air is close to indoor air (e.g. location close to heavily traffic roads or in rural areas), the current climatic conditions, the structure of the building and types of ventilation system used are important (Hermann Fromme, 2012).

Particulate matter poses more danger to human health than other common air pollutants (such as formaldehyde, carbon monoxide and ozone) (WHO 2013). The main pollutant in airborne particle is fine particulate matter ($PM_{2.5}$), which has an aerodynamic diameter of less than 2.5μm and may penetrate deep into human lungs. $PM_{2.5}$ can also run a variety of components such as heavy metals, bacteria, viruses and volatile organic compounds, due to its high penetration capability (Cao et al., 2011). In addition, $PM_{2.5}$ can result in greater harmfulness due to its smaller size (Wei Huang et al., 2012). For a modern office building, in which the particles do not have strong internal resources such as cleaning, indoor $PM_{2.5}$ may be the major source of indoor particle (Matson, 2005). Several studies determining the levels of PM in classroom, especially in Europe and Asia, have shown the high levels for both $PM_{2.5}$ and PM_{10} (Almeida et al., 2011; Borgini et al., 2011; D. D. Massey, Kulshrestha, & Taneja, 2013).

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Furthermore, several studies explained the particulate matter that consists of heavy metal or other indoor pollutants can enter the body directly via inhalation, oral ingestion and dermal contact exposure pathways (Sun, Jing, Chang, Chen, & Zeng, 2015; Wei, Gao, Wang, Zhou, & Lu, 2015). The composition of heavy metal such as Fe, As and Pb in indoor particulate matter can result in cancer and cardio injury (Massey et al., 2013). Besides that, the biological components of the environment such as microbial compound and allergens have also been emphasized because of their potential to cause health problems as particulate matter (Kim, Kabir, & Kabir, 2015).

The health problems of air pollution from both the indoor and outdoor environment have been concerned due to the risk of high exposure even at low concentrations of air pollutants. Estimated more than two million deaths to occur globally every year because of lungs and respiratory system failure due to air pollution. From these deaths, about 2.1 million are caused by $PM_{2.5}$ (Shah et al., 2013). Failure to take prompt and efficient action on the poor IAQ problems can have tremendous bad effects on human health. Furthermore, previous study has been conducted by Environmental Protection Agency (EPA) which stated that indoor air pollution is among the top five of the environmental health risks (WHO 2009). Many studies proved that indoor air contains a higher levels of pollutants compared with outdoor air (Abdul-Wahab, 2006; Diapouli, Chaloulakou, Mihalopoulos, & Spyrellis, 2008; Gioda, Fuentes-Mattei, & Jimenez-Velez, 2011). Some studies suggested that indoor air pollutants exposure can be associated with adverse health effects such as respiratory, allergies and cardiovascular diseases, skin irritation and cancer (D. Massey, Kulshrestha, Masih, & Taneja, 2012; Sloan et al., 2012; Young et al., 2011). Mohd

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Talib Latif et al. (2009) have shown that indoor dust contains a quantity of heavy metals that can potentially cause health problems to building occupants. With that, the health risk assessment has been conducted in previous research to determine the potential risks associated with toxic contaminants exposures (USEPA, 2016).

Hu et al. (2012) found that internal activities have the potential health risks that could be linked with airborne composition which can be obtained from food and beverages, arising from skin contact and particulate inhalation. Therefore, the health risks associated with composition of heavy metal in indoor particulate matter need to be assessed especially for $PM_{2.5.}$ The Occupational Safety and Health Committee of both institutes has received complaints about poor indoor air quality from students and staff. They complained about a lack of energy at the workplace which can be correlated with the physical conditions in working environment. Therefore, this study aims to measure the comfort parameter and determine the chemical composition of $PM_{2.5}$ in indoor environment and identify its possible sources to provide holistic view of current status of indoor air quality so that the authorities can come up with strategies to enhance building occupants' comfort. Besides that, health risk assessment (HRA) also will be conducted to know in detail the health risks that associated with $PM_{2.5}$ in Institusi Latihan Kementerian Kesihatan Malaysia Sungai Buloh (ILKKM SB) and Institusi Latihan Kementerian Kesihatan Malaysia Sultan Azlan Shah (ILKKM SAS).

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1.4 Research Objectives

This study aimed to conduct a comprehensive assessment of $PM_{2.5}$ chemical compositions, its possible sources and the health risk to the selected exposed population groups. The specific objectives of this study are as follows;

i. to determine the mass concentrations and composition of $PM_{2.5}$ in ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah.

ii. to identify and apportion the possible sources that contributes to the $PM_{2.5}$ concentration and composition.

iii. to estimate the target population health risks due to metal exposures to $PM_{2.5}$ based on carcinogenic and non-carcinogenic risks.

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1.5 Significance of the Study

Indoor air quality always been topic of discussion in Malaysia lately and research on indoor air and its affect to human health is a new field. Due to limitation of scientific data monitoring on indoor environment conducted in Malaysia, there will be difficult to find significant health risk associate with the office environment and learning institutions. Traditionally, buildings in Malaysia were wooden buildings with good natural ventilation but nowadays concrete buildings dominate. Some buildings have air

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conditioning units (A/C), which are not always cleaned, with possible additional fungal growth. The high temperature and high humidity may increase microbial growth.

Ambient particulate matter (PM) presents a special challenge, and it has not even been established conclusively which of its characteristics are the most significant in relation to health. Apportioning indoor exposure to the two components essential for exposure control, including PM of outdoor origin (which has penetrated indoors) and PM generated by indoor sources, is a complexity with which many studies have struggled. Since the role of internal particle generated is not fully recognized as well as to conduct the epidemiological assessment is a challenge, a better method exposure or risk assessment is still required, along with a serious focus on the control of exposure (Morawska et al., 2013).

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Exposure is a vital element of risk assessment, a process which is initiated upon identification of a hazard, and evidence that exposure constitutes risk to human health which health risk assessment is required to link the hazard with the risk to the exposed population in a quantitative way, and thus provide the basis for risk management. Other than that, there is lack of data on the indoor environment in higher learning institutions in Malaysia as well. Thus, this illustrates the more need indoor air quality studies in Malaysia higher learning institutions which may increase the knowledge on the health significance of chemical element presence in indoor particulate matter in indoor. Hopefully, this research would provide the better understanding to the authorities to come out with the effective control strategies for indoor air quality enhancement.

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1.6 Conceptual Framework of the Study

This study involves quantitative approach which include on site sampling, laboratory analysis and health risk assessment. This study was divided into four main results which are the comfort parameter assessment, chemical composition, source apportionment and health risk assessment. Figure 1.1 summarized the simplified conceptual framework design that has been applied in this study.

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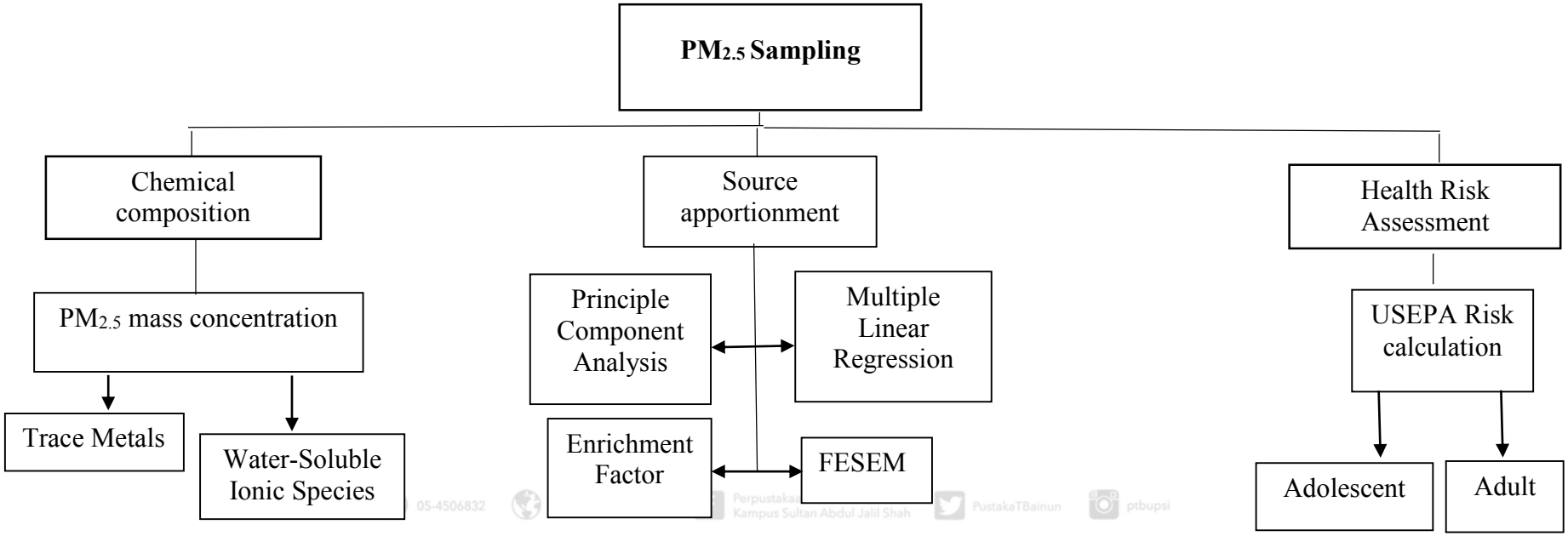


Figure 1.1. Conceptual framework design for the study

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1.7 Chapter Summary

This chapter presents an overview of the research including the background of the study and problem statements that points out the main motivation to carry out throughout this study, research objectives describes the main aims to be achieved in the end of this study, the significance of the study as well as the framework of the research.

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CHAPTER 2

LITERATURE REVIEW

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2.1 Introduction

This chapter will describe in detail on indoor air quality and the factors that will affect the quality of indoor air such as particulate matter, bioaerosols and physical parameter (temperature, relative humidity and ventilation). Besides that, the outcomes from previous study also been discussed including the composition of heavy metals in particulate matter, health risk assessment and sick building syndrome survey. The legislative requirement that related to indoor $PM_{2.5}$ are also been discussed.

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2.2 Indoor Air Quality

Indoor air quality (IAQ) does not have standard or universal definition where it is a part of indoor environmental quality (IEQ), including physical factors such as temperature, relative humidity, noise, lighting and ergonomics in addition to pollutants (Steinemann, Wargocki, & Rismanchi, 2016). United States Environmental Protection Agency (EPA, 2016) defines IAQ as quality of air within and around buildings and structures, especially when related to health and comfort of occupants inside the buildings. Indoor air quality (IAQ) is more important than outdoor air because most of people spent more than 80% of the day indoors (Chen, Chuang, & Lin, 2009). Furthermore, the level of indoor air pollutant can be five times higher that outdoor air (DOSH, 2010).

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Poor IAQ may lead to adverse health effect in office workers and schools and it has largely been ignored by building owners and organization. Nowadays an IAQ becomes a complex issue involving a multitude of factors. IAQ problems arise in non-industrial buildings, an indoor or enclosed work space that is served by a common ventilating or air conditioning system where there is person at work, but does not include premises that are used primarily as manufacturing and production facilities and vehicles. There is an inadequate quantity of ventilation is being provided for amount of air contaminants present in that space. Hence, IAQ and heating, ventilation and air-conditioning systems (HVAC) are closely related (DOSH, 2010).

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IAQ also deals with the content of interior air that could affect health and comfort of building occupants. The IAQ may be compromised by microbial contaminants (fungi, bacteria), particulate matter, carbon dioxide, carbon monoxide, nitrogen dioxide, ozone, radon, formaldehyde and volatile organic compounds (VOCs). Thus, it can lead to Sick Building Syndrome, Building Related Illnesses, pneumonia and cancer depends on severity and frequency of exposures (Leung & Chan, (2006). Therefore, it is important for IAQ monitoring and ensure that its levels are optimum for prosperity to building occupants Wang et al. (2017). The measurement of IAQ parameters will give hints to the building management to take necessary action to make sure that all occupants in the building are safely protected (Simon & Butala, 2004).

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2.2.1 Factors Affecting Indoor Air Quality

There are many factors that can lead to the poor indoor air quality. Indoor air often contains a variety of contaminants such as particulate matter, airborne microorganisms, toxic gaseous and volatile organic compounds (VOCs) generated by anthropogenic activities such as construction, transportation and industrial processes (Choo, Jalaludin, & Hashim, 2014). Temperature is one of the essential parameters needed in the indoor air quality. Occupants who felt warm over the workplace temperature will rate their work environment as poor (Paul & Taylor, 2008). Most people work comfortably at temperature between 20-26℃ as recommended in the Malaysia Guidelines on Occupational Safety and Health in The Office (DOSH, 1996). Meanwhile, Industry Code of Practice for Indoor Air Quality 2010 has specified temperature of 23-26 ℃ as

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an acceptable range for physical parameter (ICOP IAQ, 2010, ASHRAE Standard 55, 2004).

For management of moisture in the built environment, it is important to keep the indoor relative humidity (RH) at a correct level (Woloszyn, Kalamees, Abadie, Steeman, & Sasic Kalagasidis, 2009). RH is the amount of water vapor in a mixture in the air. At low indoor RH condition, it can cause several health effects such as sensory irritation of the upper respiratory tract, skin, eyes and mucous membranes dryness (Wolkoff & Kjaergaard, 2007). But, with high indoor RH level, it can be associated with serious moisture problems for the indoor climate and building envelope due to microorganisms growth (Bornehag et al., 2004) and house dust mites (Arlian, Neal, & Vyszenski-Moher, 1999). The optimum comfort range for indoor RH is 40-70 % as recommended in the Malaysian Industry Code of Practice on indoor Air Quality 2010.

Other than that, ventilation also plays a vital role to guarantee good IAQ. Ventilation is essential to maintain healthy IAQ, as it circulates air within the building as well as exchanges the inside air with the outside air. Certain factors are associated with improper ventilation such as when it is not properly designed, maintained and managed where it will allow the inflow of harmful substances that degrades the IAQ (Olli Seppänen, 2007). Some indoor pollutants may originate from outside and are transported indoors through windows, doors and any opening gaps such as gaps under doors or through cracks in the building. Ventilation with the use of windows will speed up the concentration of the pollutant inside to match with the outdoor level (Lee & Chang 2000). Besides that, ventilation particularly affects air and moisture flow within

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the building and may also result in moisture problems (Olli Seppänen, 2007). Ventilation rate could influence performance indirectly through its impact on short-term sick leave because of infectious diseases, prevalence of sick building syndrome (SBS) symptoms or dissatisfaction with air quality (Seppänen, Fisk, & Lei, 2006). In addition, the rate of production and pollutant release from various indoor sources, the rate of removal of the pollutant from the air through chemical reaction and the rate of air exchange between outdoor air by ventilation will reflect the indoor pollutant concentration (Laumbach, Meng, & Kipen, 2015). ASHRAE Standard 62-2007, entitle Ventilation for Acceptable Indoor Air Quality, contains guideline which recommend that air handling equipment provide a minimum of 20 cubic feet per minute (CFM) of outdoor air (OA) per person in typical administrative office space (ASHRAE, 2007).

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2.2.2 Indoor Air Pollutants and Sources

Indoor air pollutants comprised of particulate matter (PM), biological particles (i.e. bacteria, fungi), gaseous pollutants such as carbon monoxide (CO), carbon dioxide (CO_2) and total volatile organic compound (TVOC). Carbon monoxide is odorless, colorless, tasteless and has weight lighter than the air which can lead to heart, brain and other vital organs failure as CO may displace CO_2 in the blood (OSHA, 1994). Carbon monoxide is the main gaseous pollutant emitted from incomplete hydrocarbon fuel combustion (WHO, 2000). On the other hand, the concentration of CO_2 is influenced by the number of occupants as well as the ventilation rate of the building which it plays a role as an indicator of air circulation. CO_2 level in the building will increase after a

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few hours of people's breathing and when the concentration too high it will cause discomforts of building occupants (General Health, 2012). The long-term exposure to VOCs in the non-industrial indoor environment may cause sensory irritation and toxic effects. In addition, VOCs are the causative agents in asthma and building-related illness (BRI) and can lead to unpleasantness of indoor environment because of odors and dust (Pappas et al., 2000).

Bioaerosols are subcategory of airborne particles that are either living (e.g. bacteria, fungi) or derived from organisms that are always on, highly capable and complex variability and natural or man-made in origin. Recently, analysis of microorganism in built environment gained the attention among researchers (Huttunen et al., 2008). Bacteria and fungi are important to break down complex molecules in organic matter especially when there are water and food sources, microorganisms will multiply in most areas. Types of microorganisms vary depending on local conditions (Industrial Hygiene Associates, 2009). Outdoor microorganism communities have been shown to influence the indoor community through an open door or window. In normal condition, the level of microorganism must be lower than the level in the external environment (Industrial Hygiene Associates, 2009). High humidity, reduced ventilation, tighter buildings and types of HVAC systems used allow for the growth and distributions of various microbial (Meadow et al., 2014). Recommended relative humidity range is from 40% to 60% as appropriate to control microorganisms growth (Alsmo & Holmberg, 2007).

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Many studies reported that microbial communities are totally different between different types of indoor environments such as houses, schools, and hospitals (Kembel et al., 2012; Rintala, Pitkaranta, Toivola, Paulin, & Nevalainen, 2008). Sources of airborne microbial in the indoor contributing factors to this problem (Bowers, McLetchie, Knight, & Fierer, 2011; Bowers, Sullivan, et al., 2011; Täubel et al., 2009). The human occupancy patterns and ventilations strategies environment are not fully known but humans, pets, soils, and plants are among to have significant correlation with the level of airborne microbial in the built environment (Meadow et al., 2014). Human occupancy inside the building will increase the airborne bacterial population (Hospodsky et al., 2012). Excessive amount and concentration of bioaerosol in the indoor air may indicate deterioration of indoor air quality that can lead to various health effects (Cabo Verde et al., 2015; Nevalainen, Täubel, & Hyvärinen, 2015). Exposure to fungi will cause a few illness such as rhinitis, asthma, allergic, bronchopulmonary mycoses, allergic fungal sinusitis and hypersensitivity pneumonitis (Baxi et al., 2016). Many microbial agents able to induce some inflammatory response both *in vivo* and *in vitro* (Miller, Sun, Gilyan, Roy, & Rand, 2010).

In general, there are various sources of pollutants emission into the atmosphere from both natural and anthropogenic origin. Natural release of pollutants is usually due to dust resuspensions, release from oceans or volcanoes. Whereas, the release of anthropogenic pollutants is largely due to fuel burning and industrial emission (Ekmekcioglu & Keskin, 2007). The outdoor particle pathway entering into indoor environment are shown in Figure 2.1. Outdoor pollutants not the only sources of indoor pollutants but pollutants found indoor may be generated from inside the building

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themselves. Cooking activities, heating, cleaning agents, building materials, biological agents (i.e. dust, bacteria), indoor furniture as well as tobacco smoking are the examples of indoor-generated air pollutants (de Gennaro, Farella, Marzocca, Mazzone, & Tutino, 2013). Building occupants are also considered as contributing factor to indoor air pollution as their activities such as walking, movement and sweeping lead to coarse particles resuspension and increase indoor air pollutants concentration (Ramos, Wolterbeek, & Almeida, 2014). The high deposition rate will diminish the indoor air pollutants and resuspension rate will enhance their concentration (H. Fromme et al., 2008).

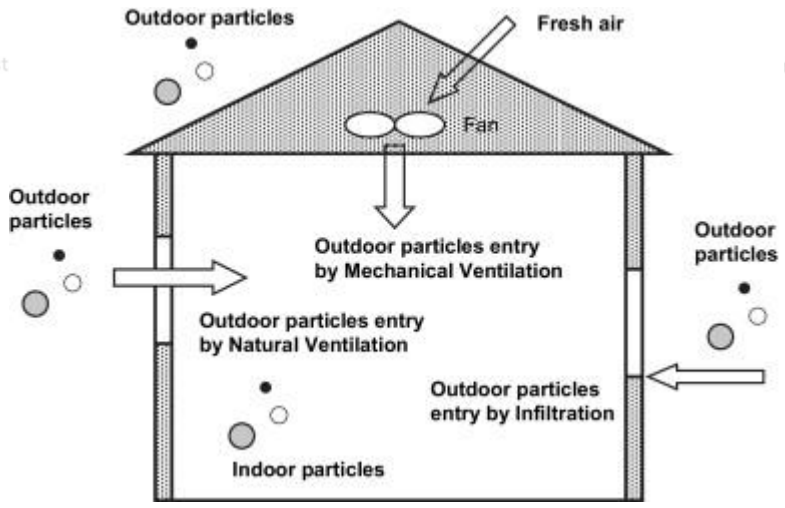


Figure 2.1. Schematic diagram of the outdoor particle pathway entering indoor environment. Source: Chen and Zhao, 2011

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2.3 Particulate Matter

Particulates are solid or liquid matter with aerodynamic diameters ranging from 0.005 to 100 µm, where the size is one of the main criteria to describe the ability of transport in the atmosphere and the ability through a respiratory system (Esworthy, 2013). Environmental Protection Agency divides particle size mainly into two categories based on their ability to penetrate the lungs as either particulate matter course (PM_{10}) with aerodynamic diameter 10µm or fine particulate matter ($PM_{2.5}$) with aerodynamic diameter of 2.5 µm (Esworthy, 2013). The effect of PM depends on the physical characteristics (such as breathing mode, rate and human occupancy), particle size was directly linked to the main cause of health problem (Brown, Gordon, Price, & Asgharian, 2013). Therefore, the smaller the particle is, the deeper it will penetrate and deposit on the respiratory tract at an increasing rate. Particles smaller than 0.1 µm are generally exhaled and most particles above 10 µm will be filtered by the nose. PM_{10} fraction will settles early and cause it to get stuck in the trachea or in the bronchi (Atkinson, Fuller, Anderson, Harrison, & Armstrong, 2010). With that, our body will react through sneezing and coughing to eliminate these intruding PM (Cadelis, Tourres, & Molinie, 2014).

Airborne particulate matter (PM) consists of a heterogeneous mixture of liquid and solid particles suspended in air that continuously vary in chemical compositions and size in space and time. The constituent of chemical in PM diverse enough to include nitrate, sulphate, organic carbon and compounds (such as polycyclic aromatic hydrocarbons), biological compounds (bacteria, fungi) and metals (plumbum, copper,

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aluminium) (WHO 2013). Those particle with less than 10μm diameter will cause the most impact on human health. These particles can penetrate the respiratory tract begins with the nose to alveoli, deep within the lungs caused by their excessive ability to penetrate. Finally, these particles will escape into the blood stream causing significant health problems (Löndahl et al., 2007).

The presence of particles in the indoor air is influenced by the ambient air concentrations, air exchange rates and other factors such as cooking, cleaning, movement and smoking (Fromme et al., 2007). Furthermore, particles in indoor environments transportation and transformation can be influenced by a series of chemical and physical processes which can lead the changes in terms of chemical compositions, their physical characteristics, their distribution patterns that will determine the final number of particles (Nazaroff, 2004).

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2.4 Chemical Composition in Particulate Matter

A lot of research work required to characterize chemical composition in PM. The study of the chemical properties in terms of major components and trace metals is necessary to provide information on several issues like the sources of emissions and the transformations processes of the PM in the atmosphere. The health risk assessment can be conducted using this information as well. The combination of different hundred chemical constituents in the air aerosols making them even more harmful to receivers.

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The example of PM chemical composition is water-soluble ionic species (WSIS) and trace metals (TM).

2.4.1 Water-Soluble Ionic Species (WSIS)

Water-soluble ionic species (WSIS) can be related to chemical species that are easily soluble in water and represents a major components of ambient particulate matter mass concentrations (Voutsa, Samara, Manoli, Lazarou, & Tzoumaka, 2014). WSIS composition in PM are known to have harmful effects on human health. In addition, some inorganic ions, particularly ammonium sulphate $(NH_4)_2SO_4$ can lead decay to stone of the building and monuments and may reduce the visibility due to light-seeing effects. Therefore, the determination of water-soluble ionic species compositions in fine particulate matter is very important to have the overview of their human health effect, bioavailability and radiative forcing properties (Ocskay, Salma, Wang, & Maenhaut, 2006).

WSIS can be released from several sources. The major water-soluble ions, like chloride (Cl^-), sodium (Na^+) and calcium (Ca^{2+}) were released into the atmosphere may originated from different natural and human activities sources and used in coarse fraction. Na^+ and Cl^- are mainly come from sea salt origin and Ca^{2+} originated from soil and road resuspension, construction activities and industrial emission. The secondary of ionic species namely, NO_3^-, SO_4^{2-} and NH_4^+ are produced via chemical reactions of

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gaseous precursors, that come from human activities (i.e. NO_x, SO_2) and biogenic (i.e. NH_3) sources (Galindo, Gil-Moltó, Varea, Chofre, & Yubero, 2013). K^+ plays a role as an indicator of biomass burning (Hays, Fine, Geron, Kleeman, & Gullett, 2005). On the other hand, Mg^{2+} and Ca^{2+} are originated from crustal sources (Deshmukh, Deb, Suzuki, & Kouvarakis, 2013).

2.4.2 Trace Metals

Trace metals represents a small portion of fine particulate matter, but concern has been put as metallic elements are seriously lead to negative impacts on human health and to the ecosystem as well (Cavallari et al., 2008). They are toxic in nature and bio-accumulate in the body via inhalation, ingestion and skin exposures (Singh, Gautam, Mishra, & Gupta, 2011). The heavy metals that also known as carcinogenic compounds such as selenium, arsenic, zinc and cadmium may composited in these particles (Kleeman, Ying, & Kaduwela, 2005). Previous study proved that heavy metal toxicity is a major threat and cause several health effects and risks associated with it (Jaishankar, Tseten, Anbalagan, Mathew, & Beeregowda, 2014).

Metals element can exist in the environment as solids, liquids and vapor (gas) and deposited into particulate matter and salt complexes with water as well. Metals or metalloid including lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), Copper (Cu), selenium (Se), nickel (Ni), silver (Ag), and zinc (Zn) that produced

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in the atmosphere are associated with aerosols. Same as ionic species, trace metals in airborne particles may come from natural and anthropogenic origin. Soil crust consist of metals like Fe, Mn, Zn, Pb, V, Cr, Ni, Co Cu, As and Cd. Anthropogenic origin such as traffic emissions derived from vehicle exhausts will enhance the concentration of toxic metals like Pb, Cu, Fe, Zn and Cd (Han, Zhou, Li, & Li, 2014). Metals can escape control mechanisms such as homeostasis, transport, compartmentalization, and bind to specified cell constituents, so they can have effects and even death (Flora, Mittal, & Mehta, 2008). Other than that, metals act as possible mediators in PM that can induce airway injury and inflammation through the Fenton reaction (Diociaiuti et al., 2001; González-Flecha, 2004).

Moreover, transition metals present in PM, particularly iron, will increase the reactive oxygen species (ROS) production in vivo (Kadiiska, Mason, Dreher, Costa, & Ghio, 1997) where it can cause damage to cellular and tissue then initiate the inflammation (Hitzfeld, Friedrichs, Ring, & Behrendt, 1997). Study done by Gilli et al. (2007) stated that PM that contains transition metals such as iron can contribute the genotoxic effects. Furthermore, there are two ways heavy metals can disrupt the metabolic functions where first they can accumulate and disrupt the function of vital organs and glands such as brain, bone, kidneys, liver and heart. Other than that, they will displace the essential mineral nutrition of their original place and inhibit their biological function (Singh et al., 2011).

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2.5 Sources of Particulate Matter

$PM_{2.5}$ associated with numbers of chemical compounds is emitted from a wide range of natural and anthropogenic sources either as primary particles or secondary formation. Primary particles are derived from natural origin such as mineral dust, sea salt, forest fires, volcanic ash, windstorms and biological agents. $PM_{2.5}$ may be emitted from anthropogenic sources like traffic emission, biomass burning, industrial, coal burning and construction activities (Kong et al., 2011). Vehicular emission is one of the important sources of $PM_{2.5}$ influencing indoor air particulate matter concentration. Mansha et al. (2012) reported that emission from motor vehicle and road dust resuspension are the main contributor to the $PM_{2.5}$ in India. There are a lot of airborne pollutants are released from vehicular emission such as SO_4^{2-}, NO_3^-, NH_4^+, heavy metals and crustal materials as well (Hsu, Lai, Wang, Chiang, & Shieh, 2008). The brake lining of automobile can contribute to Cu and Ba emission and worn off tires can lead to Zn emission (Md Firoz Khan, Hirano, & Masunaga, 2012).

$PM_{2.5}$ emissions that is originating from dust resuspension mostly come from mineral or road dust. Mineral dust is comprised of Ca, Na, Al, K and Si where the mineral dust originated from construction activities increase the Ca/Si ratio (Manousakas et al., 2015). Meanwhile, mineral dust such as Al, Fe, Si, Th and U can be found in soil (Alleman, Lamaison, Perdrix, Robache, & Galloo, 2010). The large-scale industries produce many fine aerosols which their chemical composition depends on the operating procedures and types of fuel used. Trace metals and PAH were found to have large amount in fine particles from industrial combustion (Lidia Morawska &

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Zhang, 2002). In previous study, trace metals like Cd, Cr, Pb and As were come from variety industries origin (García et al., 2006).

The human activities and building materials are characterized by a significant amount of and Ca^{2+} as mineral dust source (Murillo-Tovar et al., 2015). A study by Khan and Hirano (2012) suggested that Ca^{2+} is an indicator of soil dust contribution through shoes of occupants moving in and out from the building. In addition, the resuspended dust from broken cement floor as a result of cleaning activities, also found to contribute the increased Ca^{2+} (Srivastava & Jain, 2007). On the other hand, the sources of air pollution in Southeast Asia (SEA) is related to biomass burning activities (Chang, Hsiao, & Hwang, 2015). The potassium ion (K^{+}) are mainly originated from biomass burning activities (Hasheminassab, Daher, Ostro, & Sioutas, 2014). Table 2.1 presents the summary of sources of airborne particulate matter.

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Table 2.1

Summary of sources of airborne particulate matter

	Sources
Natural sources from outdoor	• Soil resuspension, rock erosion • Forest fires (smoke, dust, gaseous) • Ocean spray • Volcanic ash • Particles formed from secondary processes (gaseous emissions of H_2S. NH_3. NO_x and HC)
Anthropogenic sources from outdoor	• Fuel combustion and industrial emission • Traffic or vehicular emission • Dust resuspension from main road • Biomass burning • Construction activities
Indoor sources	• Human occupants. i.e. hair, skin • Pets • Plants • Human activities. i.e. movement, cooking, cleaning, tobacco smoking • Building materials • Products maintenance • Appliances combustion

Source: Morawska & Salthammer 2003

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2.6 Particulate Matter and Health

Particulate matter is capable of penetrating into the respiratory system which can lead to significant impacts to human health such as throat and lung infections depending on their size and chemical composition. The particles size ranged from 5 – 10 μm are mostly deposited in the tracheobronchial tree whereas size ranged from 1 -5 μm may penetrate deeper to bronchioles and the alveoli where the gas exchange processes take place (Löndahl et al., 2006). Figure 2.2 illustrates the compartmental deposition in respiratory tract based on size-fractionated of particles. These particles may penetrate deep into lung and induce gas exchange process interruptions. Then, deleterious health effects will occur when the particles enter the bloodstream (Fu et al., 2011). In addition, the particles with size less than 1 μm may penetrate deeply into alveoli and absorbed into cell tissues or circulation system (Valavanidis, Vlachogianni, Fiotakis, & Loridas, 2013).

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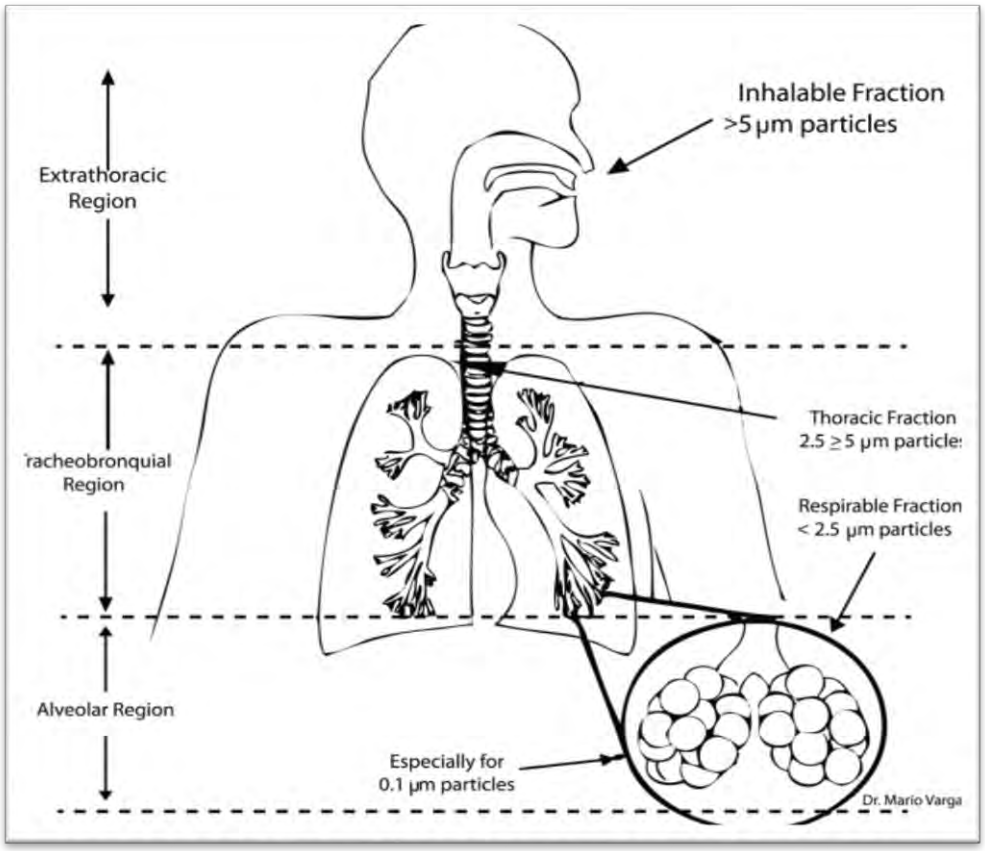


Figure 2.2. Compartmental deposition of particulate matter in respiratory tract
Source: Sierra-Vargas and Teran, 2012

There are mainly three routes in a way particulate matter may enter the body namely inhalation, ingestion or skin contact. Inhalation pathway is the main route of exposure for most chemicals particularly in the form of particles, vapors, gases and mists. When inhaled, the chemicals will either be filtered at extra thoracic region through sneezing or may be deposited into the respiratory tract. In previous study related to global burden of disease, it was demonstrated that human exposure to ambient particulate matter can lead to human morbidity and mortality. About more than three million premature death occurred yearly was estimated due to this issue (Lim et al., 2012). A long-term exposure to $PM_{2.5}$ will increase the probability of a person suffered from chronic obstructive pulmonary disease (COPD), lung cancer, acute lower

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respiratory infections (ALRI), ischemic heart disease and cerebrovascular disease (stroke, CEV) (Zheng, Pozzer, Cao, & Lelieveld, 2015). Elevated in particulate matter concentration level in ambient air can be related to respiratory symptoms such as asthma attacks, breath shortness, deterioration of lung function, cough and wheezing (Dockery et al. 1993).

Many previous studies demonstrated that particulate matter has significant negative effects to pregnancy and neonatal outcome. Particulate matters are linked with incremental of post-neonatal mortality cases where the death is from 28 to 365 days after delivery (Heal, Kumar, & Harrison, 2012). In addition, a study conducted by Bell, Ebisu, and Belanger (2007) revealed that $PM_{2.5}$ exposure may induce the reduction of birth weights. Research that are focusing on short-term exposure to PM and time-series epidemiological are needed especially in Malaysia as there are limited studies have been conducted that come out with the integration of health effects, local environment and epidemiological data.

2.7 Guideline/Standard for $PM_{2.5}$

The implementation and enforcement of air quality standard and guidelines is required to protect public health. The aim of this implementation is to eliminate or diminish to a minimum pollutants exposure that are known to be harmful to public. The monitoring of those pollutants to make sure their level is not exceeded or complied with, when the standards have been adopted. Malaysia Ambient Air Quality Standard has been used since 1989 in Malaysia but the New Ambient Air Quality Standard was upgraded and

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established to replace the older version. There are six airborne pollutants are adopted in this new standard including five existing pollutants namely, PM_{10}, SO_2, CO, NO_2 and O_3 together with the new additional pollutant which is $PM_{2.5}$. There are divided into three interim that can be used and applicable until year 2020. The first interim standard was used in year 2015, the second interim for 2018 standard and the last which is the third interim is in year 2020 where it is a complete implementation. The Malaysia Ambient Air Quality Standard is presented in Table 2.2.

Table 2.2

The Malaysia Ambient Air Quality Standard (unit in: µg m^{-3})

Pollutants	Averaging period	Ambient Air Quality Standard		
		Interim 1 (2015)	Interim 2 (2018)	Interim 3 (2020)
$PM_{2.5}$	1 y	35	25	15
	24 h	75	50	35
PM_{10}	1 y	50	45	40
	24 h	150	120	100
SO_2	1 y	305	300	250
	24 h	150	90	80
NO_2	1 y	320	300	280
	24 h	75	75	70
Ground level O_3	1 h	200	200	180
	8 h	120	120	100
*Carbon monoxide	1 h	35	35	30
	8 h	10	10	10

Note: y = year; h = hour, *carbon monoxide unit in: mg m^{-3}

In addition, both short-term (24 h) and long-term (annual averaging period) guidelines are required to act as PM pollution indicator based on the health effects. For

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annual average concentration, WHO guideline sets 10 μg m^{-3} for $PM_{2.5}$ long-term guidelines value. This guideline standard is linked with manipulation of American Cancer Society (ACS) and Harvard Six-Cities data. Meanwhile, for 24 h $PM_{2.5}$ air quality monitoring set by WHO is 25 μg m^{-3} (WHO, 2006).

The National Ambient Air Quality Standard is set by United State Environmental Protection Agency (USEPA). USEPA set six pollutants (PM, NO, CO, SO_2, O_3 and Pb) that are known hazardous to both public health and environment as recommended by the Clean Air Act. The standard is required to be reviewed periodically by EPA in order to provide maximum protection to health and environment and to keep the standard up to date. The standard has been classified by USEPA into two groups, (1) coarse particles and (2) fine particles. According to the last amendment in 2015, the recommended $PM_{2.5}$ level for annual standard is 12 μg m^{-3} for primary pollutants and 15 μg m^{-3} for secondary pollutants. Meanwhile, for 24 h standard is 35 μg m^{-3} for both primary and secondary pollutants (USEPA, 2012). The standards were classified into two groups: (1) primary, designed for human health protection including sensitive populations including children, elderly and immunocompromised person and (2) secondary that was designed for public welfare protection such as animals, vegetation or man-made materials from adverse effects of pollutants.

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2.8 Source Apportionment

Source apportionment is essential step in order to provide better understanding of particulate matter characteristic especially its sources identification. This information is crucial to reduce or control emissions of hazardous components associated with airborne aerosols. In previous study, receptor modelling approaches have been widely used to assess the contribution of each particle source such as enrichment factor analysis (EF), chemical mass balance methods (CMB) and a few types of multivariate methods like factor analysis, principal component analysis (PCA), multiple linear regression (MLR) and positive matrix factorization (PMF).

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2.8.1 Enrichment Factor Analysis (EF)

Enrichment factor analysis is carried out to assess the potential contamination of the particulate matter in heavy metals and metalloids (Almeida et al., 2011). In this EF analysis, trace metals composition in particulate matter is compared with a reference element to provide a degree estimation of to which a specific ambient aerosol has been enriched by an anthropogenic source. EF analysis has a simple concept and easy to conduct in order to perform the enrichment degree estimation. The EF method is very useful when there is lack of information on elemental composition available. However, there are a few limitations in this analysis. EF analysis is not applicable to quantify source's contribution because it only relies on the assumption of background

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composition. Besides that, EF is also unable to analyse when it comes to complex sources mixtures where several sources contribute to the same element. EF is relevant in interpreting small data set but not applicable for a large amount of data set. Trace element such as Al, Fe and Mn have been used widely in previous study as the normalization reference element. Mohamad et al. (2016) applied a similar approach and Fe was used as reference element in their study since Fe distribution was not associated with other heavy metals and has a relatively high natural concentration.

2.8.2 Principal Component Analysis (PCA)

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The chemical composition of particulate matter in indoor environment is important when it is required to identifying and determining their sources and toxicity (Mohamad et al., 2016). Principal component analysis is one of the methods that has been used widely in previous study in order to quantify patterns, reduce a large number of variables to a much smaller number of data set, detect outliers, analyse the relationship between variables and samples and produce new hypothesis as well (Bro & Smilde, 2014). Other than that, PCA also used mainly to identify different sources and their composition show without any prior knowledge of the sources (Habil, Massey, & Taneja, 2013). The PCA output includes the eigenvectors (referring to factors), which explain the chemical profile of each source. The factors that can be identified were then been extracted as airborne pollution sources based on their different source markers. PCA can be categorised as a simple and easy method to use that there is less parameter need to control compared with other methods.

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According to Seinfield and Pandis (1998), several assumptions have been listed on PCA approach to perform source apportionment such as 1) the composition of emissions sources is constant throughout the ambient and source sampling period, 2) there is no chemical reaction between elements and their concentrations are linearly additive, 3) uncertainties errors measurements are uncorrelated, random and normally distributed and 4) changes in source contribution have significant influenced by variability of the elements concentrations. The association of PCA interpretation with their assignment to potential emission sources identification was the most critical steps in this PCA analysis. There is limitation in PCA caused by uncertainty structure of the dataset, since PCA is only applicable for source identification but not able to apportion the associated sources (Paatero & Hopke 2003). Fortunately, the methods such as Multiple Linear Regression (MLR) (Tauler et al., 2008) and Absolute Principal Component Score (APCS) (Thurston & Spengler, 1985) can be combined with PCA to produce the best source apportionment of $PM_{2.5}$.

2.8.3 Multiple Linear Regression (MLR)

Multiple Linear Regression (MLR) is the approach based on fitting process of a linear-square. The amount of trace elements in the particulate matter is assumed to be proportional to the strength of sources at the receptor. MLR is performed by the observation of tracer total mass that act as the independent variables. The tracers have to be more or less independents to each another in order to produce stable MLR outcome due to multicollinearity issue (variables are correlated with each other). The

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PCA and partial least square have been conducted to overcome this issue. MLR models are recommended to be applied when the source profile are not available or known to be unreliable (Fromme et al., 2007; Zhong et al., 2014).

2.9 Health Risk Assessment

The main purpose of conducting the health risk assessment (HRA) is to connect with the harmful risk to a vulnerable population with a quantitative manner and thus provide a basis for risk management. There are two types of exposures that are very important in HRA namely lifetime exposure, which is the amount of exposure that occurs in different environment and it is important for carcinogenic pollutants. The second one is short-term exposure to high concentrations of pollutants (Morawska et al., 2013).

There are four main steps in the risk assessment procedure for both carcinogens and non-carcinogen. The first step is hazard identification, followed by exposure assessment, the dose-response assessment and the final step is risk characterization (US EPA, 2005). Hazard identification is the procedure to identify the pollutants of concern, the potential adverse health effects of their decisions on a basis of epidemiological, toxicology, clinical and environmental research. It also involves the identification of components as concerned hazards such as particulate matter (PM), Polycylic Aromatic Hydrocarbon (PAH) compounds, heavy metals (Hg, Al, Pb, Ni) and organic carbon compounds (L. Morawska et al., 2013).

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Other than that, exposure assessment will determine the total number of concerned pollutants that the receivers have been exposed to for a certain period. The value of exposure will be used to quantify the intake dose. Dose response assessment was then carried out to estimate the probability and illnesses frequency that occur. The severity of adverse health effects can be determined by the potency factor that acts as an indicator. The final step is risk characterization that will merge the results obtained from exposure and dose response assessment. The method used to quantify the risk of carcinogens and noncarcinogens are different (L. Morawska et al., 2013).

2.10 Carcinogenic and Non-Carcinogenic Health Risk Assessment of $PM_{2.5}$

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The human health risk is the probability of exposure or series of exposures that may be harmful or will cause potential damages to individual health under certain conditions. Thus, the human health risk assessment (HRA) is conducted to estimate the probability of human adverse health effects who may be exposed to presence contaminants in environment (USEPA, 2016). In general, suspended particulate matter with metals can deposit on the floor and surfaces of the interior equipment and also may contaminates food. The presence of toxic metals in institution buildings can directly enter the body through inhalation while may be exposed indirectly through ingestion of contaminated suspended particles that deposited on food, drinks or surfaces of both indoor and outdoor equipment via hand-to-mouth activities (Sulaiman, Bakri, Nazmi, & Latif, 2017). The pollutants can be classified into non-carcinogens and carcinogens as stated by International Agency for Research on Cancer (IARC), Environmental Protection

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Agency (EPA) and Integrated Risk Information Database (IRIS) (Chen, Bi, Zhang, Wu, & Feng, 2015). The International Agency for Cancer Research (IARC) has developed a category system for assessing the carcinogenicity of an agent to humans. Agents are classified based on scientific evidence obtained from animal studies and animal experiments and from relevant mechanistic and other data. A list of their categories and number of agents is shown in Table 2.3 (IARC, 2013). Human health risk assessment has four basic steps including (1) Hazard identification (2) Dose-Response Assessment (3) Exposure Assessment and (4) Risk Characterization. Therefore, HRA was carried out in this study (as described in Section 3.6) to calculate the non-carcinogenic and carcinogenic health risks via inhalation pathway. Then, all the information from each step are gathered and interpreted to come out with the meaningful conclusion of health risk (USEPA, 2016) for both institutes.

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Table 2.3

IARC classifications of carcinogenic agents

Group	**Descriptions**	**Number of agents**
Group 1	Carcinogenic to humans	111
Group 2A	Probably carcinogenic to humans	66
Group 2B	Possibly carcinogenic to humans	285
Group 3	Not classifiable as to its carcinogenicity to humans	505
Group 4	Probably not carcinogenic to humans	1

Source: International Agency for Cancer Research (2013)

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2.10.1 Hazard Identification

(a) Lead

Lead is a natural element contained in small quantities in the earth's crust which can be released from the recovery of mechanically generated particles from building materials and roadsides such as paints and cements. According to International Agency for Research Cancer (IARC), lead was considered to be in Group 2B. Lead can cause damages to human health as it can cause negative effects to the neurobehavioral which can bring to decrease in intelligence level among children (Wang et al., 2009). It may also bring negative effects to physical development as it can reduced the growth in children (Sun et al., 2015). In addition, Khan et al. (2010) reported that Pb can impair several organs, including the hematopoietic, renal and gastrointestinal specifically. The main routes of exposure to lead are inhalation (respiratory) and ingestion (gastrointestinal) of Pb-contaminated suspended particle, and being stored in soft tissues and bones (Mudipalli, 2007).

(b) Cadmium

International Agency for Research on Cancer (IARC) classified cadmium and cadmium compounds as human carcinogens (Group 1) (IARC, 2018) whereas the USEPA categorized the cadmium as probable carcinogen (Group B1) (USEPA, 2013b). Based on previous study, cadmium is generated in environment from anthropogenic sources

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namely combustion process that derived from fuel combustion and biomass burning activities. A long term of low exposure to cadmium can impair lung and kidney organs, where children and adults are expected to have the same effects (ATSDR, 2012). Cadmium will bio accumulate in kidneys over a long period of about 10-35 years which is responsible for nephrotoxicity and osteoporosis in adults (Schoeters et al., 2006). Besides that, inhalation exposure of cadmium oxide fume can result on lethal pulmonary edema and become more severe that can lead to obstructive airway disease if person exposed for a long period to high concentration of cadmium oxide (WHO, 2010).

(c) Chromium (III)

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Chromium exists in the ambient air in two states, (1) trivalent (III) state which is more stable and (2) hexavalent (VI) state that poses strong oxidizing agent and more toxic (Huang, Duan, Zhang, Cheng, & Ran, 2014). Chromium (VI) can be reduced to Chromium (III) which this contributes to the dominant Chromium (III) in the environment. Chromium (VI) is categorized as human carcinogens that can result in various negative adverse health effects via inhalation exposure pathway. Previous study reported that Chromium (VI) has been associated with breathing problems like asthma and breathing shortness which can lead to lung cancer (ATSDR, 2004). Shanker and Venkateswarlu (2011) demonstrated that Chromium (VI) can also cause other effects including kidney and liver impairment, genetic material alteration, respiratory problems, skin rashes, stomachs aches, ulcers and causing the poor immune systems.

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(d) Cobalt

International Agency for Research on Cancer (IARC) has classified cobalt and cobalt compounds as a possible carcinogenic to human (Group 2B). Cobalt can be found in rocks and soils and is also can produced by reductive smelting (ATSDR, 2011). The exposure to excessive cobalt may cause various health effects including inflammatory response (Keegan, Learmonth, & Case, 2008) and harmful to bone cell as the number of cell and resorption been reduced (Andrews, Shah, Wilkinson, & Gartland, 2011). Cobalt has significant non-cancer effects on the respiratory tract where it may lead to asthma and lung associated diseases via inhalation route exposure (Olujimi, Steiner, & Goessler, 2015).

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(e) Copper

Copper is usually function as a heat conductor because it eliminates friction heat that been used in brake linings. Copper also can be found in rubber tyres, asphalt and concrete which increase the copper constituents in the environment (Liu et al., 2009). Recently, the presence of copper associated with fine and coarse particles in the ambient air of traffic environment has been observed (Gugamsetty et al., 2012). The excessive exposure of copper can result on several harmful effects including nausea and irritation of mouth, nose and eyes (ATSDR, 2004). In contrast, prolonged exposure to low concentration of copper may cause liver and kidneys damages. In previous study, there was significant non-carcinogenic effect reported to children resulted from ingestion exposure which related to coking plant (Cao et al., 2014).

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(f) Nickel

The International Agency for Research on Cancer (IARC) has classified nickel and nickel compounds as Group 1 (human carcinogens) whereas metallic nickel is categorized as Group 2B (possibly carcinogen to humans). Meanwhile, both nickel refinery dust and nickel sub sulfide were classified as Group A (human carcinogen) by USEPA. Generally, nickel is originated from natural sources and anthropogenic activities such as wind dust and fuel combustion. It is usually used in metallurgical processes like steel and nickel-containing alloy production, electroplating and nickel-cadmium batteries. Through inhalation exposure to nickle, immediate symptoms such as headache, nausea, insomnia, vertigo and vomiting may develop to exposed person. Other than that, exposure to Nickle can be associated with chronic toxicity including lung and nasal sinus cancer and chronic bronchitis (ASTDR, 2011).

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2.10.2 Dose-Response Assessment

(a) Non-Cancer Effects

The dose-response assessment for non-cancer effects uses the reference dose (RfD) value where it refers to the levels of non-carcinogenic metals in the air to estimate the inhalation risks (unit; $mgkg^{-1}day^{-1}$). RfD is actually an estimation to the concentration of metals where exposure is allowed to occur with sufficient susceptibility, certainty

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and variability that adverse effects will not result (USEPA, 2010). In order to develop standards and regulations of ambient air concentrations, RfD values has been applied to estimate the risk of different exposures. In this study, RfD values (as described in Table 3.3) obtained from Integrated Risk Information System (IRIS).

(b) Cancer Effects

The cancer slope factor (CSF) was used to assess inhalation risk for carcinogenic metals. CSF is defined as an indication of the relative cancer potency of the chemical which is used to calculate how many cancer cases likely to be occurred to the population that exposed to the certain amount of the carcinogenic metals. CSF values in this study are based on the recommended values by the Integrated Risk Information System (IRIS) as described in Table 3.3.

2.11 Chapter Summary

Particulate air pollution has become major problem in the 21st century as particulate matter has significant negative impact on public health compared with other common air pollutants. The incremental of particulate concentrations level has caused public health concerns and environmental issues. It is important to study and monitor indoor air quality as people nowadays people spend a longer time in indoor environment and have been exposed to indoor pollutants that will cause health problems (Saraga et al.,

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2011). Many previous studies have revealed that $PM_{2.5}$ poses more danger because it may penetrate deep into human lungs. Besides that, several studies have been implemented to identify the particles compositions as $PM_{2.5}$ can run a variety of components such as heavy metals, bacteria, viruses and volatile organic compounds, due to its high penetration capability. The identification of $PM_{2.5}$ composition and its sources apportionment are very important in order to have a better understanding of $PM_{2.5}$ profile. On the other hand, health risk assessment has been widely used in many previous studies to estimate health risks associated with $PM_{2.5}$. In this study, the composition of WSIS and trace metals have been conducted as well as other parameters such as RH, temperature, total fungal and bacterial counts. Source apportionment has been conducted using PCA-MLR. Besides that, HRA also was performed to investigate the health risks of trace metals in $PM_{2.5}$ for a specific-age groups.

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CHAPTER 3

METHODOLOGY

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3.1 Introduction

In research, selection of method is important to achieve the objectives. By choosing the right sampling and analysis technique applied can produce reliable research and meaningful conclusions. This chapter will provide explanation of the methods employed in the assessment of indoor air quality in both institutes. The study location and background, sampling procedure, instruments used, data collection and measurement and data analysis are discussed in this chapter.

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3.2 Sampling Sites Description

In this study, two training institutes under Malaysia Ministry of Health, were selected through purposive sampling according to their locations; one was located in Sungai Buloh and another one in Tanjung Rambutan, Perak (Figure 3.1). These two sites were chosen to obtain a general view of $PM_{2.5}$ mass concentrations, chemical composition as well as the effect of its exposures on lecturers and students in different setting in terms of health risk. Sampling location 1, Institusi Latihan Kementerian Kesihatan Malaysia Sungai Buloh (ILKKM Sungai Buloh) (SB) was built in 2005 which is located at Jalan Hospital in Sungai Buloh (3^o 10' 0" N; 101^o 42' 59.988"E). The location is next to Sungai Buloh Hospital and about 1 km to Universiti Teknologi MARA (UiTM), Sungai Buloh campus which it was impacted by high density of traffics. Furthermore, S1 is surrounded by areas with high population density and there are several small-scale industries nearby such as, manufacturing, electronics and high-technology industries. Other than that, the agricultural activities were actively executed since there are abundances of operating retail nurseries nearby.

Sampling location 2, Institusi Latihan Kementerian Kesihatan Malaysia Sultan Azlan Shah (ILKKM SAS) (SAS) was built in 2010 is located in Tanjung Rambutan, Perak (4^o 40' 13.26"N; 101^o 9' 24.705"E). Tanjung Rambutan is a small town in Kinta district in Perak, Malaysia. It is nearby to Tanjung Rambutan railway station and located next to Hospital Bahagia Tanjung Rambutan which contribute a high volume of traffic especially during peak hours. In addition, there has been a substantial growth in number of houses in the town, especially in recent years and there are ongoing

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construction activities within 10 km from sampling sites during the sampling was undertaken. These two sampling sites were considered as a representative of the suburban area. The Occupational Safety and Health Committee of both institutes received complaints about poor indoor air quality from students and staff. They complain about sick building syndrome that can be linked to physical conditions in the work environment.

The purposive sampling was conducted to determine the sampling stations. For both SB and SAS, samplings were carried out in three different indoor areas including lecture hall, laboratory and lecturer office where all the sampling stations use the same ventilation systems (centralised air-conditioning system). These sampling stations were chosen as they were representative of the primary locations for students and lecturers spent much time. Other than that, the sampling sites were take place near to possible sources (e.g. near to the main road), the highly occupied area and frequently used. Worst case scenario (poor maintenance or high risks area) that close or approximate to work station were selected.

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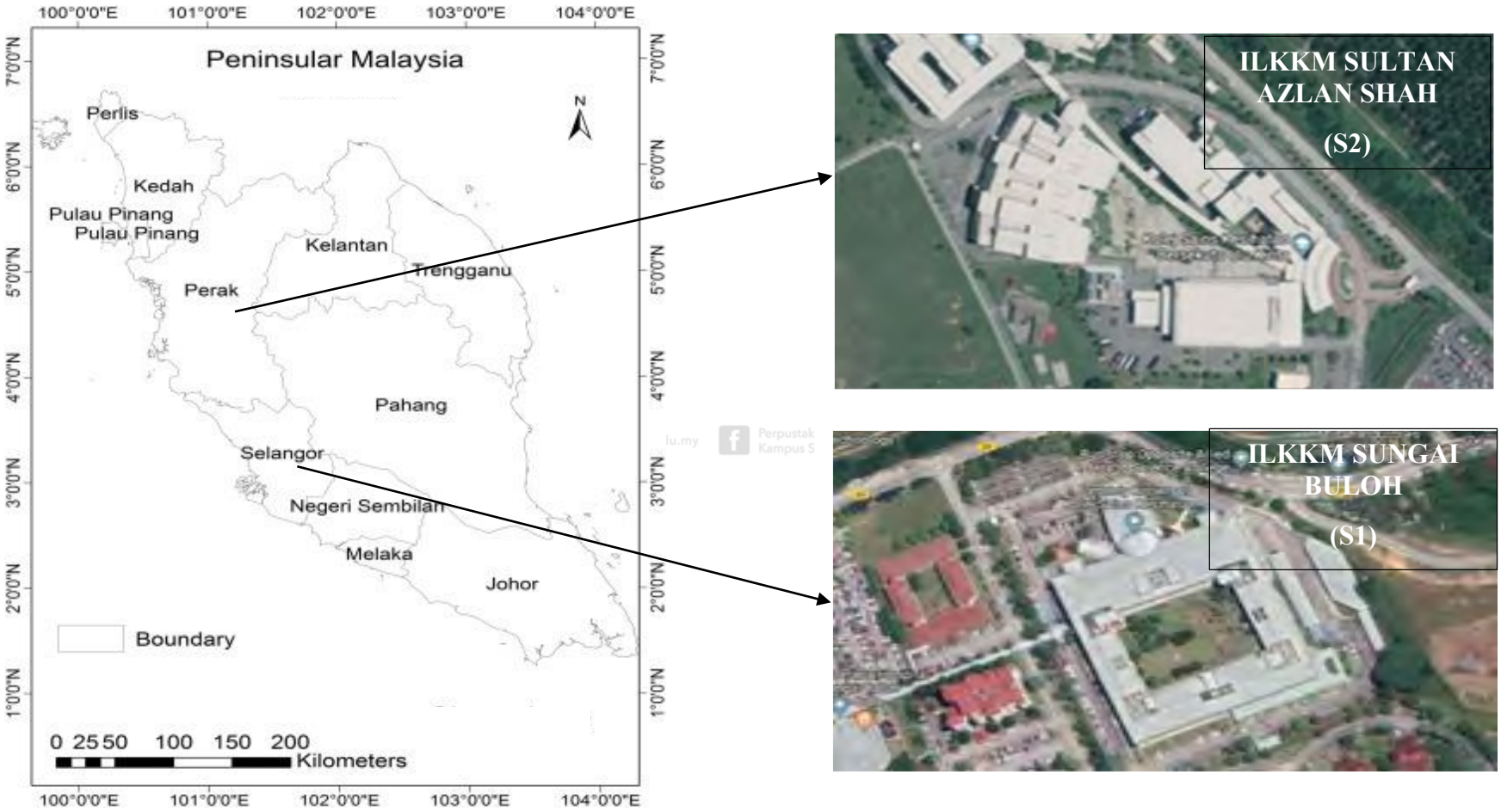


Figure 3.1. Locations of sampling stations of $PM_{2.5}$ in ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

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3.3. Relative Humidity and Temperature Assessment

The Anemometer Model Kestrel 0855YEL (Figure 3.2) was used to measure relative humidity and temperature. It is easy to handle as this air quality instrument provide direct reading, real-time measurements and will provide accurate and reliable measurements.



Figure 3.2. Anemometer Model Kestrel 0855YEL

3.4 Airborne Microbial Sampling Protocol

The sampling of airborne microorganisms was conducted in three sampling areas including laboratory, lecture hall and lecturer office for both SB and SAS. The Model DUO SAS Super 360^{TM} IAQ (DUO Surface Air System Indoor Air Quality) (Figure 3.3) was used to conduct the sampling of airborne microbiological contaminants with

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350 L air sampled volume. The DUO SAS is a microbiological air sampler that suited for Indoor Air Quality assessment and can be used to perform the assessment of microbiological colonies in ambient air. The airflow was directed onto petri dish containing Trypticase Soy Agar (TSA) treated with chloramphenicol antibiotic that was a medium for bacterial growth and Malt Extract Agar (MEA) treated with cycloheximide antibiotic as a medium of growth of fungi. Two plates were placed in the air microbial sampler at both sides for each run and pointed near to ventilation system and 3 m above from the floor level.

The airborne microbial contaminants were captured on the agar by impaction. After about 1 minute for each sampling session, the plates were taken out, sealed, labelled and incubated. TSA plates were incubated for 24 – 48 h at 35°C to enhance the bacterial growth while MEA plates were incubated at 25°C for 5 d to enhance the growth of fungi before colony forming unit was counted as suggested by NIOSH Manual of Analytical Method (NMAM) 0800. The results of the bacterial and fungal counts were expressed as the number of colony-forming units per cubic meter of air (CFU m^{-3}), calculated as an average from the readings. The data were recorded by using the following Equation 3.1;

$$\text{CFU } m^{-3} = \frac{R \times 1000}{V} \qquad (3.1)$$

Where,

R = Colony Forming Units counted on plate
V = Volume of sampled air = 350 litres of air

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Figure 3.3. Microbial Air Sampler Model DUO SAS Super 360^{TM}

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3.4.1 Preparation of Agar

i. Trypticase Soy Agar (TSA) Media with Cycloheximide

Trypticase Soy Agar is a medium for bacterial growth and been treated with cycloheximide antibiotic to supress the fungal growth. Firstly, 40 g of TSA media was weighed and dissolved in 1 L distilled water. The mixture was then dispensed into an appropriate 1 L Schott bottle, labelled and sterilized in the autoclave at 121℃ for 15 minutes. Meanwhile, the 20 ml of 0.5 mg/ml cycloheximide stock solution was prepared. The cycloheximide powder was removed from cold storage (4℃) and

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allowed to equilibrate to room temperature for a few minutes to minimize moisture uptakes. Then, 100 mg of cycloheximide was weighed and dissolved in 200 ml of 96% ethanol. The mixture was then stored in a foil covered and sealed bottle in cold storage (4°C) for future use. The autoclaved agar media was then placed in a water bath (55°C) and allowed to cool for 30 - 60 minutes. After the agar was ready, 5 ml of 0.5 mg/ml cycloheximide stock solution was poured into the agar. Then, the mixture was swirled thoroughly to mix homogenously and poured into petri dishes and allowed the media to firm up for at least 30 minutes before being stored at 8 – 15 °C. Cycloheximide is rapidly inactivated by direct light (especially ultra violet light). Hence, the plates must be protected from being exposed to direct light during storage but short exposure to laboratory lighting is acceptable.

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ii Malt Extract Agar (MEA) with Chloramphenicol

Malt Extract Agar media is used for the cultivation of fungi and chloramphenicol acts as bacterial growth suppressor agent. Firstly, 48 g of the media was weighted in 1 L of distilled water. After that, 0.2 g of chloramphenicol powder was added into the solution and mixed well. The mixture was then poured into 1 L Schott bottle, labelled, sealed and sterilized in the autoclave at 121°C for 15 minutes. The autoclaved agar media mixed with chloramphenicol was then placed in a water bath (55°C) and allowed to cool for 30 - 60 minutes before the agar was poured into the petri dishes and allowed

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the media to firm up for at least 30 minutes. The prepared media was stored at 8 - 15 °C.

3.5 $PM_{2.5}$ Sampling Protocols

$PM_{2.5}$ sampling was conducted between August 2017 until November 2017 during working days (Monday to Friday). A total number of 30 $PM_{2.5}$ samples were collected using a low volume sampler (LVS) (Figure 3.4). The LVS operated at a flow rate of 5 L min^{-1} on 8 h cycle (from 9.00 a.m. to 5.00 p.m.). Averaged 8 h sampling conducted on five consecutive weekdays at each sampling sites. During the sampling period, the inlet of the indoor sampler was located approximately 1 m above the floor level, to stimulate the location of the people breathing zone who occupied the building. The sampler was positioned in the middle of the sampling area and at least 1 metre, distance from the wall. $PM_{2.5}$ samples were collected on 47 mm (in diameter) pre-weighted micro fibre glass filter paper (0.2 μm pore size, Whatman) which were used to determine the total mass, water soluble ionic species (WSIS) and trace metals analysis in the samples.

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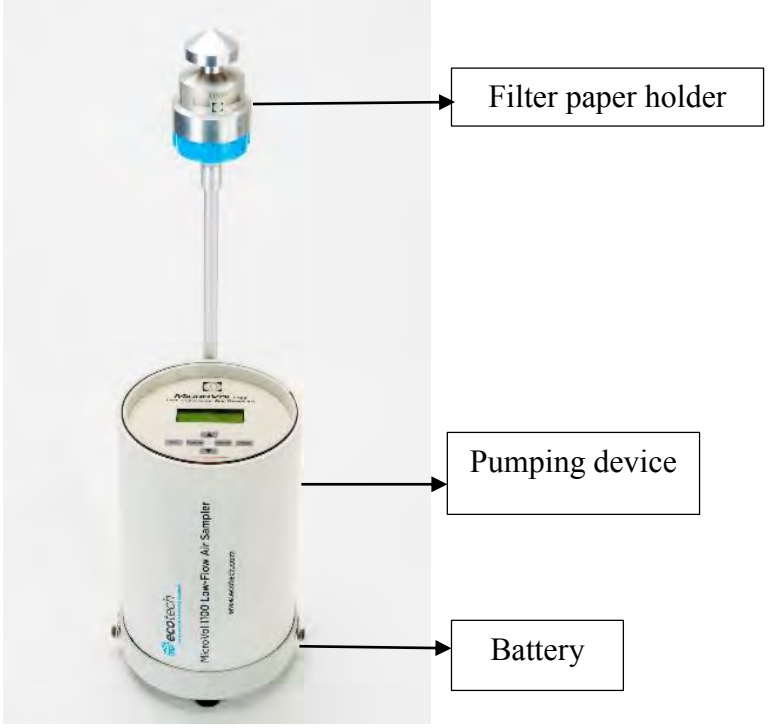


Figure 3.4. Low Volume Sampler (LVS)

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$PM_{2.5}$ mass concentrations were obtained through gravimetric method using 5-digit electronic microbalance with ±0.001 mg uncertainty. Prior to weighing, the filters were equilibrated for 24 hours inside a desicator to condition them. They were then been transported to and from the field in clean resealable plastic bags to prevent handling contamination. Filter papers were handled with plastic clamps to reduce any possibility of handling contamination. After sampling, the filter paper containing sample were then been weighed and then stored in the refrigerator (4°C) until further analysis is carried out. To determine the mass captured on the filter paper, each filter paper was weighed three times and the average is divided by the volume of total air sampling. $PM_{2.5}$ mass concentrations produced by the gravimetric method using this following Equation 3.2 – 3.4;

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$$PM2.5 = \frac{M2.5}{V} \quad (3.2)$$

$$M_{2.5} = (M_A - M_B) \times 10^6 \quad (3.3)$$

$$V = Q_{avg} \times t \times 10^{-3} \quad (3.4)$$

Where,

M_{10} = total mass (µg)

M_A = final mass after sampling (g)

M_B = initial mass before sampling (g)

10^6 = unit conversion for g to µg

V = total sample volume (m^3)

Q_{avg} = average flow rate (L min^{-1})

t = duration of sampling (min)

10^{-3} = unit conversion L to m^3

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3.6 Analytical Method

3.6.1 Water-Soluble Ionic Species Analysis

Half of each filter paper was cut into pieces. The shredded filter paper was placed into 100 mL volumetric flask for ionic composition determination. Ultrapure water (UPW, Easypure® II, Thermo Scientific, Canada) was added up to the mark. The samples were then extracted according to (Mohamad et al., 2016) for 2-h under ultrasonic conditions using an ultrasonic bath (Elmasonic S70H, UK). After that, the extract was filtered

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using a disposable syringe filter of 0.2 µm pore (Pall, USA) and a 50 cc mL^{-1} Terumo syringe. Then, the filtered solution was added with 50 mL UPW and divided into two vial tubes, each containing 15 mL for both cationic and anionic analysis.

Determination of ionic composition was performed using ion chromatography where it will retain an analytical molecule in the column based on ionic interaction. In order to measure anions (Cl^-, SO_4^{2-}, NO_3^-), ion chromatography (Dionex, model ICS-2100) has been used with six elements of the standard solution (Thermo Scientific, Six Anion Standard II) separately. From this study, only three elements have been identified and used for data analysis namely, Cl^-, SO_4^{2-}, NO_3^- with detection limit 0.008 µg m^{-3} for Cl^-, 0.02 µg m^{-3} for SO_4^{2-} and 0.06 µg m^{-3} for NO_3^-.

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For the cation analysis, ion chromatography (Dionex, model ICS-2100) was used. The detection limit identified for Na^+ in this study was 0.06 µg m^{-3}, 0.002 µg m^{-3} for NH_4^+, 0.004 µg m^{-3} for K^+, 0.008 µg m^{-3} for Mg^{2+} and 0.10 µg m^{-3} for Ca^{2+}. Calibration curves have been performed using certified standard solutions (CertiPUR® Merck, Germany) at three different concentrations of 0.5, 1 and 2 ppm for all anions and cations. Deionized water was used as a blank sample. The analysis was replicated twice to determine the accuracy and reliability of the outcome readings.

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3.6.2 Microwave Assisted Acid Digestion and Trace Metal Analysis

The microwave-assisted digestion system was used to extract multiple trace element fragments. Half of filter paper was cut into small strips using clean scissor in the laminar flow according to Md Firoz Khan et al. (2012) with some modifications. Then, the shredded filter papers were soaked in a Teflon digestion vessel (DAP-60 K, Germany) made of tetrafluoromethoxylene (TFM) (SK-10, Milestone, Germany). After that, 2 mL of analytical grade Hydrogen Peroxyde (H_2O_2) (40%, Merck KGaA, Germany) and 8 mL of analytical grade HNO_3 (65%, Merck KgaA, Germany) were placed inside the vessel under fume hood as the digestion reagents. The teflon vessel was then closed with its cover and placed in the microwave digester (Start D, Milestone, Germany) to dissolve the samples. Only ten samples can be carried out in the microwave at one time. The purpose of this step was to reduce the residual pressure in the teflon vessel. The digested samples were filtered into 50 mL volumetric flask using a disposable 20 mL Terumo syringe attached to a syringe filter (22 mm in diameter, 0.2 µm pore size, Pall, USA). Then, Ultrapure water (UPW) with a resistivity of 18.2ΩM/cm (Easypure® II, Thermo Scientific, Canada) was added to the final volume 50 mL. The sample was then transferred to the HDPE bottle and stored in the refrigerator at temperature 4°C until the analysis was carried out.

Next, the samples were used to detect elemental analysis using Inductive Coupled Plasma Mass Spectrometry (ICP-MS) (Perkin Elmer ELAN 9000, USA). The different calibration curves were performed using the multi-element calibration standard 3 (CertiPUR® PerkinElmer, USA) at concentrations of 10, 20, 30 and 50 ppb

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for instrument calibration purposes. The stock solutions of 1000 ppm (Merck, Darmstadt, Germany) have been used to provide metals working standards. The trace metals have two different modes: 1) metals with high concentrations (Al, Ca, Fe, Mg, Mn and Zn) and metals with low concentration (Ag, As, Ba, Cd, Co, Cr, Cu, K, Ni, Pb, Rb, Sr snd V). All the vessels were soaked inside the acid bath containing (HNO_3, 6%) for 24 hours and rinsed with UPW for future use.

3.6.3 Field Emission Scanning Electron Microscopy (FESEM) Analysis

Field emission scanning electron microscopy (FESEM) is the most common technique to perform analysis of particles morphology in terms of their size and surface structure. In this study, the surface morphology of $PM_{2.5}$ observation was conducted using (FESEM, Hitachi, SU 8020) coupled with Energy Dispersion System (EDS, Horiba Xmax Model). The dry and loaded glass filter paper samples were cut into 0.5 cm and put on double-side stick tape on aluminium stub and the specimens were then coated with a thin layer of platinum in an ion sputter coater to induce electrical conduction in order to obtain the maximum resolution from SEM image. After that, coated specimens were observed and SEM images were recorded. To obtain the particle visualization, the images were adjusted using a high contrast to brightness ratio and generally, the microscope was operated at an accelerating voltage in a range of 2 to 5 kV.

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3.6.4 Quality Assurance and Quality Control (QA/QC)

In this study, the quality assurance and quality control were implemented to avoid any error or interference during sampling process, sample preservation, transport and analysis. The blank samples were used in each analysis to ensure the reliability of chemical composition concentrations. The field blank filter papers were handled in the same way as an actual filter papers with great care by using gloves and plastic to avoid damage and contamination. Damaged samples were discarded and only valid samples were analysed and reported in this study. All the glassware used in sample analysis were rinsed with distilled water, soaked into 20% nitric acid for at least 24 h and heated in the furnace at 300℃ for 5 h to volatize and remove any impurities.

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Besides that, in order to determine the recovery percentage in the metal analysis, Urban Particulate Matter SRM 1648a obtained from National Institutes of Standard and Technology (NIST), USA was used as a standard reference material. The SRM, blank samples and $PM_{2.5}$ samples were prepared in the same way in terms of amount and experimental procedures. In addition, the method detection limit (MDL) obtained from three replicated measurements of the reagent blanks. The recovery efficiencies percentage of water-soluble ionic species, cation and anion standards (CertiPUR® Merck, Germany) were used. During media preparation, aseptic technique was applied where all equipment including petri dishes and workstation were aseptically disinfected using 70% alcohol to prevent cross-contamination among samples. Other than that, the process of going through the bottle mouth to Bunsen burner also being practised to ensure no contamination will occur during media pouring into petri dishes.

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3.7 Data Analysis

In this study, several descriptive data analyses including mean, standard deviation, maximum and minimum readings, correlation analysis and multivariate statistical analysis were performed using SPSS statistical package (version 25, IBM® SPSS Inc, USA). Normality test was conducted before running an appropriate test and Kolmogorov - Smirnov test was chosen as it is specific test for normality which involves large sample size. The data were observed to be normally distributed after normality test was conducted hence parametric test can be carried out to reach the objectives in this study. *T*-test analysis was performed to determine the statistical significance ($p < 0.05$) between two parameter means at both institutes. Then, means of variables at different sampling areas (laboratory, lecture hall and lecturer office) were compared using one-way ANOVA test. Pearson Correlation test was carried out to measure the strength and direction of the linear relationship between two variables.

3.7.1 Enrichment Factor (EF) Analysis

The enrichment factor (EF) has been established by Taylor (1964) and was used to estimate the possible sources of trace elements in $PM_{2.5}$ and differentiate the anthropogenic sources from natural sources. In this calculation, the mean abundances of each elements were normalised using upper continental crust (UCC) data referred to Taylor and McLennan (1985), since there was no background metal values standard in

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this country. Table 3.1 presents the UCC values for each analysed element. Fe, Al and Mn are often to be used as reference for EF analysis calculation (Mohamad et al., 2016). In this study, Fe was chosen as reference element. EF values can be expressed by the following Equation 3.10;

$$EF = \frac{[C]_{sample} / [Cref]_{sample}}{[C]_{crust} / [Cref]_{crust}} \quad (3.10)$$

Where,

$[C]_{sample}$ = concentration of C (analyte element in airborne particle)

$[Cref]_{sample}$ = the normalisation reference elements in the sample (airborne particle)

$[C]_{crust}$ = the concentration of C in the continental crust

$[Cref]_{crust}$ = the normalization reference element in the continental crust

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Table 3.1

Concentration of metals element in the upper continental crust (unit in; ppm)

Element	Value
Fe	3500
As	1.5
Pb	20
Cd	0.098
Cr	35
Co	10
Cu	25
Ni	20
V	60

Source: Taylor and McLennan (1985)

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3.7.2 Principal Component Analysis (PCA)

In order to identify the possible sources of sixteen elements associated with $PM_{2.5}$ from both institutes, the multivariate technique was performed. PCA can be calculated mathematically by using Thurston and Spengler's formula (Thurston & Spengler 1985). All factors with eigenvalues below than one was considered to be excluded as suggested by Kasier (1960). The first factor (F1) generally identified the largest fraction of the variance while following factors identified repeatedly smaller variance fractions. The factor loading explained the most representative elements of each factor which the greater factor loadings of particular element can affiliate in identifying the probable sources. Then, a varimax rotation of the normalized factor loadings was performed to maximise the variances, so that the interpretation of the results can be done easily. In this study, element variables with factor loadings more than 0.7 were selected in order to determine the source identification. The association of PCA interpretation with their assignment to potential emission sources was the most critical steps in this PCA analysis.

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3.7.3 Multiple Linear Regression (MLR)

PCA with multiple linear regression (MLR) was applied to obtain source profiles and source apportionment estimation. MLR was used to calculate the contribution of each

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element in the environment by estimating the variability between independent and dependent variables. MLR calculation can be expressed by the Equation 3.11;

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \ldots\ldots + b_iX_i \quad (3.11)$$

where,

Y = dependent variables
b = regression coefficient
X = independent variables
i = 1…..n

The score factor of each element for both institutes in this study were used as the variable in MLR model which were then compared based on the performance of the model by referring to coefficient of determination (R^2). The highest reading of R^2 showed the best linear model.

3.8 Health Risk Assessment (HRA)

For this study, the health risk assessment can be categorized as carcinogenic and non-carcinogenic health risk. Carcinogenic metals were used to perform carcinogenic health risk estimation whereas noncarcinogenic metals were used to estimate noncarcinogenic health risk. Only two age groups were involved in this health risk assessment namely adolescent ($12 \leq 18$) and adult ($19 \leq 70$ years old) as they have different behaviours,

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the level of vulnerability and their body system works differently. The calculation of HRA were based on assumptions that both adolescent and adult were directly exposed to $PM_{2.5}$ through inhalation. The exposure factors have been identified as presented in Table 3.2 before calculating both health risks.

3.8.1 Health Risk Assessment from Carcinogenic Metals

Carcinogenic health risk assessment is defined as the individual probability of developing any kind of cancer from a lifetime exposure to carcinogenic hazards. The threshold risk is expressed as 1×10^{-6} to 1×10^{-4} (USEPA, 2005). Incremental lifetime cancer risk (ILCR) was calculated using both inhalation cancer slope factor (CSF_{inh}) and the lifetime average daily dose (LADD) to estimate the risk of exposure to carcinogenic metals (USEPA, 2011). CSF was an indication of the relative potential cancer of the chemical based on the Integrated Risk Information System (IRIS) recommendation as shown in the Table 3.3. In general, LCR reading below (1×10^{-6}) can be neglected but when its reading is above 1×10^{-4}, the recovery steps should be taken. The calculation of LADD and LCR was done using Equation 3.5 – 3.6.

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$$\text{LADD } (\text{mgkg}^{-1}\text{day}^{-1}) = \frac{\text{C x IR x ED x EF}}{\text{BW x AT}} \quad (3.5)$$

$$\text{ILCR} = \text{LADD x CSF} \quad (3.6)$$

where,

C = concentration of contaminant in the atmosphere (ng m^{-3})

IR = air inhalation rate (m^3 day^{-1})

ED = exposure duration (years)

EF = exposure frequency (day $year^{-1}$)

BW = body weight (kg)

AT = average time (days x years)

LADD = lifetime exposure daily dose ($\mu gkg^{-1}day^{-1}$)

CSF = cancer slope unit ($mgkg^{-1}day^{-1}$)

Table 3.2

Exposure factor values for calculating the exposure dose in health risk assessment

Factor	Unit	Description	Adolescent 12≤18 years	Adult 19≤70 years
IR	m^3 day^{-1}	Inhalation rate	15.7	15.7
ED	years	Exposure dose	14	52
EF	days $year^{-1}$	Exposure frequency	350	350
BW*	kg	Body weight	38	66
AT	years	Averaging time	70[a], 14[b]	70, 24

*adapted from National Health and Morbidity Survey III 2006 (NHMS III, 2008)

a AT^a for carcinogens (fixed at 70 years of exposure)

b AT^b for non-carcinogens (average years of exposure)

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3.8.2 Health Risk Assessment from Non-Carcinogenic Metals

A non-carcinogenic health risk is estimated as the incremental probability of an individual developing any type of non-cancer health effects over a lifetime as a result of exposure to the potential non-carcinogenic hazards. Thus, Hazard Quotient (HQ) and Hazard Index (HI) were used as a standard EPA method to determine non-carcinogenic health risk. HQ is a ratio of exposure dose (ADD) to the compounds-specified reference dose (RfD). The particular RfD was as the maximum permissible risk estimation for the human population through daily life exposure. The toxicity values for RfD can be referred to the Table 3.2. Hence, individual potential non-carcinogenic risks can be calculated using the following Equation 3.7-3.8;

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$$HQ = \frac{ADD}{RfD} \quad (3.7)$$

$$HI = \Sigma HQ \quad (3.8)$$

where,

HQ = Hazard quotient for metals (unitless)
HI = Hazard index (unitless)
ADD = average daily dose of metals (mg kg^{-1} day^{-1})
RfD = specific reference dose (mg kg^{-1} day^{-1})

US EPA (2001) stated that if HQ value is less than one, there was no significant risk of developing non-carcinogenic effects. Whereas, when the value of HQ exceeds one, then there is some possibility of non-cancer effects may occur. The effects are

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considered more likely to occur if the HQ value is greater. The exposure dose assessment (ADD) was then calculated based on the following Equation 3.9;

$$\text{ADD (mg kg}^{-1}\text{ day}^{-1}) = \frac{\text{C x IR x ED x EF}}{\text{BW x AT}}$$

(3.9)

where,

C = concentration of the contamination in the at atmosphere (ng m^{-3})
IR = air inhalation rate (m^3 day^{-1})
ED = exposure duration (years)
EF = exposure frequency (day $year^{-1}$)
BW = body weight (kg)
AT = averaging time = ED x 365 days
ADD = average daily dose
RfD = reference dose

Table 3.3

Relative toxicity values in health risk estimation (unit; mg $kg^{-1}day^{-1}$)

	$RfD\text{-}ADD_{inh}$	RfD-CSF
Pb	3.52E-0.3	4.20E-0.2
Cd	1.00E-03	6.30E+00
Cr	6.00E-05	4.20E+01
Co	5.71E-06	9.80E+00
Cu	1.20E-02	NA*
Ni	5.40E-03	8.40E-01

*Not available

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3.9 Chapter Summary

This chapter provides the material and methods used in the sampling procedure, lab experiment and data analysis. The details experimental design on the chemical composition of $PM_{2.5}$ such as trace metals and water-soluble ionic species also described in this chapter. In addition, the analytical techniques which applied to present the analysis outcome of the different samples collected were discussed in this chapter as well.

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CHAPTER 4

RESULTS AND DISCUSSION

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4.1 Introduction

Chapter IV discusses the results of the analysis conducted using the quantitative data obtained during the study. This chapter presents the result for comfort parameters including relative humidity (RH), temperature, total bacterial and fungal counts. The $PM_{2.5}$ mass concentrations and its elemental composition are also been discussed in this chapter. Besides that, this chapter describes on the comfort parameter and focuses on the $PM_{2.5}$ characterization and its chemical composition including trace metals and ionic species. Chemical composition was discussed based on the descriptive statistics

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via ion chromatography and ICP-MS analysis. In this chapter, the correlation among chemical element of $PM_{2.5}$ are also been identified. This chapter describes the possible sources of $PM_{2.5}$ in both study sites through the application of receptor model, enrichment factor (EF) and PCA-MLR analysis. Besides that, the morphology characteristics of $PM_{2.5}$ observation by using Field Emission Scanning Electron Microscope (FESEM) are also discussed in this chapter. EF and PCA-MLR results were the main contributor in order to conduct the source apportionment. The last section of this chapter discusses on the estimation of the carcinogenic and non-carcinogenic health risks posed by adolescent group (12-<18 years) and adult group (18-<70) through inhalation pathway that has been established by USEPA.

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4.2 Comfort Parameter

4.2.1 Temperature and Relative Humidity Parameter

Table 4.1 shows the data for temperature and relative humidity (RH) measured in three sampling areas (lecture hall, laboratory and lecturer office) for both institutes during the 8 h measuring periods. ILKKM Sungai Buloh (SB) temperature values ranged from 24 to 27℃ while ILKKM Sultan Azlan Shah (SAS) ranged between 23 to 25℃. For RH, the values ranged from 61 to 72% for SB and 60 to 63% for SAS. The highest temperature reading was at SB (lecturer office) which was 27.1℃ where it has exceeded the DOSH ICOP standard.

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Whereas, laboratory of SB showed the highest reading for RH which was 72% where it also has exceeded the prescribed standard. Other than that, all sampling areas showed the temperature and RH were in acceptable range. A similar pattern also found in a study conducted in other university building (Nur Fadilah & Juliana, 2012). Table 4.2 presents the overall mean of temperature and relative humidity for SB and SAS. The comparison between SB and SAS for both parameters were examined using *T*-Test analysis (SPSS 25.0). There were no significant differences ($p < 0.05$) between both institutes for all two parameters average.

Table 4.1

Temperature (T) and relative humidity (RH) during 8 h average for ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

Sites	**Statistics**	**Lecture Hall**		**Laboratory**		**Lecturer Office**	
		T (ºC)	**RH (%)**	**T (ºC)**	**RH (%)**	**T (ºC)**	**RH (%)**
ILKKM Sungai Buloh (SB)	Min[a]	24.6	65	24.5	61	24.8	68
	Max[b]	24.7	65	26.4	72*	27.1*	69
	Mean	24.65	65	25.45	66.5	25.95	68.5
	SD[c]	0.07	0	1.34	7.78	1.63	0.71
ILKKM Sultan Azlan Shah (SAS)	Min[a]	23.1	61	24.1	60	23.9	63
	Max[b]	23.3	61	25	63	24	63
	Mean	23.2	61	24.55	61.5	23.95	63
	SD[c]	0.14	0	0.64	2.12	0.64	0

[a]Minimum, [b]Maximum, [d]Standard Deviation, *readings that exceed the acceptable limit set by DOSH

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Table 4.2

Overall mean of temperature and relative humidity for ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

Parameter	**DOSH**	**Mean (SD[a])**		***P* value[b]**
	ICOP-IAQ 2010	**Sungai Buloh**	**Sultan Azlan Shah**	
Temperature (°C)	23.0-26.0	25.35 (0.656)	23.9 (0.676)	0.591
Relative Humidity (%)	40.0-70.0	66.67 (1.756)	61.83 (1.04)	0.488

[a]Standard Deviation,[b]mean differences between Sungai Buloh and Sultan Azlan Shah

Generally, DOSH (2010) stated that the recommended comfort indoor temperature ranged from 23 to 26°C, while for RH, ranged from 40 to 70%, as shown in Table 4.2. According to Ismail, Mohd Sofian, and Abdullah (2010), the thermal discomfort of students in Malaysia mostly is due to the location of Malaysia that is located in tropical region with a warm and humid climate. Other than that, the poor operating air conditioning system and lack of mechanical ventilation will also contribute to the increase in thermal discomfort level among building occupants (Chen & Chang, 2012). Overall, in this study, the mean of temperature and RH were in acceptable range for all sampling areas in both institutes. Thus, these such conditions should be maintained to ensure the convenience of all occupants.

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4.2.2 Biological parameter

Table 4.3 presents the biological parameter; total bacterial counts (TBC) and total fungal counts (TFC) for each sampling area for both institutes. SAS lecturer office showed the highest reading for TBC with the total of 53.62 cfu m^{-3}. Laboratory of SAS shows the smallest number of bacteria counts with only 16.97 cfu m^{-3}. Whereas, for TFC, SB lecturer office showed the highest reading with 124.67 cfu m^{-3} while SAS laboratory has the smallest number of fungal with 49.1 cfu m^{-3}. Table 4.3 summarizes the overall mean of total bacterial counts and total fungal counts for SB and SAS. The t-test analysis (SPSS 25.0) shows that there were no significant differences ($p < 0.05$) between two parameters for both institutes.

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Table 4.3

Total bacterial and fungal counts average for three sampling areas of ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

Institute	Sampling area	Total Bacterial Counts (cfu m^{-3})	Total Fungal Counts (cfu m^{-3})
ILKKM Sungai Buloh	Lecture Hall	112.1	115.33
	Laboratory	32.71	76.71
	Lecturer Office	121.74	124.67
ILKKM Sultan Azlan Shah	Lecture Hall	27.52	49.1
	Laboratory	16.97	13.14
	Lecturer Office	53.62	82.76

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Table 4.4

Mean of total bacterial counts and total fungal counts for ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

Parameter	**DOSH**	**Mean (SD[a])**		***P* value[b]**
	ICOP-IAQ 2010	**Sungai Buloh**	**Sultan Azlan Shah**	
Total Bacteria Counts (cfu m^{-3})	500	88.85 (48.85)	105.57 (25.423)	0.095
Total Fungal Counts (cfu m^{-3})	1000	32.7 (18.867)	48.33 (33.816)	0.755

[a]Standard Deviation,[b]mean differences between Sungai Buloh and Sultan Azlan Shah

The high total bacterial and fungal number in lecturer office can be observed in both SB and SAS. This may be driven by the hygiene factor as well as operating air conditioning systems operates for a longer period compared with laboratory that is rarely used. According to Mazlan et al. (2015), the high reading relative humidity will enhance the proliferation of microbes. Industry code of practice on Indoor Air Quality 2010 standard (DOSH, 2010) set 500 cfu m^{-3} for total bacterial counts and 1000 cfu m^{-3} for total fungal counts as shown in Table 4.4. All sampling areas for both institutes were within the standard.

4.3 Indoor Particulate Matter ($PM_{2.5}$) Mass Concentrations

The descriptive statistics of 8-hours particulate matter ($PM_{2.5}$) mass concentrations measured in three sampling areas at both ILKKM Sungai Buloh (SB) and ILKKM

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Sultan Azlan Shah (SAS) were summarized in Table 4.5. As a whole, $PM_{2.5}$ mass concentrations recorded for all sampling areas ranged between 16.67 ± 9.59 μg m^{-3} to 125 ± 30.9 μg m^{-3}. The mean concentrations of $PM_{2.5}$ recorded at these two institutes was 51.39 ± 29.95 μg m^{-3} and 45.833 ± 20.47 μg m^{-3}, respectively. $PM_{2.5}$ mass concentrations of SB showed slightly higher than SAS but there was no significant difference (p>0.05) between these two institutes. The average of $PM_{2.5}$ mass concentration measured in this study can be considered to be high. About 80% of the samples exceeded the 25 μg m^{-3} daily $PM_{2.5}$ set by WHO 2006, 76.67% of the samples exceeded the 35 μg m^{-3} $PM_{2.5}$ NAAQS standard (USEPA, 2015) and only 20% of the total samples that exceeded the 75 μg m^{-3} Malaysia Ambient Air Quality Standard 2015 (IT-1).

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The highest $PM_{2.5}$ concentration (125 μg m^{-3}) recorded at lecture hall in Sungai Buloh was five times higher compared to the WHO daily standard; almost four times the NAAQS standard and almost two times the Malaysia Ambient Air Quality Standard (IT-1). The frequent student movements inside the lecture hall, in and out of lecture hall during the breaks in between lessons as well as cleaning activities were believed to enhance the resuspension of deposited particles. Raysoni et al. (2013) suggested that indoor air pollution was well-correlated with outdoor air pollution in terms of student activities, building envelope tightness and air exchange rates. In addition, open windows and doors during lecture session can also result in the increment level of $PM_{2.5}$ concentration since ILKKM Sungai Buloh is located nearby to main road. According to Awang et al. 2005, traffic emissions were reported to contribute almost 70% of total particulate matter emission in the city.

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Table 4.5

Descriptive statistics of 8 h $PM_{2.5}$ concentrations of lecture hall, laboratory and lecturer office for ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

Sites	**Statistics**	**$PM_{2.5}$ mass concentration (µg m^{-3})**			**Overall Mean**	***P* value**
		Lecture Hall	**Laboratory**	**Lecturer Office**		
		n = 10	**n = 10**	**n = 10**		
ILKKM Sungai Buloh (SB)	Min[a]	41.67	25	20.83	51.39± 29.95	0.526* ($p > 0.05$)
	Max[b]	125	83.33	41.67		
	Mean	79.17	45.83	29.17		
	SD[c]	30.9	13.5	8.84		
ILKKM Sultan Azlan Shah (SAS)	Min[a]	37.5	37.5	16.67	45.83±20.47	
	Max[b]	79.17	83.33	37.5		
	Mean	59.17	50.83	27.5		
	SD[c]	18.96	18.26	9.59		

Guideline/Standard	**$PM_{2.5}$ mass concentration (µg m^{-3}) for indoor air (24 hours monitoring)**
Malaysia Ambient Air Quality Standard 2015 (IT-1)	75
World Health Organization 2006 (WHO)	25
United State National Ambient Air Quality Standard (NAAQS)	35

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The total average of $PM_{2.5}$ mass concentrations for both SB and SAS were below the Malaysia Ambient Air Quality Standard (IT-1). Nevertheless, the average concentrations recorded is far greater (almost two times higher) than the limit set by WHO 2006 and NAAQS standards (USEPA, 2015). The $PM_{2.5}$ in atmosphere can be one of the internal sources of $PM_{2.5}$ as it can infiltrate or migrate into indoors through either mechanical ventilation or building envelope even in the case of doors and windows closed (Thornburg et al., 2001).

The mean differences of $PM_{2.5}$ mass concentrations between laboratory, lecture hall and lecturer office for both SB and SAS were examined using *one-way ANOVA* analysis test. Table 4.6 shows the mean of $PM_{2.5}$ mass concentrations differed significantly across the three sampling areas in ILKKM Sungai Buloh, [$F(2,12) = 4.180$, $p < 0.05$] since Levene's test indicates equal variances was assumed ($p > 0.05$). Mean of $PM_{2.5}$ mass concentrations differed significantly between three sampling areas for ILKKM Sultan Azlan Shah, [$F(2,12) = 4.27$, $p < 0.05$] since the Levene's test had uniformity variance as shown in Table 4.7.

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Table 4.6

Mean of $PM_{2.5}$ mass concentrations between sampling areas of ILKKM Sungai Buloh

Variables	Point of area	Mean of $PM_{2.5}$ mass concentrations	F-statistic (df)[a]	*p*-value
Laboratory	5	115.833 ± 28.013		0.042
Lecture Hall	5	133.333 ± 34.861	4.180 (2,12)	($p < 0.05$)
Lecturer Office	5	75 ± 34.861		

[a]One-way ANOVA test, [b]Mean differences between sampling areas of ILKKM Sungai Buloh

Table 4.7

Mean of $PM_{2.5}$ mass concentrations between sampling areas of ILKKM Sultan Azlan Shah

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Variables	Point of area	Mean of $PM_{2.5}$ mass concentrations	F-statistic (df)[a]	*P*-value
Laboratory	5	90.333 ± 36.372		0.04
Lecture Hall	5	119.167 ± 25.104	4.270 (2,12)	($p < 0.05$)
Lecturer Office	5	63.333 ± 28.013		

[a]One-way ANOVA test, [b]Mean differences between sampling areas of ILKKM Sultan Azlan Shah

Table 4.8 presents the comparison of indoor $PM_{2.5}$ concentrations recorded in this study to other previous conducted studies. In general, the average $PM_{2.5}$ mass concentrations in this study has similar patterns with study carried out by Chen et al., (2015) which reported $PM_{2.5}$ concentration value is 97.5 µg m^{-3} at Nankai University

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in Tianjin, China. Other than that, study conducted by Yang Razali et al. (2015), showed the average of $PM_{2.5}$ was almost three times lower than the average $PM_{2.5}$ concentration in this study.

Table 4.8

Comparison of indoor $PM_{2.5}$ mass concentrations between this study and other studies

$PM_{2.5}$ ($\mu g\ m^{-3}$)	**Location**	**Research**
16.67-125	Two training institutes in Malaysia	This study
97.5	Nankai University in Tianjin, China.	(Chen et al., 2015)
34.96-70.95	A Kendriya Vidyalaya school in Chinnai, India	(Chithra & Shiva Nagendra, 2012)
7-105	39 primary schools in Barcelona metropolitan areas	(Amato et al., 2014)
4-352	7 typical buildings in the central areas in Beijing	(Deng et al., 2015)
143.07	Rural homes of North central part of India	(Massey et al., 2013)
18	Three-secondary schools in Bandar Baru Bangi and Putrajaya, Malaysia	(Yang Razali et al., 2015)

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4.4 Chemical Composition

4.4.1 Water-Soluble Ionic Species (WSIS)

Water-soluble ionic species (WSIS) are chemical species associated with particulate matter which are very soluble in water under certain conditions in the lower troposphere and commonly composed of massive atmospheric aerosols (Deshmukh et al., 2013). Table 4.9 presented the 8 h mean concentrations of water-soluble ionic species in $PM_{2.5}$ collected at both institutes. The results showed that the WSIS composition collected at SB in descending order as follows; $Cl^- > Ca^{2+} > NO_3^- > Mg^{2+} > SO_4^{2-} > K^+ > NH_4^+ > Na^+$. The components in WSIS were: Cl^- (7.67 µg m^{-3}), Ca^{2+} (4.74 µg m^{-3}), NO_3^- (1.75 µg m^{-3}) and Mg^{2+} (0.93 µg m^{-3}) and their concentration varied from 0.75 – 13.22 µg m^{-3}, 0.52 – 8.99 µg m^{-3}, 0.37 – 16.19 µg m^{-3} and 0.16 – 8.67 µg m^{-3}, respectively..

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Table 4.9

Descriptive statistics of 8 h average concentrations of ionic composition in two monitored institutes (unit in: µg m^{-3})

Ionic Species	ILKKM Sungai Buloh									ILKKM Sultan Azlan Shah								
	Lecture Hall			Laboratory			Lecturer Office			Lecture Hall			Laboratory			Lecturer Office		
	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max
Na^+	0.05± 0.02	0.03	0.10	0.04 ± 0.01	0.03	0.05	0.05 ± 0.01	0.04	0.06	11.58± 2.13	9.46	16.7	11.83 ± 1.77	10.05	14.12	11.21 ± 3.18	9.00	19.99
NH_4^+	0.38± 0.36	Nd	1.25	0.33 ± 0.24	Nd	0.8	0.00 ± 0.01	Nd	0.04	0.38 ± 0.36	Nd	1.25	0.33 ± 0.24	Nd	0.80	0.00 ± 0.01	Nd	0.04
K^+	1.1 ± 0.41	Nd	1.00	0.56 ± 0.49	Nd	1.14	0.16 ± 0.34	Nd	0.81	1.60 ± 0.83	1.06	3.20	1.24 ± 0.12	1.07	1.39	1.18 ± 0.172	0.99	1.40
Ca^{2+}	5.81 ± 2.03	3.49	8.99	4.94 ± 2.01	2.61	8.95	4.02 ± 2.31	0.52	1.79	4.52 ± 0.9	2.80	6.05	4.84 ± 0.52	4.12	5.77	6.59 ± 2.71	1.65	9.73
Mg^{2+}	0.66 ± 0.62	0.16	1.86	0.56 ± 0.39	0.38	1.26	1.44 ± 2.64	Nd	8.67	0.58 ± 0.2	0.27	0.81	1.26± 2.25	0.37	7.64	1.02 ± 0.72	0.21	1.80
Cl^-	8.61 ± 0.22	0.85	13.23	7.00 ± 0.96	5.22	8.11	8.43 ± 3.90	0.75	12.85	25.74 ± 35.47	6.97	94.55	8.66 ± 3.00	1.20	12.65	9.43 ± 4.61	0.46	18.58
NO_3^-	1.28 ± 0.72	0.64	2.54	1.0 ± 0.5	0.37	1.94	2.78 ± 4.74	0.62	16.19	1.76 ± 0.93	1.04	3.37	1.55 ± 0.57	1.07	2.54	0.70 ± 0.13	0.61	1.00
SO_4^{2-}	0.38 ± 0.11	0.19	0.53	0.39 ± 0.16	0.24	0.79	1.36 ± 1.58	0.27	5.33	0.38 ± 0.15	0.19	0.67	0.50 ± 0.07	0.39	0.62	1.35 ± 2.61	0.17	8.66

Nd= Not detected

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The trend for the average WSIS concentration of $PM_{2.5}$ in SAS was in descending order as follows: $Cl^- > Na^+ > Ca^{2+} > K^+ > NO_3^- > Mg^{2+} > SO_4^{2-} > NH_4^+$. Among all analysed ions, Cl^- (14.61 μg m^{-3}), Na^+ (11.54 μg m^{-3}), Ca^{2+} (5.32 μg m^{-3}) were found to be main component for SAS and their concentration ranged from 0.46 – 94.55 μg m^{-3}, 9 – 19.99 μg m^{-3} and 1.65 – 9.73 μg m^{-3}, respectively while the other ions, NO_3^- (1.34 μg m^{-3}), SO_4^{2-} (0.74 μg m^{-3}), NH_4^+ (0.24 μg m^{-3}), K^+ (1.34 μg m^{-3}) and Mg^{2+} (0.95 μg m^{-3}).

Compared with other soluble ions, the Cl^- mass concentration was two times higher in SAS (14.61 μg m^{-3}) than those observed in SB (7.67 μg m^{-3}), indicating the sources is probably originated from industrial sources and coal burning emission (Tsitouridou, Voutsa, & Kouimtzis, 2003). Na^+ and K^+ concentrations had significant different ($p < 0.05$) between SB and SAS which SAS showed higher readings compared with SB. The indoor Na^+ level in SAS showed ten times higher than indoor Na^+ level in SB. This is probably because of this ion likely originated from indoor dust resuspension, earth crust or ocean spray (Alahmr, Othman, Abd Wahid, Halim, & Latif, 2012; Qin & Oduyemi, 2003; Abd Wahid, Latif, & Suratman, 2017). The penetration of this particle depends on the exchange of air between internal and external environment.

Other than that, the ionic species of K^+ level in SAS was observed almost three times higher than observed in K^+ level in SB. This is suggesting that the sources may originate from combustion activities emissions such as biomass burning and motor vehicles that can infiltrate into indoor (Xu et al., 2011). On average, the concentration of Cl^-, SO_4^{2-}, NH_4^+, Mg^{2+} and Ca^{2+} at SB were found to be slightly higher compared to

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the concentrations of these elements at SAS but no significant different can be found ($p > 0.05$) between these two institutes. Other than that, NO_3^- concentration at SB was slightly higher than NO_3^- concentration at SAS.

In order to compare the concentration of the WSIS between different sampling areas for each institute, one-way ANOVA was performed. For SB, the results showed that the concentration of K^+ was statistically significantly different ($p<0.05$) between the sampling areas. The concentration of K^+ in SB lecture hall (1.097 μg m^{-3}) was about two times higher (0.559 μg m^{-3}) and almost ten times higher (0.16 μg m^{-3}) than laboratory and lecturer office, respectively. This is suggesting that motor vehicle and biomass burning has potentially increased the K^+ level due to open windows and doors.

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Besides that, one-way ANOVA analysis also indicated that there was statistically difference ($p<0.05$) between the concentration of NO_3^- measured for different sampling areas at SAS where NO_3^- level in lecture hall (1.757 μg m^{-3}) was almost three times higher than lecturer office (0.703 μg m^{-3}). According to Kam et al. (2012), fossil fuel combustion from diesel vehicle may increase the NO_3^- level in lecture hall more compared with lecturer office due to frequent opens/closes activities of doors and windows.

The relationship between these WSIS for both SB and SAS were examined using Pearson Correlation analysis as presented in Table 4.10. The result showed that the concentration of some of the ions analyzed in the study related to one another,

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showing their common source of origin. In SB, Mg^{2+} concentration was strongly correlated with SO_4^{2-} ($r = 0.894$; $p < 0.01$) which it exhibits the sources originated from resuspension of road's dust for earth's crust elements especially for urban areas (Lazaridis et al., 2008).

Meanwhile, in SAS, NO_3^- concentration was significantly correlated with Cl^- concentration ($r = 0.732$; $p < 0.01$), suggesting that motor vehicle emission was the main important sources in this area. In addition, NH_4^+ was strongly correlated with Cl^- ($r = 0.685$; $p < 0.01$) and NO_3^- ($r = 0.649$; $p < 0.01$) which the sources may have originated from soil dust resuspension and biomass burning activities (Kitto, 1993). There was also a strong correlation between K^+ with NO_3^- ($r = 0.715$; $p < 0.01$) and NH_4^+ ($r = 0.73$; $p < 0.01$), suggesting that biomass burning was the significant contributor to particulate matter in a rural area as reported by (Abd Wahid, Latif, & Suratman, 2013; Zhu et al., 2012).

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Table 4.10

Correlation coefficient between ionic compositions in two monitored institutes

SB	**Cl^-**	**NO_3^-**	**SO_4^{2-}**	**Na^+**	**NH_4^+**	**K^+**	**Mg^{2+}**	**Ca^{2+}**
Cl^-	1							
NO_3^-	0.129	1						
SO_4^{2-}	-0.204	0.137	1					
Na^+	0.452	0.292	-0.035	1				
NH_4^+	-0.350	-0.223	-0.277	-0.189	1			
K^+	0.100	0.079	-0.333	0.210	0.328	1		
Mg^{2+}	-0.377	0.031	**0.894****	-0.079	-0.133	-0.13	1	
Ca^{2+}	0.022	0.168	0.027	0.024	0.090	0.443	0.296	1
SAS								
Cl^-	1							
NO_3^-	**0.732****	1						
SO_4^{2-}	0.019	-0.117	1					
Na^+	0.383	0.252	-0.131	1				
NH_4^+	**0.685****	**0.649****	-0.164	0.366	1			
K^+	0.961	**0.715****	-0.054	**0.55****	**0.73****	1		
Mg^{2+}	-0.074	-0.149	-0.041	0.008	0.017	-0.04	1	
Ca^{2+}	-0.091	-0.270	0.510	0.143	-0.180	-0.04	0.130	1

**Correlation is significant at the 0.01 level (2-tailed) and highlighted in bold.

The comparative data for indoor WSIS concentration associated with particulate matter in this study and other studies are presented in Table 4.11. The WSIS concentration of indoor PM samples in this study are agree well with studies conducted in two schools in Aveiro, Portugal (Pegas et al., 2012) except for Na^+ which was

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recorded seven times higher than in other study. On the other hand, higher mean concentration of NH_4^+, NO_3^- and SO_4^{2-} were observed in study by Zhu et al. (2012) conducted in rural areas of Northwestern China. Na^+ ion concentrations were found two times lower in two schools in Putrajaya and Kuala Lumpur, Malaysia compared with this study (Mohamad et al., 2016).

Table 4.11

Comparison of indoor water-soluble ionic species (WSIS) associated with PM_2 between this study and other studies (unit in: $\mu g\ m^{-3}$)

Location	Cations					Anions		
	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+	NO_3^-	SO_4^{2-}	Cl^-
Sungai Buloh, Malaysia	7.67	0.58	4.74	0.932	0.223	1.753	0.73	7.67
Tanjung Rambutan (**This study**)	14.61	3.39	5.32	0.953	0.237	1.337	0.74	14.61
Two schools from	5.11	1.08	10.1	0.863	0.591	4.61	4.50	NR
Kuala Lumpur, Malaysia	5.16	1.46	4.49	0.635	1.40	5.47	5.12	
Putrajaya, Malaysia (Mohamad et al., 2016)								
Rural Areas of Northwestern China (Zhu et al., 2012)	3.08	7.95	1.05	0.70	15.02	23.58	39.72	3.68
Indoor in an urban environment (Chithra & Nagendra, 2013)	3.22	0.87	3.35	0.33	7.53	4.23	12.13	3.65
Two schools in Aveiro,	0.90	0.26	1.05	0.09	0.51	1.02	1.27	0.67
Portugal (Pegas et al., 2012)	2.69	0.26	0.74	0.15	0.74	1.04	2.87	0.99

Note:

NR = Not reported

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4.4.2 Trace Metals

The result on the average of trace metals concentration in $PM_{2.5}$ for every sampling area at both SB and SAS were summarized in Table 4.12. Trace metals can be used as tracers of specific sources, for example, earth's crust (Mg, K, Fe, Ca, Al), anthropogenic (Cu, Mn, V, Zn) and also can be categorised as toxic (As, Cd, Cr, Co, Ni, Pb) (Wang, Chao, Wang, Chang-Chien, & Tsou, 2010). The average of the trace metals indicated the abundance of Fe metals in $PM_{2.5}$ samples with the highest mean concentration in SB and SAS. Meanwhile, Fe (1644.06 ± 477.88 ng m^{-3}) was a main element which composed for SAS. Among the trace metals analysed, Co and Cu concentrations were statistically significantly different ($p < 0.05$) between SB and SAS. The result showed that, Co concentration had significantly higher in SB compared with SAS whereas for Cu, SAS had significantly higher concentrations than SB.

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Table 4.12

Descriptive statistics of 8 h average concentrations of trace metals in two monitored institutes (unit in: ng m^{-3})

Ionic Species	ILKKM Sungai Buloh									ILKKM Sultan Azlan Shah								
	Lecture Hall			Laboratory			Lecturer Office			Lecture Hall			Laboratory			Lecturer Office		
	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max	Avg ± SD	Min	Max
Fe	1858.56 ± 310.21	1521.1	2314.2	1762.05 ± 261.38	1532.6	2536.07	2121.22	1421.31	2169.3	1811.03 ± 461.39	1103.6	2301.3	1623.94 ± 635.89	1361.2	2213.6	1497.22 ± 251.45	1069.7	2531.7
As	119.87 ±1.83	117.89	123.09	133.29 ±4.52	128.51	140.35	4.87±0.99	4.03	6.64	147.83 ±9.54	133.71	158.07	165.88 ±23.29	139.14	194.57	37.01±53.25	1.04	118.89
Pb	23.53± 7.45	14.96	31.24	18.11± 4.34	14.11	25.61	28.36± 5	24.44	37.5	20.3±2.2	17.84	23.87	39.34± 22.33	15.32	61.13	23.53±7.45	14.96	31.24
Cd	0.55±0.13	0.4	0.75	1.14±0.89	0.63	2.78	0.57±0.09	0.44	0.67	0.51±0.15	0.31	0.75	0.93±0.44	0.38	1.36	0.42±0.11	0.29	0.54
Cr	117.55 ±32.5	75.84	136.36	87.39± 5.03	78.89	93.29	117.73 ±10.09	106.37	129.93	108.91 ±11.13	95.12	122.69	149.04 ±41.13	32.85	169.04	117.55±32.5	160.13	75.84
Co	3.72±1.04	2.61	5.2	4.07±2.39	2.05	7.07	4.63±1.61	3.3	7.45	0.37±0.09	0.25	0.5	3.4±1.91	1.46	5.41	2.58±2.01	0.4	5.2
Cu	25±9.23	17.91	41.86	20.59± 3.02	17.26	25.23	20.99± 3.54	16.76	26.65	28.43± 7.55	21.43	41.72	49.94± 13.74	33.35	62.98	25±9.23	17.91	41.86
Ni	59.21± 24.98	28.07	85.11	42.89± 6.26	36	52.53	61.94± 14.9	45.41	86.71	50.5±3.86	46.21	56.45	106.05 ±62.43	49.21	175.89	59.21±24.98	28.07	85.11
V	9.61±5.79	2.9	16.99	6.25±2.43	4.03	10.54	12.36± 2.88	10.25	17.55	7.98±0.75	6.82	8.99	13.06± 8.35	4.78	21.95	9.61±5.79	2.9	17.0

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In order to discover the relationship between all these trace metals, Pearson Correlation test was performed. The correlation coefficient matrix between trace metals concentrations for respective sampling area for each institute is presented in Table 4.13. A significant positive correlation was found between Fe- Pb ($r = 0.91$), Fe-Cr ($r = 0.57$), Fe-Cu ($r = 0.85$), Fe-Ni ($r = 0.85$), Fe-V ($r = 0.87$), Pb-Cr ($r = 0.72$), Pb-Co ($r = 0.69$), Pb-Ni ($r = 0.80$), Pb-V ($r = 0.91$), Cr-Ni ($r = 0.70$), Cr-V ($r = 0.73$) and Ni-V ($r = 0.84$), which all significant at 0.01 level in SB. Meanwhile, Pb-Cu ($r = 0.51$) and Cr-Cu ($r = 0.51$) were significantly correlated with each other at 0.05 level.

For SAS, a strong correlation exhibited by Fe-Pb (r = 0.65), Fe-Cd (r = 0.59), Fe-Co (r = 0.54), Fe-Cu (r = 0.62), Fe-V (r = 0.59), Pb-Cd (r = 0.90), Pb-Co (r= 0.80). Pb-Cu (r = 0.83), Pb-Ni (r = 0.96), Pb-V (r = 0.92), Cd-Co (r = 0.61), Cd-Cu (r = 0.81), Cd-Ni (r = 0.87), Cd-V (r = 0.71), Co-Cu (r = 0.65), Co-Ni (r = 0.79), Co-V (r = 0.80), Cu-Ni (r = 0.81), Cu-V (r = 0.68) and Ni-V (r = 0.94) at 0.01 significant level. In addition, a moderate significant correlation ($p < 0.05$) were observed for As with Cd (r = 0.52). For the sampling areas of each institute $PM_{2.5}$ elemental concentration comparison, one-way ANOVA analysis was conducted. The results showed that there were significant different ($p < 0.05$) for Fe, As, Pb and Cr concentration among three sampling areas in SB. One-way ANOVA analysis also showed there were significantly different for As, Cd, Co and Cu concentration between all sampling areas in SAS.

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Table 4.13

Correlation coefficient matrix of trace metals detected in $PM_{2.5}$ samples in ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

SB	**Fe**	**As**	**Pb**	**Cd**	**Cr**	**Co**	**Cu**	**Ni**	**V**
Fe	1								
As	-0.43	1							
Pb	**0.91****	-0.53	1						
Cd	-0.26	0.26	-0.12	1					
Cr	**0.88****	-0.35	**0.72****	-0.20	1				
Co	0.42	-0.17	**0.69****	0.49	0.22	1			
Cu	**0.57****	0.13	**0.51***	0.09	**0.51***	0.33	1		
Ni	**0.85****	-0.31	**0.80****	-0.19	**0.70****	0.41	0.45	1	
V	**0.87****	-0.48	**0.91****	0.03	**0.73****	**0.64****	0.35	**0.84****	1
SAS									
Fe	1								
Al	0.29								
As	0.24	1							
Zn	0.22	**0.51***							
Pb	**0.65****	0.22	1						
Cd	**0.61****	**0.52***	**0.90****	1					
Cr	0.20	-0.04	0.26	0.18	1				
Co	**0.54****	-0.14	**0.80****	**0.61****	0.37	1			
Cu	**0.59****	0.45	**0.83****	**0.81****	0.41	**0.65****	1		
Ni	**0.62****	0.20	**0.96****	**0.87****	0.44	**0.79****	**0.81****	1	
V	**0.59****	-0.01	**0.92****	**0.71****	0.36	**0.80****	**0.68****	**0.94****	1

*Correlation is significant at the 0.05 level (2-tailed) and highlighted in bold
**Correlation is significant at the level 0.01 level (2-tailed) and highlighted in bold

The concentration of trace elements associated with $PM_{2.5}$ obtained from this study were compared with the trace metals concentration from other cities. The comparison of the trace metals elements is summarized in Table 4.14. The element concentration of Fe at both SB and SAS institutes in this study was much higher when compared with other cities such as Kuala Lumpur (123 ng m^{-3}) and Agra, India (1900

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ng m^{-3}). However, for Pb, Cr, Cu and Ni elements concentrations in this study were lower compared to these elements observed in Agra, India.

Other than that, As element concentration were higher in SB and SAS when compared to study conducted in Nanjing, China (As = 48.2 ng m^{-3}), Lisbon, Portugal (As = 0.262 ng m^{-3}) and Kuala Lumpur (As = 1.7 ng m^{-3}). Pb element concentration reported by Hu et al. (2012) was two times higher observed in this study. Whereas, for Cu element, Agra, India reported to have almost seven times higher than Cu level in SB and SAS but there was no much different with Cu concentration observed in Nanjing, China. In addition, the concentration of Ni in study conducted by Kulshrestha et al. (2009) was almost six times higher than Ni concentration in this study.

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Table 4.14

*Comparison of metal concentrations associated with indoor $PM_{2.5}$ with other studies (*unit in: ng m^{-3}*)*

Location	**Fe**	**As**	**Pb**	**Cd**	**Cr**	**Co**	**Cu**	**Ni**
Sungai Buloh, Malaysia	1913.95	119.87	23.53	0.55	117.5	3.72	25	59.217
Ulu Kinta, Malaysia (**This study**)	1644.06	116.91	27.73	0.62	125.17	2.12	34.46	1.92
Nanjing, China (Hu et al., 2012)	NR	48.2	59.6	61.9	11.7	19.4	29.2	16.3
Lisbon, Portugal (Almeida et al., 2011)	NR	0.262	NR	NR	(a)	0.145	NR	NR
Rural Areas of Northwestern China (Zhu et al., 2012)	0.96	(a)	0.63	0.03	(a)	(a)	(a)	(a)
Agra, India (Kulshrestha et al., 2009)	1900	NR	1100	NR	600	NR	200	300

*NR = not reported, (a) = below the limit

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4.5 Source Identification and Apportionment of $PM_{2.5}$ by Receptor Model

In order to perform source identification and apportionment of particulate matter ($PM_{2.5}$), multivariate statistics were applied where it was the main technique of receptor model approaches. Enrichment factor (EF) analysis was carried out to estimate the

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possible sources of the elements associated with $PM_{2.5.}$ In addition, a multivariate approach, namely, principal component analysis (PCA) and multiple linear regression (MLR) are able to identify sources from the composition of water-soluble ionic species (WSIS) and trace metals dataset. Besides that, the assessment of the $PM_{2.5}$ morphology characteristic will also be done by using Field Emission Scanning Electron Microscopy (FESEM).

Therefore, the results of this study are mainly summarized in four sections. The first section is source identification of $PM_{2.5}$ for both institutes using enrichment factor (EF) analysis. The second section is also to identify and clarify the source factors of $PM_{2.5}$ by using principle component analysis (PCA) and the third section is source apportionment using a combination of principle component analysis (PCA) and multiple linear regression (MLR) to obtain the percentage of total percentage of possible sources contribution of each element. Finally, the last section is morphology characterization for a better understanding of the properties and sources of atmospheric $PM_{2.5.}$

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4.5.1 Enrichment Factor (EF) analysis

Estimation of the possible sources of the elements in $PM_{2.5}$ was conducted using enrichment factor (EF) analysis. The EF method is able to analyse if the source of crust significantly increases the metals composition in the particulate matter. The outcome result from EF analysis can be classified into three groups, namely, (1) Group 1 for low

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enrichment factor which includes metals with an EF values below 10, (2) Group 2 for moderately enriched factor which presents metals with an EF values in the range of 10 to 100 and lastly (3) Group 3 for highly enriched factor which consists metals indicating EF values greater than 100 (Shridhar, Khillare, Agarwal, & Ray, 2010). In this study, EF was calculated for selected metals in each dataset of ILKKM Sungai Buloh (SB) and ILKKM Sultan Azlan Shah (SAS) using Fe as a reference element. The results of EF analysis for trace metals at both SB and SAS is presented in Figure 4.1.

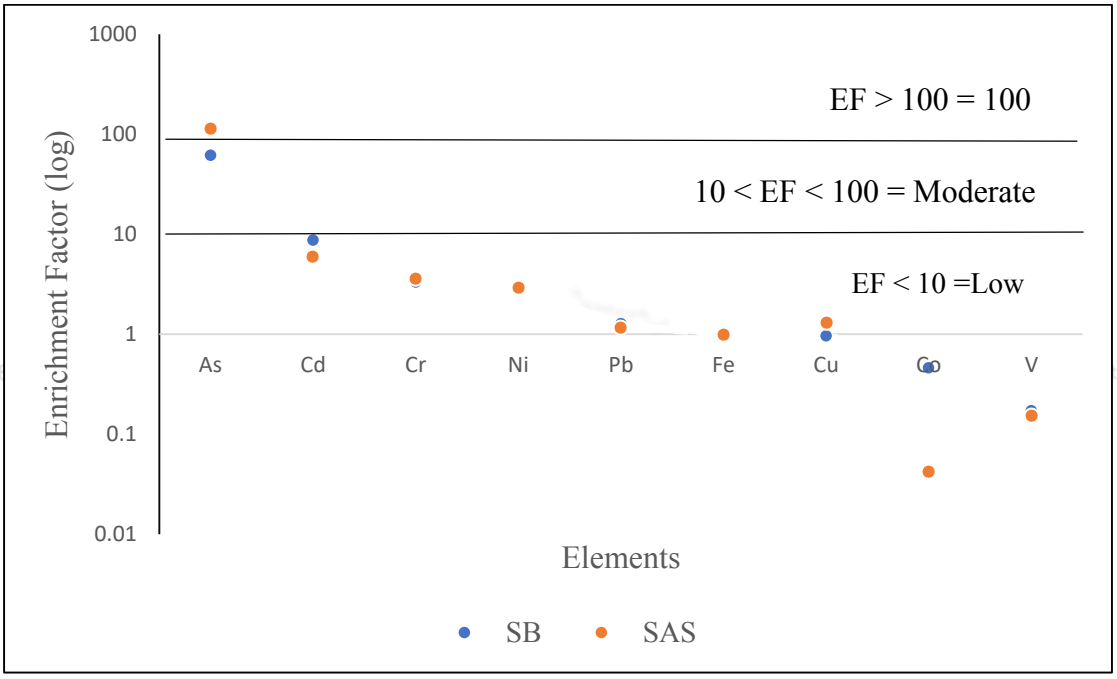


Figure 4 .1. Enrichment factor for metals detected in $PM_{2.5}$ in ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah

Based on the figure, the EF values of SB and SAS ranged from 0.173 – 114.31 and decreased in the following order of As > Cd > Cr > Ni > Pb > Fe > Cu > Co > V for SB and As > Cd > Cr > Ni > Pb > Fe > Cu > V > Co for SAS. At SB, As was moderately enriched (10 < EF < 100). These elements were suggested to be released from the anthropogenic origin and mixed natural sources, mainly from building

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materials, dust resuspension, industrial or traffic emissions, respectively. Meanwhile Cd, Cr, Ni, Pb, Fe, Cu, Co and V were minimal enriched (EF < 10) and were believed these elements originated from crustal or natural sources. Han et al. (2014) suggested that the high EFs values of metals indicates the major origin from anthropogenic sources compared to natural or crustal sources. A study by Martin et al. (2016), suggested that the dominance of As concentration was associated mining industry. The industrial emission contribution to the sampling site was likely to have originated from some factories that located approximately 3 km away from SB. Generally, the factories were based on manufacturing, electronics and high-technology industries.

Meanwhile, for SAS, high enrichment of As (EF > 100) were observed indicating that As was originated from anthropogenic sources whereas, the rest metals such as Cd, Cr, Ni, Pb, Fe, Cu, Co and V showed low enrichment (EF < 10) which these elements were classified to have originated from crustal sources. In this case, although the As is among the lowest concentration reading in the metal group analyzed, but its EF values are high, suggesting that the anthropogenic sources contributed to the presence of this metal in both SB and SAS.. According to García-Aleix et al. (2014), As was the major source of industrial emission especially from ceramic products. Other than that, the mining industry also was characterized as the major contributor to increase As concentration level in $PM_{2.5}$ (Zhang, Jin, Johnson, & Giesy, 2016). There are a few mining company and factories nearby to SAS.

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When the comparison of the results for EF values obtained in SB and SAS was perfomed, the estimated EFs for each metal were found to be relatively common for all sampling sites. The sequences of the EF values for all analyzed metal found at both sites were also almost the same. Although the nature of the institutes and its environment is quite different, the grouping of each metal is still in line with anthropogenic and natural sources. The EF distribution pattern associated with each metal suggests a common source for these metals and indicates that the location of both sites, which refers to the suburban area, contributes to the primary input of metal at both institutes.

4.5.2 Principal Component Analysis (PCA)

In order to identify the potential sources, principle component analysis (PCA) with varimax rotation was conducted to the datasets of SB and SAS. The factor loadings after varimax rotation can be classified as strong (> 7.0), moderate (0.5-0.7) and weak (< 0.5) (Wahid et al., 2014). In this study, only strong factor loadings were considered to identify the possible sources of $PM_{2.5}$ in the sampling areas. The PCA was initially performed using eight elements of WSIS and eight elements of trace metals datasets in this study. The communalities of elements that were greater than 0.7 suggests that four factors were sufficient to describe most of the variances of the elements. The loading of the elements at ILKKM SB and ILKKM SAS are presented in Table 4.15 and Table 4.16, respectively. Whereas, the summary of relative contribution of identified sources from elemental composition for significant factors are presented in Table 4.17 and 4.18.

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Table 4.15

Varimax-rotated component matrix following PCA of the SB $PM_{2.5}$ dataset

	SB			
	Factor			
Variable	**F1**	**F2**	**F3**	**F4**
Cl^-	-0.166	-0.272	**0.702**	0.034
NO_3^-	0.242	0.098	0.622	0.068
SO_4^{2-}	0.166	**0.823**	0.032	-0.310
Na^+	-0.116	-0.029	**0.728**	0.128
NH_4^+	0.166	-0.253	-0.573	0.545
K^+	0.181	-0.219	0.186	**0.822**
Mg^{2+}	0.170	**0.868**	-0.079	-0.046
Ca^{2+}	-0.015	0.259	0.196	0.623
Fe	0.598	-0.394	-0.082	0.114
As	-0.414	-0.308	-0.315	0.693
Pb	**0.884**	0.347	0.023	-0.070
Cd	-0.196	0.247	-0.276	0.480
Cr	**0.856**	-0.043	-0.240	-0.050
Co	0.453	0.554	-0.031	0.333
Cu	0.489	0.062	-0.410	0.395
Ni	**0.941**	-0.017	0.094	0.094
V	**0.887**	0.312	-0.028	-0.042
Eigenvector	4.844	3.015	2.065	1.761
% of total variance	28.493	17.736	12.145	10.358
Cumulative (%)	28.493	46.229	58.374	68.731

*Values > 0.70 are highlighted in **bold**

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(a) ILKKM Sungai Buloh (SB)

The total variance percentage was approximately 68.73 % for sampling areas in SB and was explained by four factors, as presented in Table 4.15. Factor 1 had strong loadings for Ni (0.941), V (0.887), Pb (0.884) and Cr (0.856), which these elements were attributed to the traffic emissions. The high concentration of Pb and V in Petaling Jaya and Bangi, Malaysia were result from traffic emissions (Amil, Latif, Khan, & Mohamad, 2016; Khan et al., 2016). Pb has been identified to originate from traffic emission while the high level of V concentration indicated the fuel emission contribution (Mazzei et al., 2008). According to Lestari and Mauliadi (2009), the high level of Pb and V concentrations resulted from traffic emission source. According to Yu et al. (2013), the traffic emission source might result from a high concentration of Pb. A high level of V concentration demonstrated the vehicle emissions source contribution in New Taipei City, Taiwan (Gugamsetty et al., 2012). The location of ILKKM SB is adjacent to Hospital Sungai Buloh and Universiti Teknologi Mara (UITM), Campus Sungai Buloh. Thus, the sampling area experienced the high volume of traffic on the roads and this contributes to high density of traffic emissions especially in the morning and evening hours.

A strong loading for and Mg^{2+} (0.868) and SO_4^{2-} (0.823) were identified in Factor 2. These elements are known to be common constituents of building materials and crustal sources such as soil dust resuspension and combustion process. Mg^{2+} predominated in the $PM_{2.5}$, possibly due to soil erosion (Hsu et al., 2008). The dominance of Mg^{2+} can be labelled as earth crust sources or outdoor soils, might be

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brought into the building through footwear (Fromme et al., 2008). On the other hand, SO_4^{2-} ion was a tracer for outdoor combustion activity, for example gasoline combustion (Saliba, Atallah, & Al-Kadamany, 2009). Sources of SO_4^{2-} can be also associated the combustion of substances for heating or fuels emission from building materials. SO_2 gas has a tendency to react with humidity H_2O in the atmosphere and produce sulfuric acid (H_2SO_4) which will increase ion SO_4^{2-} concentration indirectly (Zhong et al., 2014). Soil dust might be introduced into indoor environment by occupant activity and also through wind blowing from outdoor as well.

Factor 3 was assigned as sea salt due to high loadings of Na^+ and Cl^- with a variance of 0.702 and 0.728, respectively. Khan et al. (2016) suggested that the abundance of Na^+ in $PM_{2.5}$ samples in a suburban area of Bangi, Malaysia derived from sea salt source. The dominance of Na^+ presence resulted from the emission of marine sources (Tahir, Suratman, Fong, Hamzah, & Latif, 2013). A study conducted in Kuala Terengganu, Malaysia by Tahir et al. (2013) demonstrated the dominance of both Na^+ and Cl^- originated from sea salt source. Moreover, Srimuruganandam and Nagendra (2012) also characterized the contribution of Na^+ as marine aerosol in an urban roadside in Chennai City, India. Marine aerosols were produced by breaking waves bringing air bubbles to the sea surface. In this study, the sea salt was thought to come from Kuala Selangor beach which is located about 40 km away from ILKKM SB.

Factor 4 was strongly loaded with K^+ (0.8212) indicating the elements originated from biomass burning. A high significant concentration of K^+ was observed during a biomass burning period hence, indicating K^+ role as a chemical tracer of

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biomass burning (Hays et al., 2005). The dominance of K^+ element can be released during biomass burning (Li, Pósfai, Hobbs, & Buseck, 2003). The K^+ ion has been clarified as an excellent trace marker representing a biomass burning (Mustaffa, Latif, Ali, & Khan, 2014). In addition, Wang et al. (2005) also suggested that the presence of K^+ indicating they came from biomass burning activities The presence of K^+ was predominantly from burning of biomass that occurred near to ILKKM SB due to agricultural activities including the burning of agricultural waste and forest-clearing as there are abundance of retail nurseries nearby.

(b) ILKKM Sultan Azlan Shah (SAS)

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More than 78% of the total variances at indoor SAS was extracted in the form of four factors as shown in Table 4.16. Factor 1 showed a strong loading of six metals including Ni, Pb, V, Cu, Cd and Co with variance of 0.980, 0.966, 0.903, 0.888, 0.882 and 0.830, respectively, indicating these elements to be potential markers for combustion-related emission. The presence of Pb, Cu, Cd and Ni elements are most likely to have originated from fossil fuel combustion, whether vehicle exhaust emissions or non-engine combustion sources, like tyres and clutch wear (Sternbeck, Sjödin, & Andréasson, 2002; Tahir et al., 2013). The abundance of Ni and V play an important role as element markers for oil combustion (Koçak, Mihalopoulos, & Kubilay, 2009; Lee & Hieu, 2011; Mazzei et al., 2008). Cd had been correlated with smelters which may well have been derived from accumulators and vehicle carburettors combustion (Thurston, Ito, & Lall, 2011). In addition, V distribution in the environment generally has been related to

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the fossil fuels emission, such as the combustion of heavy fuel oil specifically (Balakrishna, Pervez, & Bisht, 2011). The location of ILKKM SAS is approximately 1 km to railway station, contributed to the release of combustion-associated sources. In addition, there are also several automobile repairs shops nearby to the sampling site.

Table 4.16

Varimax-rotated component matrix following PCA of the SAS $PM_{2.5}$ dataset.

SAS				
	Factor			
Variable	**F1**	**F2**	**F3**	**F4**
Cl^-	-0.153	**0.928**	0.043	-0.093
NO_3^-	0.340	**0.786**	-0.307	-0.099
SO_4^{2-}	0.105	-0.027	**0.702**	-0.060
Na^+	0.016	0.614	0.209	0.114
NH_4^+	0.062	**0.808**	-0.312	0.063
K^+	-0.115	**0.967**	0.038	-0.034
Mg^{2+}	-0.096	-0.044	0.013	**0.982**
Ca^{2+}	0.028	-0.053	**0.733**	0.147
Fe	-0.096	-0.044	0.013	**0.982**
As	0.244	0.192	**-0.794**	0.025
Pb	**0.965**	-0.046	-0.064	-0.124
Cd	**0.888**	-0.117	-0.318	0.032
Cr	0.459	0.125	0.320	0.221
Co	**00830**	-0.165	0.284	-0.091
Cu	**0.882**	0.318	-0.107	0.008
Ni	**0.980**	-0.024	-0.023	-0.044
V	**0.903**	-0.003	0.116	-0.141
Eigenvector	5.509	3.785	2.104	1.969
% of total variance	32.405	22.262	12.376	11.585
Cumulative (%)	32.405	54.667	67.043	78.628

*Values > 0.70 are highlighted in **bold**

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Factor 2 was identified as construction and renovation activities by the strong loading of Cl^- (0.928), NH_4^+ (0.808) and NO_3^- (0.786). Similar observation were discussed by Masiol et al. (2014) whereby the pollution would come from chemical reaction (NO_3^-, NH_4^+). The abundance of Cl^- and NH_4^+ indicating these elements to have originated from chemical reaction that derived from construction activities (Mazzei et al., 2008). According to Mariani and de Mello (2007), at a stable atmosphere with lower temperature favours the production of NO_3^- aerosol reacting with NH_4^+, converting the nitrate gaseous into particle phase. The massive renovation process that has been carried out at the Hospital Raja Permaisuri Bainun building that is located 15 km away from SAS might be the major contribution of renovation activities. In addition, there were also construction activities within 10 km away from the sampling sites during sampling process was undertaken.

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The building material and crustal origin were characterized as Factor 3 by a significant amount of As, Ca^{2+}, SO_4^{2-} with loading factor of -0.794, 0.733 and 0.702, respectively. As was believed to be originated from paint sources on the building surfaces (Estokova et al. 2010). The high loading of Ca^{2+} was characterized as mineral dust source by Murillo-tovar, Saldarriaga-noreña, and Hernández-mena (2015). Other than that, the resuspended dust from broken cement floor as a result of cleaning activities, also found to contribute the increased Ca^{2+} (Srivastava & Jain, 2007). A study by Khan et al. (2012) suggested that Ca^{2+} is an indicator of soil dust contribution derived from building materials through shoes of occupants moving in and out from the building. In addition, Ca^{2+} is a common constituents of building materials like plaster and in gypsum ($CaSO_4.2H_2O$) as well. The abundance of SO_4^{2-} was most likely have

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been derived from photochemical process which converts SO_2 to SO_4^{2-} (Terzi et al., 2010). The oxidation of SO_2 (obtained directly from exhaust discharge) in the presence of water results the H_2SO_4 formation that will lead to acid rain events. Both SO_2 and H_2SO_4 gaseous may interact with limestone contained asphalt concrete, generating calcium sulphate (CaSO4), with thermodynamic preferences to react with SO_2 gas (Zannoni, Valotto, Visin, & Rampazzo, 2016). Thus, the resuspension of mineral or soil dust from crustal origin and building material might be the possible originated sources and become more effectively transported to indoors via open doors and windows on drier days.

Factor 4 was strong loaded with Fe (0.982) and Mg^{2+} (0.982) which these elements were determined to be element markers of traffic emission and human activities. Human activities such occupants' movement in and out most likely enhance the resuspension of the surface dust inside the building. In addition, cleaning process such as sweeping or vacuuming after school and office hours also have had a significant incremental of indoor heavy metals (Mohamad et al., 2016). The increased of Fe concentrations might result from the high traffics volume on the roads (Mazzei et al., 2008). The abundance of Fe element may result from iron impurity in fuel combustion in outdoor environment (Sahu, Elumalai, Gautam, Singh, & Singh, 2018). The location of ILKKM SAS is adjacent to Hospital Bahagia Tanjung Rambutan where air quality was influenced by a high density of local traffic where the dust resuspension from outdoor can be brought inside through clothes and footwears.

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Table 4.17

Summary of element loading factors and possible sources for SB

	Factor			
	1	**2**	**3**	**4**
Strong[a] elements	Pb, Cr, Ni, V	SO_4^{2-}, Mg^{2+}	Cl^-, Na^+	K^+
Possible source	Traffic emission	Building material / crustal origin	Sea salt	Biomass burning

[a]Strong factor loadings are greater than 0.70

Table 4.18

Summary of element loading factors and possible sources for SAS

	Factor			
	1	**2**	**3**	**4**
Strong[a] elements	Ni, Pb, V, Cu, Cd, Co	Cl^-, NO_3^-, NH_4^+	Ca^{2+}, SO_4^{2-}	Mg^{2+}, Fe
Possible source	Combustion-related emission	Construction / renovation activities	Building material / crustal origin	Traffic emission

[a]Strong factor loadings are greater than 0.70

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4.6 Multiple Linear Regression (MLR)

As stated previously, the PCA-MLR was applied to the element dataset whereby MLR was employed using $PM_{2.5}$ mass concentration as the dependent variable whilst the principle components as independent variables. According to Thurston and Spengler (1985), the absolute factor scores has been regressed against 8 h $PM_{2.5}$ mass

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concentration using MLR analysis in order to perform source apportionment into percentage mass contribution of each identified possible source. Percentage of possible sources contribution of each element is presented in Figure 4.2 and 4.3. In SB, biomass burning sources dominated with 48% contribution to $PM_{2.5}$ on a mass basis, followed by sea salt (29%), building material (21%) and traffic emission (2%). Based on Figure 4.3, the human activities and building materials / crustal sources accounted as major sources with 81% contribution in SAS. The second highest contribution is combustion-related emission with 12% followed by construction / renovation activities (7%) and traffic emission (0.2%). In this study, the comprehensive analysis of the data suggests that the probable sources that derived from the range elements in $PM_{2.5}$ at two different sites arose locally. The different background areas provided high impact against sources and distribution pattern of atmospheric particulate matter.

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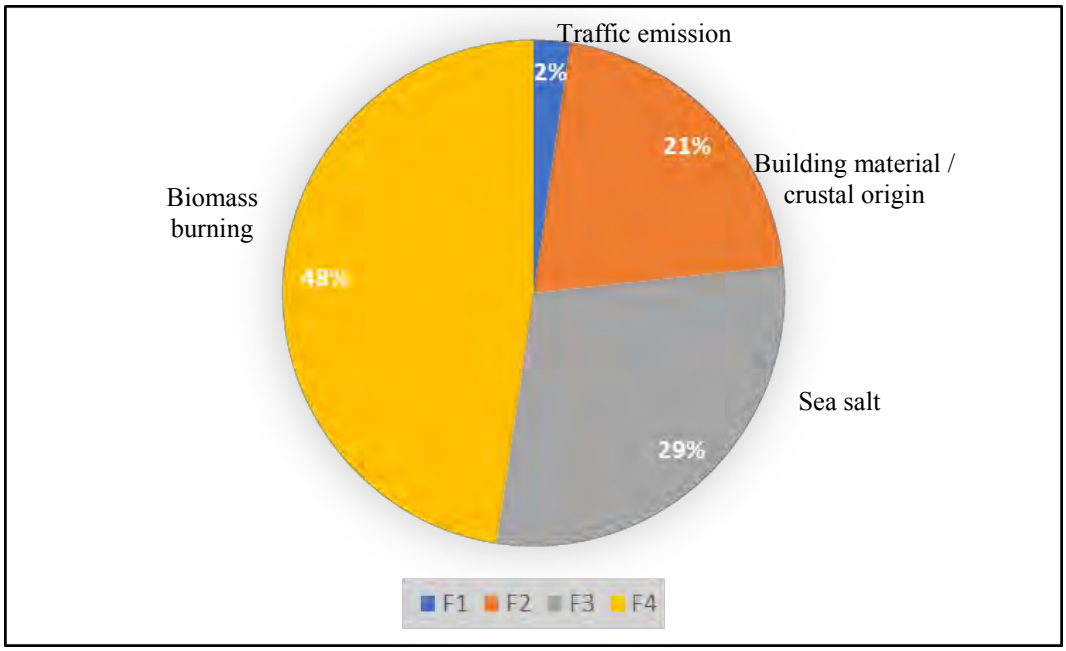


Figure 4.2. Percentage of possible sources contribution of elements in SB

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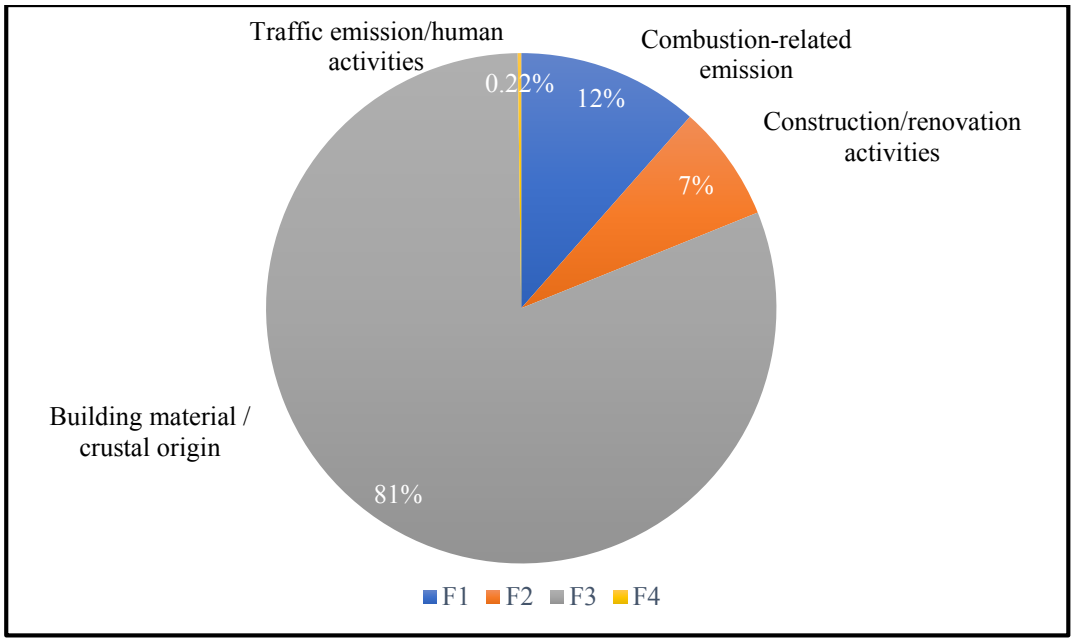


Figure 4.3. Percentage of possible sources contribution of elements in SAS

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4.7 Morphology Characteristic of Particulate Matter ($PM_{2.5}$)

FESEM image analysis of particulate matter ($PM_{2.5}$) in SB and SAS are presented in Figure 4.4 and 4.5, respectively, showing a wide range of particle sizes and shapes. The morphology characteristic of $PM_{2.5}$ can be influenced by the sources, type of pollutants and formation mechanism. In general, the particles are observed to be homogeneously distributed on filter paper for all sampling site in both institutes. Based on the magnification of grey-scale images, the $PM_{2.5}$ sizes ranged from 9.92 – 59.6 nm in SB and 13.9 – 33.8 nm in SAS.

Based on the morphology and sizes of the particle in Figure 4.4, two main classes of particles were identified in SB, namely, anthropogenic and natural sources.

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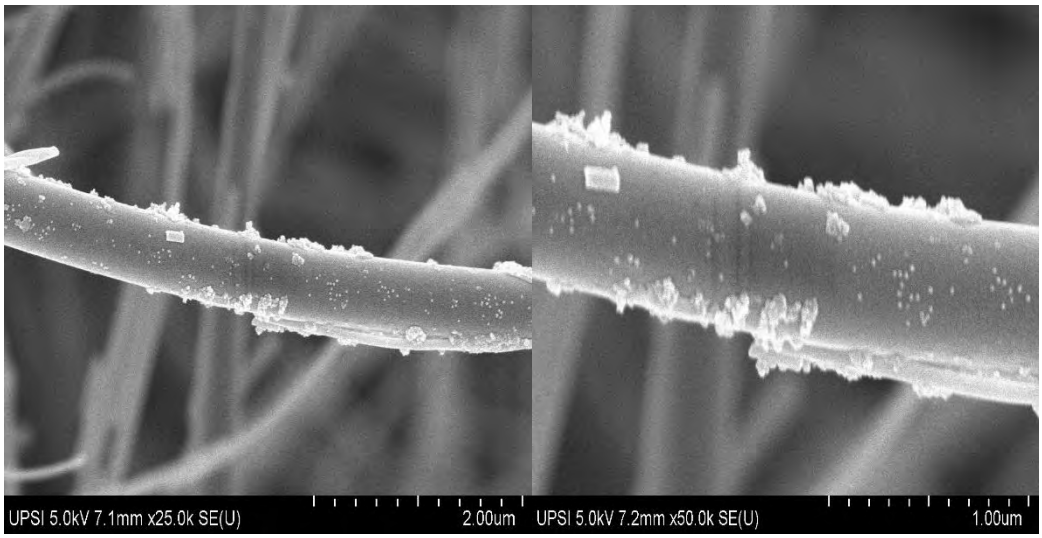
In the anthropogenic particles, the presence of irregular spherical shapes fine particles (<2.5 μm) in FESEM micrograph can be seen. This strongly demonstrates the influence of vehicular activity and combustion of petrol or diesel associated with embedded $PM_{2.5}$ in the outdoor environment (Talbi, Kerchich, Kerbachi, & Boughedaoui, 2018). In addition, Shi et al. (2015) suggested that road dust might also contribute to this fine particle production in the atmosphere. Besides that, the natural particles emitted are square, irregular in shape and larger in size possibly originate from the sea salt as the ILKKM SB location is near to Kuala Selangor ocean. Similar observation was discussed by Moreno, Sagnotti, Dinarès-Turell, Winkler and Cascella (2003).



(a) (b)

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(c) (d)

Figure 4.4. FESEM images of $PM_{2.5}$ samples collected in SB with the scale bar of (a) 10 µm, (b) 5 µm, (c) 2 µm and (d) 1 µm

According to Figure 4.5, assessment by FESEM image analysis identified the dominance of two types of particles which are originating from anthropogenic and natural sources. The small clustered spherical particles observed with the size that is less than 1 µm, possibly originate from the combustion process of fossil fuel (Anake, Ana, & Benson, 2016; Chithra & Nagendra, 2013). Moreover, the irregular shapes of the particles represents the construction activities (Li et al., 2010). In contrast, the irregular shape and aggregate in chainlike suggests that particles have been originated from the natural sources attributed to soil dust and resuspension of dust from the roads (Anake et al., 2016). Overall, both institutes showed almost similar observation in terms of size and shape of embedded $PM_{2.5}$ in the atmosphere and the outcome obtained through FESEM analysis are in agreement with PCA-MLR result obtained previously in this study.

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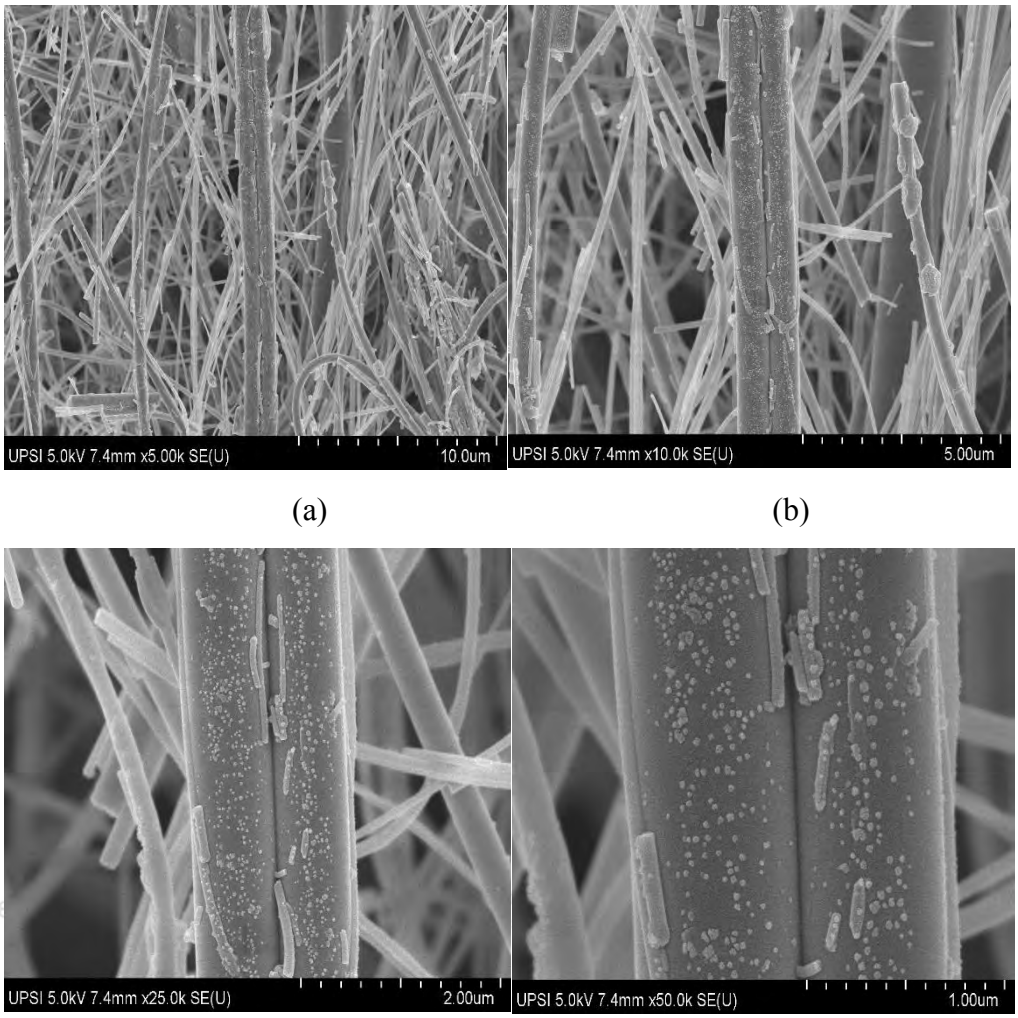


Figure 4.5. FESEM images of $PM_{2.5}$ samples collected in SAS with the scale bar of(a) 10 µm, (b) 5 µm, (c) 2 µm and (d) 1 µm

4.8 Health Risk Assessment

4.8.1 Exposure Assessment

(a) Non-Cancer Effects

An average daily dose (ADD) is used for the non-carcinogenic metal exposure assessment which ADD is expressed in a per-unit-body-weight basis ($mgkg^{-1}day^{-1}$). In this study, there are only six heavy metals are selected, namely Pb, Cd, Cr, Co, Cu and

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Ni for non-carcinogenic risk estimation. The ADD values for specific age groups, adolescent and adult were calculated as presented in Table 4.19. The ADD for all metals in descending order is as follows; Cd < Co < Cu < Pb < Ni < Cr for SB meanwhile for SAS is as follows; Co < Cd < Cr < Ni < Cu < Pb.

According to Table 4.19, the inhalation exposure to Cr for adolescent in SB and SAS were 4.02E-05 $mgkg^{-1}day^{-1}$ and 4.96E-05 $mgkg^{-1}day^{-1}$, respectively. For adult, the ADD values of Cr were 5.01E-05 $mgkg^{-1}day^{-1}$ and 6.19E-05 $mgkg^{-1}day^{-1}$, respectively. Whereas, the estimated ADD values of Cd via inhalation for the adolescent group were 2.95E-07 $mgkg^{-1}day^{-1}$ and 2.45E-07 $mgkg^{-1}day^{-1}$ while for the adult group were 3.68E-07 $mgkg^{-1}day^{-1}$ and 3.06E-07 $mgkg^{-1}day^{-1}$ for SB and SAS, respectively. Adult group showed the greater ADD values compared with adolescent group for both SB and SAS.

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Table 4.19

Average daily dose (ADD) (mgkg^{-1}day^{-1}) of age-specific groups for each non-carcinogenic metal in SB and SAS

Site	Metals	Adolescent	Adult
SB	Pb	8.81E-06	1.1E-05
	Cd	2.95E-07	3.68E-07
	Cr	4.02E-05	5.01E-05
	Co	1.6E-06	1.99E-06
	Cu	8.32E-06	1.04E-05
	Ni	2.06E-05	2.57E-05
SAS	Pb	1.10E-05	1.37E-05
	Cd	2.45E-07	3.06E-07
	Cr	4.96E-05	6.19E-05
	Co	8.39E-07	1.05E-06
	Cu	1.37E-05	1.71E-05
	Ni	2.85E-05	3.55E-05

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(b) Cancer Effects

The lifetime average daily dose (LADD) is used for carcinogenic metals in order to conduct exposure assessment. The LADD values for inhalation exposure route of age-

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specific groups is presented in Table 4.20. The estimated LADD values for the adult group was greater than the adolescent group for both SB and SAS. The LADD values for carcinogenic metals via inhalation occurred in the following order Cd < Co < Cu < Pb < Ni < Cr and Cd < Co < Pb < Cu < Ni < Cr for Sb and SAS, respectively.

Based on Table 4.20, the LADD values via inhalation exposure for adolescent in SB ranged between 5.90E-08 $mgkg^{-1}day^{-1}$ (Cd), 3.19E-07 $mgkg^{-1}day^{-1}$ (Co), 1.66E-06 $mgkg^{-1}day^{-1}$ (Cu), 1.76E-06 $mgkg^{-1}day^{-1}$ (Pb), 4.12E-06 $mgkg^{-1}day^{-1}$ (Ni) and 8.03E-06 $mgkg^{-1}day^{-1}$ (Cr), while in SAS, the LADD values ranged from 4.90E-08 $mgkg^{-1}day^{-1}$ (Cd), 1.68E-07 $mgkg^{-1}day^{-1}$ (Co), 2.20E-06 (Pb), 2.73E-06 $mgkg^{-1}day^{-1}$ (Cu), 5.70E-06 $mgkg^{-1}day^{-1}$ (Ni) and 9.92E-06 $mgkg^{-1}day^{-1}$ (Cr). Whereas for adult group in, Cr showed the highest LADD value while Cd has the lowest LADD values for both SB and SAS.

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Table 4.20

Lifetime average daily dose (LADD) (mgkg^{-1}day^{-1}) of age-specific groups for each carcinogenic metal in SB and SAS

Site	Metals	Adolescent	Adult
SB	Pb	1.76E-06	3.77E-06
	Cd	5.90E-08	1.26E-07
	Cr	8.03E-06	1.72E-05
	Co	3.19E-07	6.83E-07
	Cu	1.66E-06	3.56E-06
	Ni	4.12E-06	8.80E-06
SAS	Pb	2.20E-06	4.70E-06
	Cd	4.90E-08	1.05E-07
	Cr	9.92E-06	2.12E-05
	Co	1.68E-07	3.59E-07
	Cu	2.73E-06	5.84E-06
	Ni	5.70E-06	1.22E-05

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4.8.2 Risk Characteristic

(a) Non-Cancer Risk

Hazard Quotient (HQ) was calculated to characterize the risk to human receptor from being exposed to non-carcinogenic metals via a single pathway. HQ is a numerical ratio to determine whether exposure to chemicals is harmful or not which it is calculated for a single metal for each pathway. If the calculated HQ is less than 1, there are considered no adverse health effect will occur but if HQ value exceeds 1, then the adverse health effect considered are possible. The hazard index (HI) is the sum of HQ and is used to investigate the overall probability for the significant non-carcinogenic risk of all the chemicals. Same as HQ, if HI value is below 1, it indicates that there is no significant risk of non-carcinogenic effects but if HI above 1, shows there is a chance of non-carcinogenic effects occurring, with increased probability as the value of HQ and HI increases.

The HQ and HI values via inhalation exposure for non-carcinogenic metals of each age-specific group (adolescent and adult) in SB and SAS is summarised in Table 4.21. The HQ value ranged from 2.45E-04 to 1.03. In SB, the lowest HQ (2.79E-01) was estimated among the adolescent group when being exposed to Co by the route of inhalation. Meanwhile the highest HQ value (8.35E-01) was estimated among the adult group as a result of Cr exposure by inhalation pathway. The HQ value for adolescent and adult group were ranked in descending order as follows; Cr > Co > Ni > Pb > Cd > Cu in SB.

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Whereas, in SAS, the result showed that HQ (1.03E+00) of Cr exhibits the highest values among the adult group where it exceeds the safe level of HQ ≤ 1, as determined by USEPA. Meanwhile, the lowest HQ (2.45E-04) values was estimated for adolescent group as a result to Cd exposure via inhalation route. Based on the Table 4.20, the HQ of all metals for both adolescent and adult group decreased in order of Cr > Co > Ni > Pb > Cu > Cd.

According to Table 4.21, HI value for adult group was higher than adolescent group for both SB and SAS with (H = 1.19) and (H = 1.23), respectively. This showed that there was significant (HI > 1) risk of non-carcinogenic cancer adverse health effects can occur for adult group. Meanwhile, HI value for adolescent group was (HI = 9.56E-01) and (HI = 9.83E-01) for SB and SAS, respectively.

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The HI values of non-carcinogenic elements on adolescent and adult groups decreased in order; Cr > Co > Ni > Pb > Cd > Cu for SB and Cr > Co > Ni > Pb > Cu > Cd for SAS, indicating that Cr potentially harms the health of children and adults on both institutes as Cr contributed 70% and 84% of total non-carcinogenic elements, respectively. In terms of non-carcinogenic metals, the presence of Cr increases the probability of potential adverse health effects to occur. According to source apportionment method, Cr is identified originating from anthropogenic sources, such as automobile and industrial emission (Chen et al., 2015). Therefore, modifications and improvement to ventilation systems can be implemented to prevent health risk among building occupants (Othman, Latif, & Mohamed, 2016). It is crucial to control air quality effectively to minimize the health risks (Kim et al., 2015).

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Table 4.21

Hazard Quotient (HQ) and hazard index (HI) values for non-carcinogenic metals of each specific age group in SB and SAS

Site	Group	Metals	HI = ΣHQ
SB	**Adolescent**	Pb	2.50E-03
		Cd	2.95E-04
		Cr	6.69E-01
		Co	2.79E-01
		Cu	6.93E-04
		Ni	3.81E-03
			ΣHQ = 9.56E-01
	Adult	Pb	3.12E-03
		Cd	3.68E-04
		Cr	8.35E-01
		Co	3.49E-01
		Cu	8.65E-04
		Ni	4.75E-03
			ΣHQ = 1.19E+00**
SAS	**Adolescent**	Pb	3.12E-03
		Cd	2.45E-04
		Cr	8.26E-01
		Co	1.47E-01
		Cu	1.14E-03
		Ni	5.28E-03
			ΣHQ = 9.83E-01
	Adult	Pb	3.89E-03
		Cd	3.10E-04
		Cr	1.03E+00*
		Co	1.83E-01
		Cu	1.41E-03
		Ni	6.58E-03
			ΣHQ = 1.23E+00**

*indicates significant HQ value and **indicates significant HI value

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(b) Cancer Risks

The calculated carcinogenic risk represents the probability of developing any type of cancer to an individual in a lifetime exposure to carcinogenic elements is called incremental lifetime cancer risks (ILCR). This is evaluated by multiplying the lifetime average dose (LADD) inhalation values with a chemical-specific dose response data (CSF). The acceptable risk for carcinogen elements ranged between 1×10^{-6} and 1×10^{-4} (USEPA 2012). The ILCR for Pb, Cd, Cr, Co and Ni of each age-specific group in SB and SAS were presented in Table 4.22. The results showed that the ILCR values for five analysed metals were in the following order of Cr > Ni > Co > Cd > Pb. The estimated ILCR ranged from 9.24E-08 to 8.90E-04. The highest ILCR was posed by adult group in SAS (9.10E-04) where nine to ten individuals in 10,000 may develop cancer due to the exposure of $PM_{2.5}$ carcinogenic elements.

Based on the result, ILCR values via inhalation pathway of Pb and Cd were lower than acceptable limit for both adolescent and adult groups, suggesting that Pb and Cd in $PM_{2.5}$ can be considered negligible in SB and SAS. In contrast, the recovery step should be taken for pollution control of Cr as its ILCR value was higher than acceptable level (3.37E-04) and (4.17E-04) for SB and SAS, respectively. In this study, only the total of Cr was determined to have significant carcinogenic risks. Other than that, the integrated risks of carcinogenic elements were not significant for carcinogenic health effects as all the ILCR values were within the acceptable level ($1 \times 10^{-6} – 1 \times 10^{-4}$). Similar observations have be found in the study done by Mohamad et al. (2016) where cancer risks attributed by Cr.

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Table 4.22

Incremental lifetime cancer risks (ILCR) for carcinogenic metals of each age-specific group in SB and SAS

Site	Metals	Adolescent	Adult
SB	Pb	7.39E-08	1.58E-07
	Cd	3.72E-07	7.94E-07
	Cr	3.37E-04	7.22E-04
	Co	3.13E-06	6.69E-06
	Ni	3.46E-06	7.39E-06
Σ		3.44E-04	7.37E-04
SAS	Pb	9.24E-08	1.97E-07
	Cd	3.09E-07	6.62E-07
	Cr	4.17E-04	8.9E-04
	Co	1.65E-06	3.52E-06
	Ni	4.79E-06	1.02E-05
Σ		4.23E-04	9.10E-04

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4.9 Chapter Summary

The analysis of all comfort parameter including temperature, relative humidity, total bacterial and fungal counts generally demonstrated that the readings are within the acceptable limits recommended by Industry code of practice on Indoor Air Quality 2010 standard (DOSH, 2010). Thus, these such conditions should be maintained to ensure the convenience of all occupants and indoor air quality monitoring from time to time should be carried out. The elemental composition including water-soluble ionic species (WSIS) and trace metals associated with $PM_{2.5}$ collected from three sampling areas at both SB and SAS suggested that the indoor and outdoor sources play the important role in the $PM_{2.5}$ concentrations, characterization and its source identification. This study revealed that the concentration of Na^+ and K^+ were about ten times and three times higher in SAS compared with SB, respectively. It is strongly believed that, the contribution of these species is possibly from earth crust, sea spray, biomass burning and motor vehicles emission. In terms of metal elements, Fe was a dominant metal at both SB and SAS indicates the existence of anthropogenic sources of these elements.

The enrichment factor analysis relative to earth's crust dominance was performed to estimate anthropogenic sources compared with natural sources. The result showed As to have the highest enrichment factor, indicating the pollutant contribution was most likely to have originated from vehicle and industrial emissions. Cd, Cr, Ni, Fe, Cu, Co and V were minimal enriched (EF < 10) since the elements are mostly crustal or natural sources. Then, sixteen chemical species have been analysed in $PM_{2.5}$ using

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multivariate analysis technique, namely, PCA-MLR (principle component analysis-multi linear regression). The outcome from the analysis demonstrated that building materials, biomass burning, traffic emission, sea salt, crustal origin, construction / renovation activities and combustion-related emission were identified as the possible sources at both institutes.

PCA-MLR analysis identified four factors involved as pollutant contribution in SB and SAS. Biomass burning are identified as the major contribution representing 48% at SB while 81% of the element sources are building materials / crustal origin identified in SAS. Other key sources of elements in $PM_{2.5}$ at SB were sea salt sources (29%), building materials / crustal origin (21%) and traffic emission (2%). Other sources in SAS were combustion-related emission (12%), construction / renovation activities (7%) and traffic emission (0.2%). The analysed FESEM images observation in this study is in line with the PCA-MLR analysis outcome, indicating that the main contribution sources of $PM_{2.5}$ in the atmosphere are from anthropogenic and natural sources for both SB and SAS. Overall, the results obtained in this study are in agreement with the previous study by Zhong et al. (2014) conducted in Biology building, Universiti Kebangsaan Malaysia (UKM), demonstrating the that the major contribution was derived from indoor environment.

In this study, the health risks (cancer and non-cancer risks) associated with $PM_{2.5}$ via inhalation pathway were assessed. Based on the outcome of the result in SAS, nine to ten individuals out of 10,000 population were estimated to have a chance to being affected by cancer in a lifetime exposure due to high carcinogenic elements

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concentrations in $PM_{2.5}$ that originating from anthropogenic sources. Other than that, non-carcinogenic risks associated with $PM_{2.5}$ via inhalation were estimated. The results showed that the adult group has significant risks of having adverse health effects in a lifetime exposure to non-carcinogenic metals emitted by $PM_{2.5}$. In this perspective, concerns on adults need special attention as adults occupied the building institutions (lecturer office, lecture hall and laboratory) that nearby the roadside which exposed to high concentrations of both carcinogenic and non-carcinogenic elements. Number of vehicles and the industrial emissions were the possible threat sources for both ILKKM Sungai Buloh (SB) and ILKKM Sultan Azlan Shah (SAS). Other than metals that associated with $PM_{2.5}$, there are also other chemical constituents that may contribute to major health concerns such as organic compounds that is not being assessed in this study. In conclusion, the health protection of adult group in these two institutes needed to be emphasized since the risk characterization for selected metals based on inhalation exposure route are significant.

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CHAPTER 5

CONCLUSIONS

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5.1 Conclusions

The average of four comfort parameters including temperature, relative humidity, total bacterial count and total fungal count were in acceptable range for all sampling areas in both SB and SAS as suggested by Industry code of practice on Indoor Air Quality 2010 standard. There are no significant differences ($p > 0.05$) between these two institutes for all four mentioned comfort parameters. Besides that, a total number of 30 $PM_{2.5}$ samples were collected at two training institutes under Malaysia Ministry of Health (MOH) with different background in ILKKM Sungai Buloh (SB) and ILKKM

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Sultan Azlan Shah (SAS) were analysed for better understanding on their chemical characterization and potential sources identification. The samplings were conducted in three selected areas with different settings including laboratory, lecture hall and lecturer office at each institute. The average concentration of $PM_{2.5}$ recorded ranged between 51.39 ± 29.95μg/m^3 and 45.833 ± 20.47 μg/m^3 for SB and SAS, respectively. No significant different ($p > 0.05$) was observed on $PM_{2.5}$ mass concentrations between these two institutes. In this study, the average 8-h of $PM_{2.5}$ concentration can be considered to be high as about 20% of the $PM_{2.5}$ samples exceeded the 75 μg/m^3 Malaysia Ambient Air Quality Standard 2015 (IT-1).

The $PM_{2.5}$ chemical composition including water-soluble ionic species (WSIS) and trace metals suggested that indoor sources along with outdoor sources have important role in the $PM_{2.5}$ mass concentration and their characteristics. In this study, the trend for the average of WSIS concentrations in $PM_{2.5}$ was $Cl^- > Ca^{2+} > NO_3^- > Mg^{2+} > SO_4^{2-} > K^+ > NH_4^+ > Na^+$ for SB and $Cl^- > Na^+ > Ca^{2+} > K^+ > NO_3^- > Mg^{2+} > SO_4^{2-} > NH_4^+$ for SAS. On average, there are no significant different can be observed ($p > 0.05$) on these element concentrations between both institutes. On the other hand, the average of the trace metals indicated the presence of As, Pb, Cd, Cr, Cu, Ni and V in $PM_{2.5}$ samples with the highest mean concentration in one trace element of Fe for both SB and SAS. Element Fe ((1644.06 ± 477.88 ng m^{-3}) metals composing of 84.2% of total elemental mass concentrations for SB. Meanwhile, Fe (4032.59 ± 2340.85 ng m^{-3}) was the major element which accounted for 80.86% of $PM_{2.5}$ total trace metals for SAS.

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The average of the trace metals indicated the abundance of Fe metals in $PM_{2.5}$ samples with the highest mean concentration in SB and SAS. Fe (1913.95 ± 479.47 ng m^{-3}) metal accounted for 84.2% of total elemental mass concentrations while for Cd, Co and V accounted less than 1%.

The enrichment factor (EF) analysis was carried out for possible sources of $PM_{2.5}$ estimation. Based on this analysis in SB, As was moderately enriched (10 < EF < 100). These metals were suggested to be released from the anthropogenic and natural sources, particularly from building materials and mining industries. Other metals such as Cd, Cr, Ni, Pb, Fe, Cu, Co and V were minimal enriched (EF < 10) that were believed to have originated from crustal or natural origin. Meanwhile in SAS, As was highly enriched (EF > 100), suggesting that As were originated from anthropogenic sources whereas, the rest metals such as Cd, Al, Cr, Ni, Pb, Fe, Cu, Co and V showed low enrichment (EF < 10) which these elements were classified to have originated from crustal sources.

Based on the receptor modelling results, the major sources of $PM_{2.5}$ composition in SB were biomass burning of 48% of total contribution to $PM_{2.5}$ mass, followed by sea salt (21%), building materials / crustal origin (21%) and traffic emission (2%). The resuspension of building material / crustal sources was suggested as a major source with 81% contribution in SAS followed by combustion-related with 12%, construction / renovation activities (7%) and traffic emission (0.2%). Besides that, Field Emission Scanning Electron Microscopy (FESEM) image analysis also been conducted and the irregular shape of particles and their sizes are less than 1 μm were observed, indicating

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the sources were originating from anthropogenic and natural origin. Higher level of pollutants inside the institute building most probably due to penetration via natural ventilation which doors and windows are frequently open especially in laboratory and lecture hall sites. Other than that, the different background areas also provided high impact against sources and distribution pattern of atmospheric particulate matter.

A health risk assessment was conducted based on the carcinogenic and non-carcinogenic metals via inhalation pathway. This assessment was divided into two populations based on different age group of adolescence (12-<18 years) and adult (18-<70 years). Carcinogenic health risk (ILCR) from trace metals exposure were estimated to be 3.44E-04 and 7.37E-04 for adolescent and adult group, respectively in SB. Meanwhile, ILCR reading for adolescent was 4.23E-04 and 9.10E-04 for adult in SAS. In this study, only the total of Cr was determined to have significant carcinogenic risks with ILCR reading of 7.22E-04 and 8.9E-04 for adult group in SB and SAS, respectively. The highest ILCR value was observed in adult group in SAS (9.10E-04) where nine to ten individuals in 10,000 may develop cancer due to the exposure of $PM_{2.5}$ carcinogenic elements. Non-carcinogenic health risk from non-carcinogenic metals suggested that the HI for adult group was higher than adolescent group with HI reading of 1.19E+00 and 9.56E-0, respectively in SB while HI value for adult was 1.23E+00 and 9.83E-01 for adolescent in SAS. From this value, it was suggested that adult group have the possibility to develop adverse health effects while for the adolescent group, there were no adverse health effects were expected to occur and may be deemed to have negligible hazard. This study was believed to provide holistic view of current status of indoor air quality so that the authorities can come up with strategies

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to enhance building occupants' comfort and can provide in detail the health risks that associated with $PM_{2.5}$ in Institusi Latihan Kementerian Kesihatan Malaysia Sungai Buloh (ILKKM SB) and Institusi Latihan Kementerian Kesihatan Malaysia Sultan Azlan Shah (ILKKM SAS).

5.1 Limitations in the Study

i. The sample size was small and only two institutes were selected due to limited source of funding and instruments.
ii. The small sample size may not generate a sufficient information on the $PM_{2.5}$ characterization at the site to produce good statistical results that are less generalisable to other groups.
iii. The respective individual sites may not be representative of an entire city which the study did not cover all areas that the human may be exposed to.

5.2 Recommendations for Future Research

Through this study, the chemical composition of indoor $PM_{2.5}$ in ILKKM Sungai Buloh and ILKKM Sultan Azlan Shah were investigated. In addition, the probable sources of $PM_{2.5}$ were identified and apportioned using multivariate receptor model. The carcinogenic and non-carcinogenic health risk estimation were conducted in order to

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investigate the health effects associated with $PM_{2.5}$ chemical composition towards the target populations. Overall, the comprehensive study of the chemical composition, source apportionment and health risk assessment were successfully conducted in this study despite of all the limitations. However, certain parts of this study can be improved or emphasized in future studies, recommended as follows;

i. The inclusion of organic carbon (OC) assessment must also be incorporated into the study since it has the largest portion of $PM_{2.5}$ mass in order to have a complete $PM_{2.5}$ chemical compositions assessment.

ii. In order to have a complete assessment of health risk, mortality risk also must be conducted a part from non-carcinogenic and carcinogenic health risks as guidance to public health authorities.

iii. The air exchange rates, construction materials, and ventilation practices assessments are necessarily incorporated in the study for better understanding on the indoor-outdoor air exchange as guidance to authorities to design the effective control strategies to reduce pollutant emissions.

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05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

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05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

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05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

REFERENCES

Abdul-Wahab, S. A. (2006). Indoor and Outdoor Relationships of Atmospheric Particulates in Oman. *Indoor and Built Environment*, *15*(3), 247–255. https://doi.org/10.1177/1420326X06066322

Alahmr, F. O. M., Othman, M., Abd Wahid, N. B., Halim, A. A. & Latif, M. T. (2012). Compositions of dust fall around semi-Urban Areas in Malaysia. *Aerosol and Air Quality Research*, *12*(4), 629–642. https://doi.org/10.4209/aaqr.2012.02.0027

Alleman, L. Y., Lamaison, L., Perdrix, E., Robache, A. & Galloo, J. C. (2010). PM10 metal concentrations and source identification using positive matrix factorization and wind sectoring in a French industrial zone. *Atmospheric Research*, *96*(4), 612–625. https://doi.org/10.1016/j.atmosres.2010.02.008

Almeida, S. M., Canha, N., Silva, A., Do Carmo Freitas, M., Pegas, P., Alves, C., Pio, C. A. (2011). Children exposure to atmospheric particles in indoor of Lisbon primary schools. *Atmospheric Environment*, *45*(40), 7594–7599. https://doi.org/10.1016/j.atmosenv.2010.11.052

Alsmo, T. & Holmberg, S. (2007). Sick Buildings or Not: Indoor Air Quality and Health Problems in Schools. *Indoor and Built Environment*, *16*(6), 548–555. https://doi.org/10.1177/1420326X07084414

Amato, F., Rivas, I., Viana, M., Moreno, T., Bouso, L., Reche, C. & Àlvarez-pedrerol, M. (2014). Science of the Total Environment Sources of indoor and outdoor $PM_{2.5}$ concentrations in primary schools. *Science of the Total Environment, The*, *490*, 757–765. https://doi.org/10.1016/j.scitotenv.2014.05.051

Amil, N., Latif, M. T., Khan, M. F. & Mohamad, M. (2016). Seasonal variability of $PM_{2.5}$ composition and sources in the Klang Valley urban-industrial environment. *Atmospheric Chemistry and Physics*, *16*(8), 5357–5381. https://doi.org /10.5194/acp-16-5357-2016

Anake, W. U., Ana, G. R. E. E. & Benson, N. U. (2016). Study of Surface Morphology, Elemental Composition and Sources of Airborne Fine Particulate Matter in Agbara Industrial Estate , Nigeria. *Internacional Journal of Applied Environmental Sciences*, *11*(4), 881–890.

Andrews, R. E., Shah, K. M., Wilkinson, J. M. & Gartland, A. (2011). Effects of cobalt and chromium ions at clinically equivalent concentrations after metal-on-metal hip replacement on human osteoblasts and osteoclasts: Implications for skeletal health. *Bone*, *49*(4), 717–723. https://doi.org/10.1016/j.bone.2011.06.007

Arlian, L. G., Neal, J. S. & Vyszenski-Moher, D. L. (1999). Reducing relative humidity to control the house dust mite Dermatophagoides farinae. *The Journal of Allergy and Clinical Immunology*, *104*(4 Pt 1), 852–856.

Ashmore, M. R., & Dimitroulopoulou, C. (2009). Personal exposure of children to air pollution. *Atmospheric Environment*, *43*(1), 128–141. https://doi.org/10.1016/j.atmosenv.2008.09.024

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Atkinson, R. W., Fuller, G. W., Anderson, H. R., Harrison, R. M. & Armstrong, B. (2010). Urban Ambient Particle Metrics and Health. *Epidemiology*, *21*(4), 501–511. https://doi.org/10.1097/EDE.0b013e3181debc88

Baxi, S. N., Portnoy, J. M., Larenas-Linnemann, D., Phipatanakul, W., Barnes, C., Grimes, C.,Williams, B. (2016). Exposure and Health Effects of Fungi on Humans. *Journal of Allergy and Clinical Immunology: In Practice*, *4*(3), 396–404. https://doi.org/10.1016/j.jaip.2016.01.008

Bell, M. L., Ebisu, K. & Belanger, K. (2007). Ambient air pollution and low birth weight in Connecticut and Massachusetts. *Environmental Health Perspectives*, *115*(7), 1118–1125. https://doi.org/10.1289/ehp.9759

Borgini, A., Tittarelli, A., Ricci, C., Bertoldi, M., De Saeger, E. & Crosignani, P. (2011). Personal exposure to $PM_{2.5}$ among high-school students in Milan and background measurements: The EuroLifeNet study. *Atmospheric Environment*, *45*(25), 4147–4151. https://doi.org/10.1016/j.atmosenv.2011.05.026

Bornehag, C. G., Sundell, J., Bonini, S., Custovic, A., Malmberg, P., Skerfving, S., Verhoeff, A. (2004). Dampness in buildings as a risk factor for health effects, EUROEXPO: A multidisciplinary review of the literature (1998-2000) on dampness and mite exposure in buildings and health effects. *Indoor Air*, *14*(4), 243–257. https://doi.org/10.1111/j.1600-0668.2004.00240.x

Bowers, R. M., McLetchie, S., Knight, R. & Fierer, N. (2011). Spatial variability in airborne bacterial communities across land-use types and their relationship to the bacterial communities of potential source environments. *The ISME Journal*, *5*(4), 601–612. https://doi.org/10.1038/ismej.2010.167

Bowers, R. M., Sullivan, A. P., Costello, E. K., Collett, J. L., Knight, R. & Fierer, N. (2011). Sources of bacteria in outdoor air across cities in the midwestern United States. *Applied and Environmental Microbiology*, *77*(18), 6350–6356. https://doi.org/10.1128/AEM.05498-11

Braniš, M., Řezáčová, P., & Domasová, M. (2005). The effect of outdoor air and indoor human activity on mass concentrations of PM_{10}, $PM_{2.5}$, and PM_1 in a classroom. *Environmental Research*, *99*(2), 143–149. https://doi.org/10.1016/j.envres.2004.12.001

Brown, J. S., Gordon, T., Price, O. & Asgharian, B. (2013). Thoracic and respirable particle definitions for human health risk assessment. *Particle and Fibre Toxicology*, *10*(1), 12. https://doi.org/10.1186/1743-8977-10-12

Cabo Verde, S., Almeida, S. M., Matos, J., Guerreiro, D., Meneses, M., Faria, T.,Viegas, C. (2015). Microbiological assessment of indoor air quality at different hospital sites. *Research in Microbiology*, *166*(7), 557–563. https://doi.org/10.1016/j.resmic.2015.03.004

Cadelis, G., Tourres, R., & Molinie, J. (2014). Short-term effects of the particulate pollutants contained in Saharan dust on the visits of children to the emergency department due to asthmatic conditions in Guadeloupe (French archipelago of the Caribbean). *PLoS ONE*, *9*(3). https://doi.org/10.1371/journal.pone.0091136

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Cao, J., Yang, C., Li, J., Chen, R., Chen, B., Gu, D. & Kan, H. (2011). Association between long-term exposure to outdoor air pollution and mortality in China: A cohort study. *Journal of Hazardous Materials*, *186*(2–3), 1594–1600. https://doi.org/10.1016/j.jhazmat.2010.12.036

Cao, S., Duan, X., Zhao, X., Ma, J., Dong, T., Huang, N., Wei, F. (2014). Health risks from the exposure of children to As, Se, Pb and other heavy metals near the largest coking plant in China. *Science of the Total Environment*, *472*, 1001–1009. https://doi.org/10.1016/j.scitotenv.2013.11.124

Cavallari, J. M., Eisen, E. A., Fang, S. C., Schwartz, J., Hauser, R., Herrick, R. F., & Christiani, D. C. (2008). $PM_{2.5}$ metal exposures and nocturnal heart rate variability: A panel study of boilermaker construction workers. *Environmental Health: A Global Access Science Source*, *7*, 1–8. https://doi.org/10.1186/1476-069X-7-36

Chang, C. H., Hsiao, Y. L. & Hwang, C. (2015). Evaluating spatial and temporal variations of aerosol optical depth and biomass burning over southeast asia based on satellite data products. *Aerosol and Air Quality Research*, *15*(7), 2625–2640. https://doi.org/10.4209/aaqr.2015.10.0589

Chen, A. & Chang, V. W. (2012). Human health and thermal comfort of of fi ce workers in Singapore. *Building and Environment*, *58*, 172–178. https://doi.org/10.1016/j.buildenv.2012.07.004

Chen, C. & Zhao, B. (2011). Review of relationship between indoor and outdoor particles: I/O ratio, infiltration factor and penetration factor. *Atmospheric Environment*, *45*(2), 275–288. https://doi.org/10.1016/j.atmosenv.2010.09.048

Chen, H.-W., Chuang, C.-Y. & Lin, H.-T. (2009). Indoor air distribution of nitrogen dioxide and ozone in urban hospitals. *Bulletin of Environmental Contamination and Toxicology*, *83*(2), 147–150. https://doi.org/10.1007/s00128-009-9631-x

Chen, P., Bi, X., Zhang, J., Wu, J. & Feng, Y. (2015). Assessment of heavy metal pollution characteristics and human health risk of exposure to ambient $PM_{2.5}$ in Tianjin, China. *Particuology*, *20*, 104–109. https://doi.org/10.1016/j.partic.2014.04.020

Chithra, V. S. & Nagendra, S. M. S. (2013). Chemical and morphological characteristics of indoor and outdoor particulate matter in an urban environment. *Atmospheric Environment*, *77*, 579–587. https://doi.org/10.1016/j.atmosenv.2013.05.044

Chithra, V. S. & Shiva Nagendra, S. M. (2012). Indoor air quality investigations in a naturally ventilated school building located close to an urban roadway in Chennai, India. *Building and Environment*, *54*, 159–167. https://doi.org/10.1016/j.buildenv.2012.01.016

Choo, C. P., Jalaludin, J. & Hashim, Z. (2014). School's Indoor Air Quality and Respiratory Health Implications among Children. *Aensi Journals*, *8*(14), 112–121

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

de Gennaro, G., Farella, G., Marzocca, A., Mazzone, A. & Tutino, M. (2013). Indoor and outdoor monitoring of volatile organic compounds in school buildings: Indicators based on health risk assessment to single out critical issues. *International Journal of Environmental Research and Public Health*, *10*(12), 6273–6291. https://doi.org/10.3390/ijerph10126273

Deng, G., Li, Z., Wang, Z., Gao, J., Xu, Z., Li, J. & Wang, Z. (2015). Indoor/outdoor relationship of $PM_{2.5}$ concentration in typical buildings with and without air cleaning in Beijing. *Indoor and Built Environment*, *26*(1), 60–68. https://doi.org/10.1177/1420326X15604349

Deshmukh, D. K., Deb, M. K., Suzuki, Y. & Kouvarakis, G. N. (2013). Water-soluble ionic composition of $PM_{2.5\text{-}10}$ and $PM_{2.5}$ aerosols in the lower troposphere of an industrial city Raipur, the eastern central India. *Air Quality, Atmosphere and Health*, *6*(1), 95–110. https://doi.org/10.1007/s11869-011-0149-0

Diapouli, E., Chaloulakou, A., Mihalopoulos, N. & Spyrellis, N. (2008). Indoor and outdoor PM mass and number concentrations at schools in the Athens area. In *Environmental Monitoring and Assessment* (Vol. 136, pp. 13–20). https://doi.org/10.1007/s10661-007-9724-0

Diociaiuti, M., Balduzzi, M., De Berardis, B., Cattani, G., Stacchini, G., Ziemacki, G., Paoletti, L. (2001). The Two $PM_{2.5}$ (Fine) and $PM_{2.5–10}$ (Coarse) Fractions: Evidence of Different Biological Activity. *Environmental Research*, *86*(3), 254–262. https://doi.org/10.1006/enrs.2001.4275

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

Douglas W.Dockery, Sc.D; C.Arden Pope III, Ph.D; Xiping Xu, M.D, Ph.D, John D. Spenngler, Ph.D; James H.Ware, Ph.D; Martha E. Fay, M.P.H;Benjamin G. Ferris, Jr, M.D and Frank E. Speizer, M. . (1993). The New England Journal of Medicine Downloaded from nejm.org at Arizona Health Sciences Center and UMC on August 13, 2013. For personal use only. No other uses without permission. Copyright © 1993 Massachusetts Medical Society. All rights reserved. *Massachusetts Medical Society*, *329*(24). https://doi.org/10.1145/1077246.1077257

Ekmekcioglu, D. & Keskin, S. S. (2007). Characterization of indoor air particulate matter in selected elementary schools in Istanbul, Turkey. *Indoor and Built Environment*, *16*(2), 169–176. https://doi.org/10.1177/1420326X07076777

Esworthy, R. (2013). *Air Quality : EPA' s 2013 Changes to the Particulate Matter (PM) Standard*. *congressional research service* (Vol. 7–5700).

Flora, S. J. S., Mittal, M. & Mehta, A. (2008). Heay metal induced oxidative stress & its possible reversal by chelation therapy. *Indian J MEd Res*.

Fromme, H., Diemer, J., Dietrich, S., Cyrys, J., Heinrich, J., Lang, W., Twardella, D. (2008). Chemical and morphological properties of particulate matter (PM_{10}, $PM_{2.5}$) in school classrooms and outdoor air. *Atmospheric Environment*, *42*(27), 6597–6605. https://doi.org/10.1016/j.atmosenv.2008.04.047

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Fromme, H., Twardella, D., Dietrich, S., Heitmann, D., Schierl, R., Liebl, B. & Rüden, H. (2007). Particulate matter in the indoor air of classrooms-exploratory results from Munich and surrounding area. *Atmospheric Environment*, *41*(4), 854–866. https://doi.org/10.1016/j.atmosenv.2006.08.053

Fromme, H. (2012). Particles in the Indoor Environment. In S. Kumar (Ed.), *Air Quality – Monitoring and Modeling* (pp. 117–144). Shanghai: InTech.

Galindo, N., Gil-Moltó, J., Varea, M., Chofre, C., & Yubero, E. (2013). Seasonal and interannual trends in PM levels and associated inorganic ions in southeastern Spain. *Microchemical Journal*, *110*(3), 81–88. https://doi.org/10.1016/j.microc.2013.02.009

García-Aleix, J. R., Delgado-Saborit, J. M., Verdú-Martín, G., Amigó-Descarrega, J. M. & Esteve-Cano, V. (2014). Trends in arsenic levels in PM_{10} and $PM_{2.5}$ aerosol fractions in an industrialized area. *Environmental Science and Pollution Research*, *21*(1), 695–703. https://doi.org/10.1007/s11356-013-1950-0

García, J. H., Li, W. W., Cárdenas, N., Arimoto, R., Walton, J. & Trujillo, D. (2006). Determination of $PM_{2.5}$ sources using time-resolved integrated source and receptor models. *Chemosphere*, *65*(11), 2018–2027. https://doi.org/10.1016/j.chemosphere.2006.06.071

Gilli, G., Traversi, D., Rovere, R., Pignata, C. & Schilirò, T. (2007). Chemical characteristics and mutagenic activity of PM_{10} in Torino, a Northern Italian City. *Science of the Total Environment*, *385*(1–3), 97–107. https://doi.org/10.1016/j.scitotenv.2007.07.006

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Gioda, A., Fuentes-Mattei, E. & Jimenez-Velez, B. (2011). Evaluation of cytokine expression in BEAS cells exposed to fine particulate matter ($PM_{2.5}$) from specialized indoor environments. *International Journal of Environmental Health Research*, *21*(2), 106–119. https://doi.org/10.1080/09603123.2010.515668

González-Flecha, B. (2004). Oxidant mechanisms in response to ambient air particles. *Molecular Aspects of Medicine*, *25*(1–2), 169–182. https://doi.org/10.1016/j.mam.2004.02.017

Gugamsetty, B., Wei, H., Liu, C. N., Awasthi, A., Tsai, C. J., Roam, G. D., Chen, C. F. (2012). Source Characterization and Apportionment of PM_{10}, $PM_{2.5}$ and $PM_{0.1}$ by Using Positive Matrix Factorization. *Aerosol and Air Quality Research*, *12*(4), 476–491. https://doi.org/10.4209/aaqr.2012.04.0084

Habil, M., Massey, D. D. & Taneja, A. (2013). Exposure of children studying in schools of India to PM levels and metal contamination: Sources and their identification. *Air Quality, Atmosphere and Health*, *6*(3), 575–587. https://doi.org/10.1007/s11869-013-0201-3

Han, L., Zhou, W., Li, W., & Li, L. (2014). Impact of urbanization level on urban air quality: A case of fine particles ($PM_{2.5}$) in Chinese cities. *Environmental Pollution*, *194*, 163–170. https://doi.org/10.1016/j.envpol.2014.07.022

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Han, N. M., M., Latif, M. T., Othman, M., Dominick, D., Mohamad, N., Juahir, H. & Tahir, N. M. (2014). Composition of selected heavy metals in road dust from Kuala Lumpur city centre. *Environmental Earth Sciences*, *72*(3), 849–859. https://doi.org/10.1007/s12665-013-3008-5

Hasheminassab, S., Daher, N., Ostro, B. D., & Sioutas, C. (2014). Long-term source apportionment of ambient fine particulate matter ($PM_{2.5}$) in the Los Angeles Basin: A focus on emissions reduction from vehicular sources. *Environmental Pollution*, *193*(x), 54–64. https://doi.org/10.1016/j.envpol.2014.06.012

Hays, M. D., Fine, P. M., Geron, C. D., Kleeman, M. J. & Gullett, B. K. (2005). Open burning of agricultural biomass: Physical and chemical properties of particle-phase emissions. *Atmospheric Environment*, *39*(36), 6747–6764. https://doi.org/10.1016/j.atmosenv.2005.07.072

Heal, M. R., Kumar, P. & Harrison, R. M. (2012). Particles, air quality, policy and health. *Chemical Society Reviews*, *41*(19), 6606–6630. https://doi.org/10.1039/c2cs35076a

Hitzfeld, B., Friedrichs, K. H., Ring, J. & Behrendt, H. (1997). Airborne particulate matter modulates the production of reactive oxygen species in human polymorphonuclear granulocytes. *Toxicology*, *120*(3), 185–195. https://doi.org/10.1016/S0300-483X(97)03664-0

Hospodsky, D., Qian, J., Nazaroff, W. W., Yamamoto, N., Bibby, K., Rismani-Yazdi, H. & Peccia, J. (2012). Human occupancy as a source of indoor airborne bacteria. *PLoS ONE*, *7*(4). https://doi.org/10.1371/journal.pone.0034867

Hsu, Y. C., Lai, M. H., Wang, W. C., Chiang, H. L. & Shieh, Z. X. (2008). Characteristics of Water-Soluble Ionic Species in Fine ($PM_{2.5}$) and Coarse Particulate Matter ($PM_{10–2.5}$) in Kaohsiung, Southern Taiwan. *Journal of the Air & Waste Management Association*, *58*(12), 1579–1589. https://doi.org/10.3155/1047-3289.58.12.1579

Hu, X., Zhang, Y., Ding, Z., Wang, T., Lian, H., Sun, Y., & Wu, J. (2012). Bioaccessibility and health risk of arsenic and heavy metals (Cd, Co, Cr, Cu, Ni, Pb, Zn and Mn) in TSP and $PM_{2.5}$ in Nanjing, China. *Atmospheric Environment*, *57*, 146–152. https://doi.org/10.1016/j.atmosenv.2012.04.056

Huang, Wei, Cao, J., Tao, Y., Dai, L., Lu, S. E., Hou, B., Zhu, T. (2012). Seasonal variation of chemical species associated with short-term mortality effects of $PM_{2.5}$ in Xi'an, a central city in China. *American Journal of Epidemiology*, *175*(6), 556–566. https://doi.org/10.1093/aje/kwr342

Huang, Wen, Duan, D., Zhang, Y., Cheng, H. & Ran, Y. (2014). Heavy metals in particulate and colloidal matter from atmospheric deposition of urban Guangzhou South China. *Marine Pollution Bulletin* https://doi.org/10.1016/j.marpolbul.2013.12.041

Huttunen, K., Rintala, H., Hirvonen, M. R., Vepsäläinen, A., Hyvärinen, A., Meklin, T., Nevalainen, A. (2008). Indoor air particles and bioaerosols before and after renovation of moisture-damaged buildings: The effect on biological activity and microbial flora. *Environmental Research*, *107*(3), 291–298. https://doi.org/10.1016/j.envres.2008.02.008

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Ismail, M., Mohd Sofian, N. Z., & Abdullah, A. M. (2010). Indoor Air Quality in Selected Samples of Environment Asia. *EnvironmentAsia 3*, *special is*, 103–108. https://doi.org/10.14456/ea.2010.48

J.L., P., M., K., W., D. F., J.A., M., G., F., & P.E., T. (2011). Ambient air pollution and apnea and bradycardia in high-risk infants on home monitors. *Environmental Health Perspectives*, *119*(9), 1321–1327. https://doi.org/10.1289/ehp.1002739

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, *7*(2), 60–72. https://doi.org/10.2478/intox-2014-0009

Kadiiska, M. B., Mason, R. P., Dreher, K. L., Costa, D. L., & Ghio, a J. (1997). In vivo evidence of free radical formation in the rat lung after exposure to an emission source air pollution particle. *Chemical Research in Toxicology*, *10*(10), 1104–1108. https://doi.org/10.1021/tx970049r

Kam, W., Liacos, J. W., Schauer, J. J., Delfino, R. J., & Sioutas, C. (2012). Size-segregated composition of particulate matter (PM) in major roadways and surface streets. *Atmospheric Environment*, *55*, 90–97. https://doi.org/10.1016/j.atmosenv.2012.03.028

Kasier, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, *XX*(1), 141–151.

Keegan, G. M., Learmonth, I. D., & Case, C. P. (2008). A systematic comparison of the actual, potential, and theoretical health effects of cobalt and chromium exposures from industry and surgical implants. *Critical Reviews in Toxicology*. https://doi.org/10.1080/10408440701845534

Kembel, S. W., Jones, E., Kline, J., Northcutt, D., Stenson, J., Womack, A. M., … Green, J. L. (2012). Architectural design influences the diversity and structure of the built environment microbiome. *The ISME Journal*, *6*(8), 1469–1479. https://doi.org/10.1038/ismej.2011.211

Khan, M. F., Latif, M. T., Saw, W. H., Amil, N., Nadzir, M. S. M., Sahani, M., Chung, J. X. (2016). Fine particulate matter in the tropical environment: Monsoonal effects, source apportionment, and health risk assessment. *Atmospheric Chemistry and Physics*, *16*(2), 597–617. https://doi.org/10.5194/acp-16-597-2016

Khan, Md Firoz, Hirano, K., & Masunaga, S. (2012). Assessment of the sources of suspended particulate matter aerosol using US EPA PMF 3.0. *Environmental Monitoring and Assessment*, *184*(2), 1063–1083. https://doi.org/10.1007/s10661-011-2021-y

Khan, Md Firoz, Sulong, N. A., Latif, M. T., Nadzir, M. S. M., Amil, N., Hussain, D. F. M., … Mizohata, A. (2016). Comprehensive assessment of PM2.5 physicochemical properties during the Southeast Asia dry season (southwest monsoon). *Journal of Geophysical Research*, *121*(24), 14589–14611. https://doi.org/10.1002/2016JD025894

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Kim, K., Kabir, E., & Kabir, S. (2015). A review on the human health impact of airborne particulate matter. *Environment International*, *74*, 136–143. https://doi.org/10.1016/j.envint.2014.10.005

Kitto, M. E. (1993). Trace-element patterns in fuel oils and gasolines for use in source apportionment. *Air and Waste*, *43*(10), 1381–1388. https://doi.org/10.1080/1073161X.1993.10467213

Kleeman, M. J., Ying, Q., & Kaduwela, A. (2005). Control strategies for the reduction of airborne particulate nitrate in California's San Joaquin Valley. *Atmospheric Environment*, *39*(29), 5325–5341. https://doi.org/10.1016/j.atmosenv.2005.05.044

Koçak, M., Mihalopoulos, N., & Kubilay, N. (2009). Origin and source regions of PM 10 in the Eastern Mediterranean atmosphere. *Atmospheric Research*, *92*(4), 464–474. https://doi.org/10.1016/j.atmosres.2009.01.005

Kong, S., Lu, B., Ji, Y., Zhao, X., Chen, L., Li, Z., Bai, Z. (2011). Levels, risk assessment and sources of PM10 fraction heavy metals in four types dust from a coal-based city. *Microchemical Journal*, *98*(2), 280–290. https://doi.org/10.1016/j.microc.2011.02.012

Kulshrestha, A., Satsangi, P. G., Masih, J., & Taneja, A. (2009). Metal concentration of $PM_{2.5}$ and PM_{10} particles and seasonal variations in urban and rural environment of Agra, India. *Science of the Total Environment*, *407*(24), 6196–6204. https://doi.org/10.1016/j.scitotenv.2009.08.050

Latif, M. T., Yong, S. M., Saad, A., Mohamad, N., Baharudin, N. H., Mokhtar, M. Bin, & Tahir, N. M. (2014). Composition of heavy metals in indoor dust and their possible exposure: A case study of preschool children in Malaysia. *Air Quality, Atmosphere and Health*, *7*(2), 181–193. https://doi.org/10.1007/s11869-013-0224-9

Laumbach, R., Meng, Q., & Kipen, H. (2015). What can individuals do to reduce personal health risks from air pollution? *Journal of Thoracic Disease*, *7*(1), 96–107. https://doi.org/10.3978/j.issn.2072-1439.2014.12.21

Lazaridis, M., Aleksandropoulou, V., Hanssen, J. E., Dye, C., Eleftheriadis, K., & Katsivela, E. (2008). Inorganic and carbonaceous components in indoor/outdoor particulate matter in two residential houses in Oslo, Norway. *Journal of the Air and Waste Management Association*, *58*(3), 346–356. https://doi.org/10.3155/1047-3289.58.3.346

Lee, B. K., & Hieu, N. T. (2011). Seasonal Variation and Sources of Heavy Metals in Atmospheric Aerosols in a esidential Area of Ulsan, Korea. *Aerosol and Air Quality Research*, *11*(6), 679–688. https://doi.org/10.4209/aaqr.2010.10.0089

Lestari, P., & Mauliadi, Y. D. (2009). Source apportionment of particulate matter at urban mixed site in Indonesia using PMF. *Atmospheric Environment*, *43*(10), 1760–1770. https://doi.org/10.1016/j.atmosenv.2008.12.044

Leung, M., & Chan, A. H. S. (2006). Control and management of hospital indoor air quality. *Medical Science Monitor : International Medical Journal of Experimental and Clinical Research*, *12*(3), SR17-R23.

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Li, J., Pósfai, M., Hobbs, P. V., & Buseck, P. R. (2003). Individual aerosol particles from biomass burning in southern Africa: 2, Compositions and aging of inorganic particles. *Journal of Geophysical Research: Atmospheres*, *108*(D13), n/a-n/a. https://doi.org/10.1029/2002jd002310

Li, W., Shao, L., Wang, Z., Shen, R., Yang, S., & Tang, U. (2010). Size, composition, and mixing state of individual aerosol particles in a South China coastal city Weijun. *Journal of Environmental Sciences*, *22*(4), 561–569

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., Ezzati, M. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: A systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, *380*(9859), 2224–2260. https://doi.org/10.1016/S0140-6736(12)61766-8

Liu, Y., Gao, Y., Zhang, L., Wang, T., Wang, J., Jiao, F., Chen, C. (2009). Potential Health Impact on Mice after Nasal Instillation of Nano-Sized Copper Particles and Their Translocation in Mice. *Journal of Nanoscience and Nanotechnology*, *9*(11), 6335–6343. https://doi.org/10.1166/jnn.2009.1320

Löndahl, J., Massling, A., Pagels, J., Swietlicki, E., Vaclavik, E., & Loft, S. (2007). Size-Resolved Respiratory-Tract Deposition of Fine and Ultrafine Hydrophobic and Hygroscopic Aerosol Particles During Rest and Exercise. *Inhalation Toxicology*, *19*(2), 109–116. https://doi.org/10.1080/08958370601051677

Löndahl, J., Pagels, J., Swietlicki, E., Zhou, J., Ketzel, M., Massling, A., & Bohgard, M. (2006). A set-up for field studies of respiratory tract deposition of fine and ultrafine particles in humans. *Journal of Aerosol Science*, *37*(9), 1152–1163. https://doi.org/10.1016/j.jaerosci.2005.11.004

M.B., A., A.B., J., A.M., A., M.B., I., M.N., H., R., A., Noor, H. (2000). Air quality in Malaysia: Impacts, management issues and future challenges. *Respirology*, *5*(2), 183–196. https://doi.org/http://dx.doi.org/10.1046/j.1440-1843.2000.00248.x

Manousakas, M., Diapouli, E., Papaefthymiou, H., Migliori, A., Karydas, A. G., Padilla-Alvarez, R., Eleftheriadis, K. (2015). Source apportionment by PMF on elemental concentrations obtain3qed by PIXE analysis of PM_{10} samples collected at the vicinity of lignite power plants and mines in Megalopolis, Greece. *Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms*, *349*, 114–124. https://doi.org/10.1016/j.nimb.2015.02.037

Mansha, M., Ghauri, B., Rahman, S., & Amman, A. (2012). Characterization and source apportionment of ambient air particulate matter ($PM_{2.5}$) in Karachi. *Science of the Total Environment, 425*(July 2001), 176–183. https://doi.org/10.1016/j.scitotenv.2011.10.056

Mariani, R. L., & de Mello, W. Z. (2007). $PM_{2.5-10}$, $PM_{2.5}$ and associated water-soluble inorganic species at a coastal urban site in the metropolitan region of Rio de Janeiro. *Atmospheric Environment*, *41*(13), 2887–2892. https://doi.org/10.1016/j.atmosenv.2006.12.009

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Martin, R., Dowling, K., Pearce, D. C., Florentine, S., Mcknight, S., Stelcer, E., Bennett, J. W. (2016). Trace metal content in inhalable particulate matter deposits using a laboratory-based approach. *Environmental Geochemistry and Health*. https://doi.org/10.1007/s10653-016-9833-1

Masiol, M., Squizzato, S., Rampazzo, G., & Pavoni, B. (2014). Source apportionment of $PM_{2.5}$ at multiple sites in Venice (Italy): Spatial variability and the role of weather. *Atmospheric Environment*, *98*(2014), 78–88. https://doi.org/10.1016/j.atmosenv.2014.08.059

Massey, D. D., Kulshrestha, A., & Taneja, A. (2013). Particulate matter concentrations and their related metal toxicity in rural residential environment of semi-arid region of India. *Atmospheric Environment*, *67*, 278–286.

Massey, D., Kulshrestha, A., Masih, J., & Taneja, A. (2012). Seasonal trends of PM10, PM5.0, PM2.5 & PM1.0 in indoor and outdoor environments of residential homes located in North-Central India. *Building and Environment*, *47*(1), 223–231. https://doi.org/10.1016/j.buildenv.2011.07.018

Matson, U. (2005). Indoor and outdoor concentrations of ultrafine particles in some Scandinavian rural and urban areas. *Science of the Total Environment*, *343*(1–3), 169–176. https://doi.org/10.1016/j.scitotenv.2004.10.002

Mazlan[1], S. M., Hamzah[2], A., Mahmud, M., Pengajian, [1]Pusat, Pembangunan, S., Persekitaran, D., Mazlan, S. M. (2015). Kualiti udara dalam bangunan di bangunan Sains Biologi, Fakulti Sains dan Teknologi, Universiti Kebangsaan Malaysia. *Malaysian Journal of Society and Space 11*, *1*(1), 87–96.

Mazzei, F., D'Alessandro, A., Lucarelli, F., Nava, S., Prati, P., Valli, G., & Vecchi, R. (2008). Characterization of particulate matter sources in an urban environment. *Science of the Total Environment*, *401*(1–3), 81–89. https://doi.org/10.1016/j.scitotenv.2008.03.008

Meadow, J. F., Altrichter, A. E., Kembel, S. W., Kline, J., Mhuireach, G., Moriyama, M., Bohannan, B. J. M. (2014). Indoor airborne bacterial communities are influenced by ventilation, occupancy, and outdoor air source. *Indoor Air*, *24*(1), 41–48. https://doi.org/10.1111/ina.12047

Miller, J. D., Sun, M., Gilyan, A., Roy, J., & Rand, T. G. (2010). Inflammation-associated gene transcription and expression in mouse lungs induced by low molecular weight compounds from fungi from the built environment. *Chemico-Biological Interactions*, *183*(1), 113–124. https://doi.org/10.1016/j.cbi.2009.09.023

Mohai, P., Kweon, B. S., Lee, S., & Ard, K. (2011). Air pollution around schools is linked to poorer student health and academic performance. *Health Affairs*, *30*(5), 852–862. https://doi.org/10.1377/hlthaff.2011.0077

Mohamad, N., Latif, M. T. & Khan, M. F. (2016). Source apportionment and health risk assessment of PM_{10} in a naturally ventilated school in a tropical environment. *Ecotoxicology and Environmental Safety*, *124*, 351–362. https://doi.org/10.1016/j.ecoenv.2015.11.002

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Mohd Talib Latif, Mohamed Rozali Othman, Chong Lee Kim, Siti Aminah Murayadi, & Khairul Nazri Ahmad Sahaimi. (2009). Composition of Household Dust in Semi-urban Areas in Malaysia. *Indoor and Built Environment*, *18*(2), 155–161. https://doi.org/10.1177/1420326X09103014

Morawska, L., Afshari, A., Bae, G. N., Buonanno, G., Chao, C. Y. H., Hnninen, Wierzbicka, A. (2013). Indoor aerosols: From personal exposure to risk assessment. *Indoor Air*. https://doi.org/10.1111/ina.12044

Morawska, Lidia, & Zhang, J. (2002). Combustion sources of particles. 1. Health relevance and source signatures. *Chemosphere*, *49*(9), 1045–1058. https://doi.org/10.1016/S0045-6535(02)00241-2

Mudipalli, A. (2007). Lead hepatotoxicity & potential health effects. *Indian Journal of Medical Research*.

Murillo-Tovar, M. A., Saldarriaga-Noreña, H., Hernández-Mena, L., Campos-Ramos, A., Cárdenas-González, B., Ospina-Noreña, J. E., … Smith, W. (2015). Potential sources of trace metals and ionic species in PM2.5 in Guadalajara, Mexico: A case study during dry season. *Atmosphere*, *6*(12), 1858–1870. https://doi.org/10.3390/atmos6121834

Mustaffa, N. I. H., Latif, M. T., Ali, M. M., & Khan, M. F. (2014). Source apportionment of surfactants in marine aerosols at different locations along the Malacca Straits. *Environmental Science and Pollution Research*, *21*(10), 6590–6602. https://doi.org/10.1007/s11356-014-2562-z

Nazaroff, W. W. (2004). Indoor particle dynamics. *Indoor Air, Supplement*, *14*(SUPPL. 7), 175–183. https://doi.org/10.1111/j.1600-0668.2004.00286.x

Nevalainen, A., Täubel, M., & Hyvärinen, A. (2015). Indoor fungi: Companions and contaminants. *Indoor Air*, *25*(2), 125–156. https://doi.org/10.1111/ina.12182

Nur Fadilah, & Juliana, J. (2012). Indoor Air Quality (IAQ) and Sick Buildings Syndrome (SBS) among Office Workers in New and Old Building in Universiti. *Health and the Environment Journal*, *3*(2).

Ocskay, R., Salma, I., Wang, W., & Maenhaut, W. (2006). Characterization and diurnal variation of size-resolved inorganic water-soluble ions at a rural background site. *Journalof Environmental Monitoring*, *8*(2), 300–306. https://doi.org/10.1039/b513915e

Olujimi, O., Steiner, O., & Goessler, W. (2015). Journal of African Earth Sciences Pollution indexing and health risk assessments of trace elements in indoor dusts from classrooms , living rooms and offices in Ogun State , Nigeria. *Journal of African Earth Sciences*, *101*, 396–404. https://doi.org/10.1016/j.jafrearsci.2014.10.007

Othman, M., Latif, M. T., & Mohamed, A. F. (2016). The PM_{10} compositions, sources and health risks assessment in mechanically ventilated office buildings in an urban environment. *Air Quality, Atmosphere and Health*, *9*(6), 597–612. https://doi.org/10.1007/s11869-015-0368-x

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Pappas, G. P., Stover, B., Barnhart, S., Herbert, R. J., Henderson, W., & Koenig, J. (2000). The respiratory effects of volatile organic compounds. *International Journal of Occupational and Environmental Health*, *6*(1), 1–8. https://doi.org/10.1179/oeh.2000.6.1.1

Paul, W. L., & Taylor, P. A. (2008). A comparison of occupant comfort and satisfaction between a green building and a conventional building. *Building and Environment*, *43*(11), 1858–1870. https://doi.org/10.1016/j.buildenv.2007.11.006

Pegas, P. N., Nunes, T., Alves, C. A., Silva, J. R., Vieira, S. L. A., Caseiro, A., & Pio, C. A. (2012). Indoor and outdoor characterisation of organic and inorganic compounds in city centre and suburban elementary schools of Aveiro, Portugal. *Atmospheric Environment*, *55*, 80–89. https://doi.org/10.1016/j.atmosenv.2012.03.059

Qin, Y., & Oduyemi, K. (2003). Chemical composition of atmospheric aerosol in Dundee, UK. *Atmospheric Environment*, *37*(1), 93–104. https://doi.org/10.1016/S1352-2310(02)00658-1

Ramos, C. A., Wolterbeek, H. T., & Almeida, S. M. (2014). Exposure to indoor air pollutants during physical activity in fitness centers. *Building and Environment*, *82*, 349–360. https://doi.org/10.1016/j.buildenv.2014.08.026

Raysoni, A. U., Stock, T. H., Sarnat, J. A., Montoya Sosa, T., Ebelt Sarnat, S., Holguin, F., Li, W. W. (2013). Characterization of traffic-related air pollutant metrics at four schools in El Paso, Texas, USA: Implications for exposure assessment and siting schools in urban areas. *Atmospheric Environment*, *80*, 140–151. https://doi.org/10.1016/j.atmosenv.2013.07.056

Rintala, H., Pitkaranta, M., Toivola, M., Paulin, L., & Nevalainen, A. (2008). Diversity and seasonal dynamics of bacterial community in indoor environment. *BMC Microbiology*, *8*(1), 56. https://doi.org/10.1186/1471-2180-8-56

Sahu, V., Elumalai, S. P., Gautam, S., Singh, N. K., & Singh, P. (2018). Characterization of indoor settled dust and investigation of indoor air quality in different micro-environments. *International Journal of Environmental Health Research*, *28*(4), 419–431. https://doi.org/10.1080/09603123.2018.1481498

Saliba, N. A., Atallah, M., & Al-Kadamany, G. (2009). Levels and indoor-outdoor relationships of PM_{10} and soluble inorganic ions in Beirut, Lebanon. *Atmospheric Research*, *92*(1), 131–137. https://doi.org/10.1016/j.atmosres.2008.09.010

Saraga, D., Pateraki, S., Papadopoulos, A., Vasilakos, C., & Maggos, T. (2011). Studying the indoor air quality in three non-residential environments of different use: A museum, a printery industry and an office. *Building and Environment*, *46*(11), 2333–2341. https://doi.org/10.1016/j.buildenv.2011.05.013

Schoeters, G., Den Hond, E., Zuurbier, M., Naginiene, R., Van Den Hazel, P., Stilianakis, N., Koppe, J. G. (2006). Cadmium and children: Exposure and health effects. *Acta Paediatrica, International Journal of Paediatrics*, *95*(SUPPL. 453), 50–54. https://doi.org/10.1080/08035320600886232

Seppänen, O., Fisk, W. J., & Lei, Q. H. (2006). Ventilation and performance in office work. *Indoor Air*, *16*(1), 28–36. https://doi.org/10.1111/j.1600-

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

0668.2005.00394.x

Seppänen, Olli. (2007). Ventilation strategies for good indoor air quality and energy efficiency. *International Journal of Ventilation*, *6*(4), 297–306.

Shah, A. S. V, Langrish, J. P., Nair, H., McAllister, D. A., Hunter, A. L., Donaldson, K., Mills, N. L. (2013). Global association of air pollution and heart failure: A systematic review and meta-analysis. *The Lancet*, *382*(9897), 1039–1048. https://doi.org/10.1016/S0140-6736(13)60898-3

Shridhar, V., Khillare, P. S., Agarwal, T., & Ray, S. (2010). Metallic species in ambient particulate matter at rural and urban location of Delhi. *Journal of Hazardous Materials*, *175*(1–3), 600–607. https://doi.org/10.1016/j.jhazmat.2009.10.047

Sierra-Vargas, M. P., & Teran, L. M. (2012). Air pollution: Impact and prevention. *Respirology*, *17*(7), 1031–1038. https://doi.org/10.1111/j.1440-1843.2012.02213.x

Simon, M., & Butala, V. (2004). The influence of indoor environment in office buildings on their occupants: Expected-unexpected. *Building and Environment*, *39*(3), 289–296. https://doi.org/10.1016/j.buildenv.2003.09.011

Singh, R., Gautam, N., Mishra, A., & Gupta, R. (2011). Heavy metals and living systems: An overview. *Indian Journal of Pharmacology*, *43*(3), 246. https://doi.org/10.4103/0253-7613.81505

Sloan, C. D., Andrew, A. S., Gruber, J. F., Mwenda, K. M., Moore, J. H., Onega, T., Duell, E. J. (2012). Indoor and outdoor air pollution and lung cancer in New Hampshire and Vermont. *Toxicological & Environmental Chemistry*, *94*(3), 605–615. https://doi.org/10.1080/02772248.2012.659930

Srimuruganandam, B., & Shiva Nagendra, S. M. (2012). Application of positive matrix factorization in characterization of PM_{10} and $PM_{2.5}$ emission sources at urban roadside. *Chemosphere*, *88*(1), 120–130. https://doi.org/10.1016/j.chemosphere.2012.02.083

Srivastava, A., & Jain, V. K. (2007). A study to characterize the suspended particulate matter in an indoor environment in Delhi, India. *Building and Environment*, *42*(5), 2046–2052. https://doi.org/10.1016/j.buildenv.2006.03.007

Steinemann, A., Wargocki, P., & Rismanchi, B. (2016). Ten questions concerning green buildings and indoor air qiality. *Building and Environment*, *xxx*, 1–6. https://doi.org/10.1016/j.buildenv.2016.11.010

Sternbeck, J., Sjödin, Å., & Andréasson, K. (2002). Metal emissions from road traffic and the influence of resuspension - Results from two tunnel studies. *Atmospheric Environment*, *36*(30), 4735–4744. https://doi.org/10.1016/S1352-2310(02)00561-7

Straus, D. C. (2009). Molds, mycotoxins, and sick building syndrome. *Toxicology and Industrial Health*, *25*(9–10), 617–635. https://doi.org/10.1177/0748233709348287

Sulaiman, F. R., Bakri, N. I. F., Nazmi, N., & Latif, M. T. (2017). Assessment of heavy metals in indoor dust of a university in a tropical environment. *Environmental*

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

Forensics, *18*(1), 74–82. https://doi.org/10.1080/15275922.2016.1263903

Sun, J. L., Jing, X., Chang, W. J., Chen, Z. X., & Zeng, H. (2015). Cumulative health risk assessment of halogenated and parent polycyclic aromatic hydrocarbons associated with particulate matters in urban air. *Ecotoxicology and Environmental Safety*, *113*, 31–37. https://doi.org/10.1016/j.ecoenv.2014.11.024

Tahir, N. M., Suratman, S., Fong, F. T., Hamzah, M. S., & Latif, M. T. (2013). Temporal distribution and chemical characterization of atmospheric particulate matter in the eastern coast of Peninsular Malaysia. *Aerosol and Air Quality Research*, *13*(2), 584–595. https://doi.org/10.4209/aaqr.2012.08.0216

Täubel, M., Rintala, H., Pitkäranta, M., Paulin, L., Laitinen, S., Pekkanen, J., Nevalainen, A. (2009). The occupant as a source of house dust bacteria. *Journal of Allergy and Clinical Immunology*, *124*(4). https://doi.org/10.1016/j.jaci.2009.07.045

Tauler, R., Paatero, P., Henry, R. C., Spiegelman, C., Park, E. S., Poirot, R. L., Hopke, P. K. (2008). Chapter Fiveteen Identification, Resolution and Apportionment of Contamination Sources. *Developments in Integrated Environmental Assessment*, *3*, 269–284. https://doi.org/10.1016/S1574-101X(08)00615-7

Taylor S.R. (1964). Abundance of chemical elements in the continental crust : a new table. *Geochimica et Cosmochimica Acta*, *28*, 1273–1285.

Terzi, E., Argyropoulos, G., Bougatioti, A., Mihalopoulos, N., Nikolaou, K., & Samara, C. (2010). Chemical composition and mass closure of ambient PM_{10} at urban sites. *Atmospheric Environment*, *44*(18), 2231–2239. https://doi.org/10.1016/j.atmosenv.2010.02.019

Thornburg, J., Ensor, D. S., Rodes, C. E., Lawless, P. A., Sparks, L. E., & Mosley, R. B. (2001). Penetration of Particles into Buildings and Associated Physical Factors. Part I: Model Development and Computer Simulations. *Aerosol Science and Technology*, *34*(3), 284–296. https://doi.org/10.1080/02786820150217858

Thurston, G. D., Ito, K., & Lall, R. (2011). A source apportionment of U . S . fi ne particulate matter air pollution. *Atmospheric Environment*, *45*(24), 3924–3936. https://doi.org/10.1016/j.atmosenv.2011.04.070

Thurston, G. D., & Spengler, J. D. (1985). A quantitative assessment of source contributions to inhalable particulate matter pollution in metropolitan Boston. *Atmospheric Environment (1967)*, *19*(1), 9–25. https://doi.org/10.1016/0004-6981(85)90132-5

Tsitouridou, R., Voutsa, D., & Kouimtzis, T. (2003). Ionic composition of PM_{10} in the area of Thessaloniki, Greece. *Chemosphere*, *52*(5), 883–891. https://doi.org/10.1016/S0045-6535(03)00313-8

Valavanidis, A., Vlachogianni, T., Fiotakis, K., & Loridas, S. (2013). Pulmonary oxidative stress, inflammation and cancer: Respirable particulate matter, fibrous dusts and ozone as major causes of lung carcinogenesis through reactive oxygen species mechanisms. *International Journal of Environmental Research and Public Health*, *10*(9), 3886–3907. https://doi.org/10.3390/ijerph10093886

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Voutsa, D., Samara, C., Manoli, E., Lazarou, D., & Tzoumaka, P. (2014). Ionic composition of $PM_{2.5}$ at urban sites of northern Greece: Secondary inorganic aerosol formation. *Environmental Science and Pollution Research*, *21*(7), 4995–5006. https://doi.org/10.1007/s11356-013-2445-8

Wahid, N. B A, Latif, M. T., Suan, L. S., Dominick, D., Sahani, M., Jaafar, S. A., & Mohd Tahir, N. (2014). Source identification of particulate matter in a semi-urban area of Malaysia using multivariate techniques. *Bulletin of Environmental Contamination and Toxicology*, *92*(3), 317–322. https://doi.org/10.1007/s00128-014-1201-1

Wahid, N.B.A., Latif, M. T., & Suratman, S. (2013). Composition and source apportionment of surfactants in atmospheric aerosols of urban and semi-urban areas in Malaysia. *Chemosphere*, *91*(11), 1508–1516. https://doi.org/10.1016/j.chemosphere.2012.12.029

Wahid, Nurul Bahiyah Abd, Latif, M. T., & Suratman, S. (2017). Composition and possible sources of anionic surfactants from urban and semi-urban street dust. *Air Quality, Atmosphere and Health*, *10*(9), 1051–1057. https://doi.org/10.1007/s11869-017-0493-9

Wang, Q., Zhao, H. H., Chen, J. W., Gu, K. D., Zhang, Y. Z., Zhu, Y. X., Ye, L. X. (2009). Adverse health effects of lead exposure on children and exploration to internal lead indicator. *Science of the Total Environment*, *407*(23), 5986–5992. https://doi.org/10.1016/j.scitotenv.2009.08.038

Wang, S. K., Chew, S. P., Jusoh, M. T., Khairunissa, A., Leong, K. Y., & Azid, A. A. (2017). WSN based indoor air quality monitoring in classrooms. *American Institute of Physics*, *020063*(1808), 020063. https://doi.org/10.1063/1.4975296

Wang, Y. F., Chao, H. R., Wang, L. C., Chang-Chien, G. P., & Tsou, T. C. (2010). Characteristics of heavy metals emitted from a heavy oil-fueled power plant in Northern Taiwan. *Aerosol and Air Quality Research*, *10*(2), 111–118. https://doi.org/10.4209/aaqr.2009.09.0056

Wang, Y., Zhuang, G., Tang, A., Yuan, H., Sun, Y., Chen, S., & Zheng, A. (2005). The ion chemistry and the source of $PM_{2.5}$ aerosol in Beijing. *Atmospheric Environment*, *39*(21), 3771–3784. https://doi.org/10.1016/j.atmosenv.2005.03.013

Wei, X., Gao, B., Wang, P., Zhou, H., & Lu, J. (2015). Pollution characteristics and health risk assessment of heavy metals in street dusts from different functional areas in Beijing, China. *Ecotoxicology and Environmental Safety*, *112*, 186–192. https://doi.org/10.1016/j.ecoenv.2014.11.005

Wolkoff, P., & Kjaergaard, S. . (2007). The dichotomy of relative humidity on indoor air quality. *Environment International*, *33*(6), 850–857. https://doi.org/10.1016/j.envint.2007.04.004

Woloszyn, M., Kalamees, T., Abadie, M. O., Steeman, M., & Sasic Kalagasidis, A. (2009). The effect of combining a relative-humidity-sensitive ventilation system with the moisture-buffering capacity of materials on indoor climate and energy efficiency of buildings. *Building and Environment*, *44*(3), 515–524. https://doi.org/10.1016/j.buildenv.2008.04.017

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Xu, Z., Wu, Y., Shen, F., Chen, Q., Tan, M., & Yao, M. (2011). Bioaerosol science, technology, and engineering: Past, present, and future. *Aerosol Science and Technology*, *45*(11), 1337–1349. https://doi.org/10.1080/02786826.2011.593591

Yang Razali, N. Y., Latif, M. T., Dominick, D., Mohamad, N., Sulaiman, F. R., & Srithawirat, T. (2015). Concentration of particulate matter, CO and CO_2 in selected schools in Malaysia. *Building and Environment*, *87*, 108–116. https://doi.org/10.1016/j.buildenv.2015.01.015

Young, S. H., Cox-Ganser, J. M., Shogren, E. S., Wolfarth, M. G., Li, S. Q., Antonini, J. M., … Park, J. H. (2011). Pulmonary inflammation induced by office dust and the relation to 1 3--glucan using different extraction techniques. *Toxicological and Environmental Chemistry*, *93*(4), 806–823. https://doi.org/10.1080/02772248.2011.554229

Yu, L., Wang, G., Zhang, R., Zhang, L., Song, Y., Wu, B., Chu, J. (2013). Characterization and source apportionment of $PM_{2.5}$ in an urban environment in Beijing. *Aerosol and Air Quality Research*, *13*(2), 574–583. https://doi.org/10.4209/aaqr.2012.07.0192

Zannoni, D., Valotto, G., Visin, F., & Rampazzo, G. (2016). Sources and distribution of tracer elements in road dust : The Venice mainland case of study. *Journal of Geochemical Exploration*, *166*, 64–72. https://doi.org/10.1016/j.gexplo.2016.04.007

Zhang, L., Jin, X., Johnson, A. C., & Giesy, J. P. (2016). Hazard posed by metals and As in PM 2.5 in air of five megacities in the Beijing-Tianjin-Hebei region of China during APEC. *Environmental Science and Pollution Research*, *23*(17), 17603–17612. https://doi.org/10.1007/s11356-016-6863-2

Zheng, S., Pozzer, A., Cao, C. X., & Lelieveld, J. (2015). Long-term (2001-2012) concentrations of fine particulate matter ($PM_{2.5}$) and the impact on human health in Beijing, China. *Atmospheric Chemistry and Physics*, *15*(10), 5715–5725. https://doi.org/10.5194/acp-15-5715-2015

Zhong, J. N. M., Latif, M. T., Mohamad, N., Wahid, N. B. A., Dominick, D., & Juahir, H. (2014). Source Apportionment of Particulate Matter (PM_{10}) and Indoor Dust in a University Building. *Environmental Forensics*, *15*(1), 8–16. https://doi.org/10.1080/15275922.2013.872712

Zhu, C. S., Cao, J. J., Shen, Z. X., Liu, S. X., Zhang, T., Zhao, Z. Z., … Zhang, E. K. (2012). Indoor and outdoor chemical components of $PM_{2.5}$ in the rural areas of Northwestern China. *Aerosol and Air Quality Research*, *12*(6), 1157–1165. https://doi.org/10.4209/aaqr.2012.01.0003

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APPENDIX A

LETTER OF PERMISSION FOR SAMPLING FROM MEDICAL RESEARCH OF ETHICS COMMITTEE

JAWATANKUASA ETIKA & PENYELIDIKAN PERUBATAN
(Medical Research & Ethics Committee)
KEMENTERIAN KESIHATAN MALAYSIA
d/a Kompleks Institut Kesihatan Negara
Blok A, No 1, Jalan Setia Murni U13/52,
Seksyen U13, Bandar Setia Alam,
40170 Shah Alam, Selangor. Tel: 03-3362 8888/8205

Ruj.Kami: KKM/NIHSEC/ P19-1207 (4)
Tarikh : 01 -July-2019

Puan INTAN IDURA BINTI MOHAMAD ISA
Institut Latihan Kementerian Kesihatan Malaysia (ILKKM) Sungai Buloh, Selangor

Dato'/ Tuan/ Puan,

NMRR-17-3546-37840 (IIR)
COMPOSITION AND HRA OF INDOOR PARTICULATE MATTER (PM2.5) FROM SELECTED COLLEGES IN MALAYSIA

This letter is made in reference to the above study.

2. The Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia (MOH) has determined that this study **DOES NOT** require MREC review / approval as **this study has no direct intervention / human subjects**

3. You may conduct your research without the need for further submission or reports to MREC.

"BERKHIDMAT UNTUK NEGARA"

Yours Sincerely,

.....
DR HJH SALINA ABDUL AZIZ
Chairperson
Medical Research & Ethics Committee
Ministry of Health Malaysia

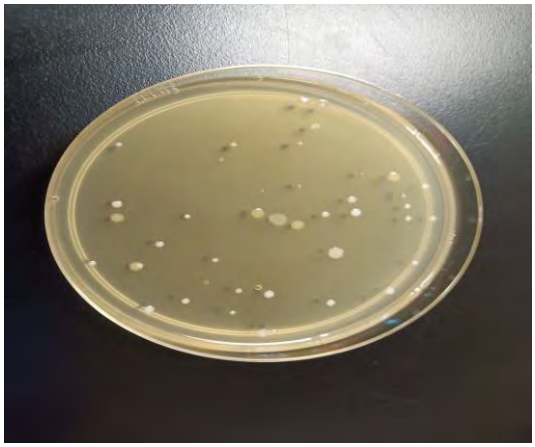
MD/Exempt/Approval2019/Mrecshare

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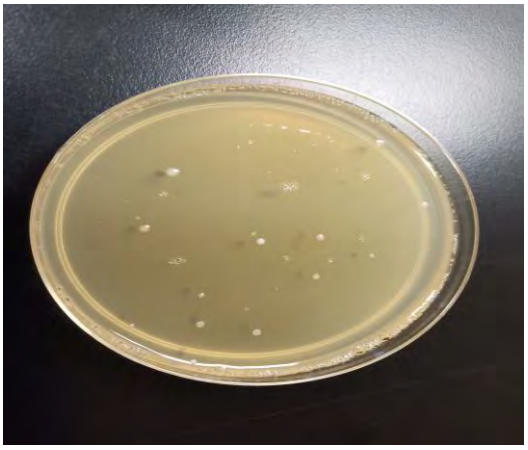
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APPENDIX B

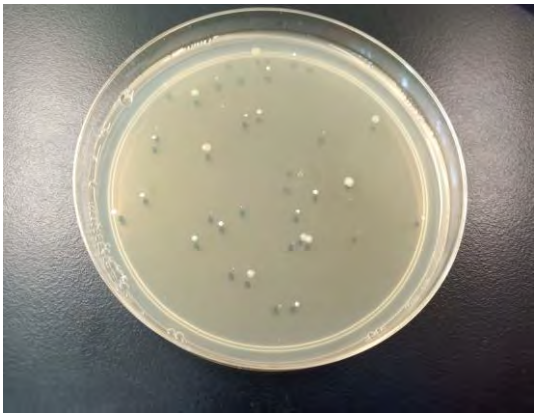
BACTERIAL COLONY FROM SAMPLING STATIONS IN ILKKM SUNGAI BULOH



(a) Lecturer office



(b) Laboratory



(c) Lecture room

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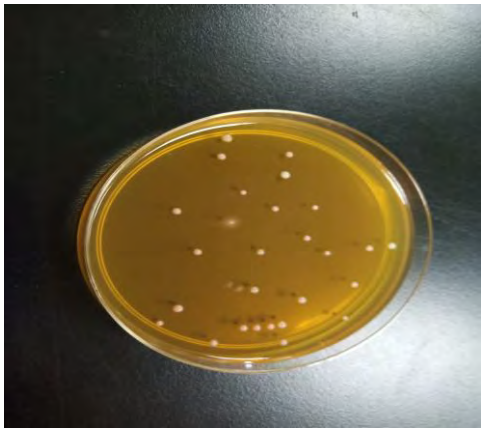
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APPENDIX C

FUNGAL COLONY FROM SAMPLING STATIONS IN ILKKM SUNGAI BULOH



(a) Lecturer office



(b) Laboratory



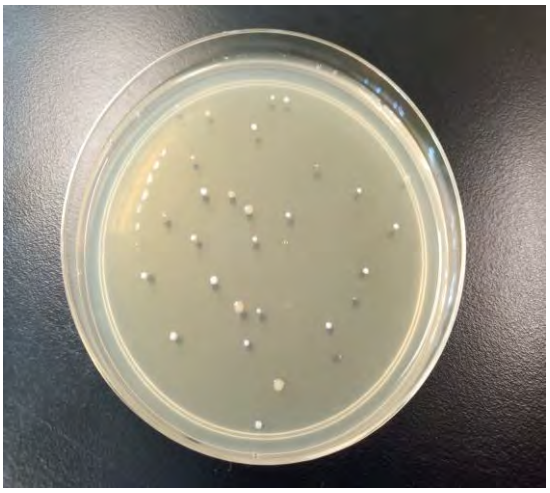
(c) Lecture room

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APPENDIX D

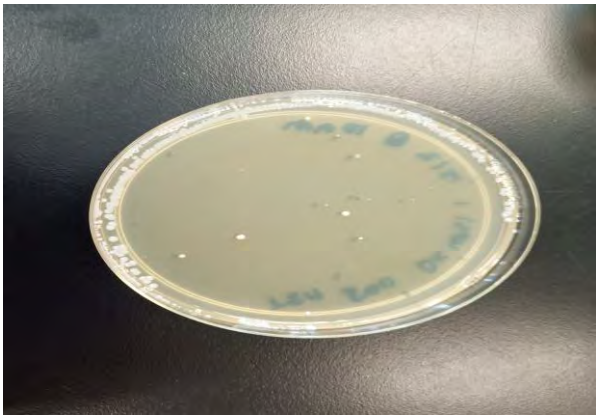
BACTERIAL COLONY FROM SAMPLING STATIONS IN ILKKM SULTAN AZLAN SHAH



(a) Lecturer Office



(b) Laboratory



(c) Lecture room

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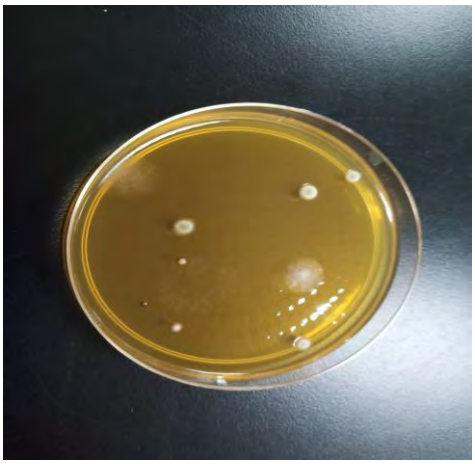
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APPENDIX E

FUNGAL COLONY FROM SAMPLING STATIONS IN ILKKM SULTAN AZLAN SHAH



(a) Lecturer office



(b) Laboratory



(c) Lecture Room

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APPENDIX F

RECOVERY AND METHOD DETECTION LIMIT FOR WATER-SOLUBLE IONIC SPECIES ANALYSIS

	RECOVERY (%)	MDL (ng m^{-3})
Fe	90	12.6
As	89	0.04
Cd	86	0.003
Co	112	0.006
Cr	61	0.47
Cu	93	0.003
Ni	114	0.04
Pb	60	0.03
V	95	0.24

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APPENDIX G

RECOVERY AND METHOD DETECTION LIMIT FOR TRACE METALS ANALYSIS

	RECOVERY (%)	MDL (μg m^{-3})
SO_4^{2-}	90	0.02
Cl^-	98	0.008
NO_3^-	103	0.06
Na^+	101	0.06
K^+	97	0.004
NH_4^+	92	0.002
Ca^{2+}	95	0.10
Mg^{2+}	96	0.008

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APPENDIX H

CONFERENCE ATTENDED

A Oral presenter. International Conference on Science & Technology Research (ICSTR Malaysia), The regency Scholar's Inn, Universiti Teknologi Malaysia, Kuala Lumpur.

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APPENDICES I

ACCEPTED ARTICLE



[JSML] Editor Decision

Dr. Chee Fah Wong
Nurul Bahiyah Abd Wahid & 6 more
May 13, 3:13 PM

Nurul Bahiyah Abd Wahid, Intan Idura Mohamad Isa, Ahmad Khairuddin Hassan, Muhammad Izzat Iman Razali, Ahmad Haziq Hasrizal, Muhammad Firdaus Muzamil, Mohammad Soef Hazmie:

We have reached a decision regarding your submission to Journal of Science and Mathematics Letters, "INDOOR PARTICULATE MATTER (PM2.5) AND COMFORT PARAMETER IN A UNIVERSITY BUILDING".

Our decision is to: Accept Submission

Dr. Chee Fah Wong
cheefah@fsmt.upsi.edu.my

Department of Biology

Faculty of Science and Mathematics

Universiti Pendidikan Sultan Idris

35900 Tanjong Malim

Perak

Malaysia

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APPENDIX J

WORKSHOP ATTENDED

A Lab Safety Course 2017, Universiti Pendidikan Sultan Idris Tanjung Malim, Perak.

B Journal Article Writing Workshop for Postgraduate Student, Hotel Seri Malaysia, Ipoh, Perak.e

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