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

INTAN IDURA BINTI MOHAMAD ISA

UNIVERSITI PENDIDIKAN SULTAN IDRIS

2020

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

INTAN IDURA BINTI MOHAMAD ISA

THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE
MASTER BY RESEARCH

FACULTY OF SCIENCE AND MATHEMATICS
UNIVERSITI PENDIDIKAN SULTAN IDRIS

2020

UPSI/IPS-3/BO 32
Pind : 00 m/s: 1/1

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

Please tick (√)
Project Paper ☐
Masters by Research ☐
Master by Mixed Mode ☐
PhD ☐

INSTITUTE OF GRADUATE STUDIES

DECLARATION OF ORIGINAL WORK

This declaration is made on the ....day of................20.......

i. Student's Declaration:

I, ______________________________ (PLEASE INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled ______________________________ ______________________________ is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

____
Signature of the student

ii. Supervisor's Declaration:

I ______________________ (SUPERVISOR'S NAME) hereby certifies that the work entitled ______________________________ ______________________________ ______________(TITLE) was prepared by the above named student, and was submitted to the Institute of Graduate Studies as a * partial/full fulfillment for the conferment of ______________________________ (PLEASE INDICATE THE DEGREE), and the aforementioned work, to the best of my knowledge, is the said student's work.

______________ Date

______________ Signature of the Supervisor

UPSI/IPS-3/BO 31
Pind.: 01 m/s:1/1

UNIVERSITI PENDIDIKAN SULTAN IDRIS
SULTAN IDRIS EDUCATION UNIVERSITY

INSTITUT PENGAJIAN SISWAZAH /
INSTITUTE OF GRADUATE STUDIES

BORANG PENGESAHAN PENYERAHAN TESIS/DISERTASI/LAPORAN KERTAS PROJEK
DECLARATION OF THESIS/DISSERTATION/PROJECT PAPER FORM

Tajuk / *Title*: ______________________________

____

No. Matrik /*Matric No.*: ______________________________

Saya / *I* : ______________________________

(Nama pelajar / *Student's Name*)

mengaku membenarkan Tesis/Disertasi/Laporan Kertas Projek (Kedoktoran/Sarjana)* ini disimpan di Universiti Pendidikan Sultan Idris (Perpustakaan Tuanku Bainun) dengan syarat-syarat kegunaan seperti berikut:-
acknowledged that Universiti Pendidikan Sultan Idris (Tuanku Bainun Library) reserves the right as follows:-

1. Tesis/Disertasi/Laporan Kertas Projek ini adalah hak milik UPSI.
   The thesis is the property of Universiti Pendidikan Sultan Idris
2. Perpustakaan Tuanku Bainun dibenarkan membuat salinan untuk tujuan rujukan dan penyelidikan.
   Tuanku Bainun Library has the right to make copies for the purpose of reference and research.
3. Perpustakaan dibenarkan membuat salinan Tesis/Disertasi ini sebagai bahan pertukaran antara Institusi Pengajian Tinggi.
   The Library has the right to make copies of the thesis for academic exchange.
4. Sila tandakan (√) bagi pilihan kategori di bawah / *Please tick (√) from the categories below:-*

☐ **SULIT/*CONFIDENTIAL*** — Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub dalam Akta Rahsia Rasmi 1972. / *Contains confidential information under the Official Secret Act 1972*

☐ **TERHAD/*RESTRICTED*** — Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan ini dijalankan. / *Contains restricted information as specified by the organization where research was done.*

☐ **TIDAK TERHAD / *OPEN ACCESS***

____
(Tandatangan Pelajar/ Signature)

____
(Tandatangan Penyelia / *Signature of Supervisor*) & (Nama & Cop Rasmi / *Name & Official Stamp*)

Tarikh: ______________

Catatan: Jika Tesis/Disertasi ini **SULIT @ TERHAD**, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan ini perlu dikelaskan sebagai **SULIT** dan **TERHAD**.

Notes: If the thesis is CONFIDENTAL or RESTRICTED, please attach with the letter from the related authority/organization mentioning the period of confidentiality and reasons for the said confidentiality or restriction.

ACKNOWLEDGEMENT

In the name of Allah the Almighty for all His blessing, strength, passion and good health throughout ups and down during this Master journey.

Alhamdulillah, first and foremost, I would like to express my sincere gratitude to my supervisor, Dr. Nurul Bahiyah binti Abd Wahid for the continuous support of my master study and related research, for her patience, motivation and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis.

Also, I would like to express my high appreciation to Mr Anas Ahmad Jamhari from Universiti Kebangsaan Malaysia (UKM) for the assistant regarding trace metals analysis and Dr. Eliani Ezani from Universiti Putra Malaysia (UPM) for her help regarding airborne microorganism analysis. My appreciation also goes to all laboratory assistants, Mr Hairul, Mr Hashimi, Mr Faizi and Mrs Dewi and other labmates especially Miss Helmiah and Mrs Farah for their technical support and encouragement throughout the labwork sessions.

I would like to thanks Bahagian Latihan Kementerian Kesihatan Malaysia who approved my study leave to accomplish this master journey. I would also wish to convey my gratitude to Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris (UPSI) for the laboratory and research facilities with such a pleasant working environment throughout my years in UPSI.

To my dearest husband, Mr Mohamad Jauhari I wholly dedicate this thesis to you. Thank you for the unconditional love and support all the time. I am also grateful to my beloved parents, Mr Mohamad Isa and Mrs. Umi Kalsom who continuously gave love, passion, physical and mental supports. All of you is my inspiration to keep walking until the finishing line. Your prayer for me was what sustained me thus far. To my kids, sisters and brothers, thank you very much for everything.

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.

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.

TABLE OF CONTENTS

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

LIST OF TABLES

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

LIST OF FIGURES

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

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

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

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

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

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.

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).

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).

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).

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

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).

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.

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 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).

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.

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.

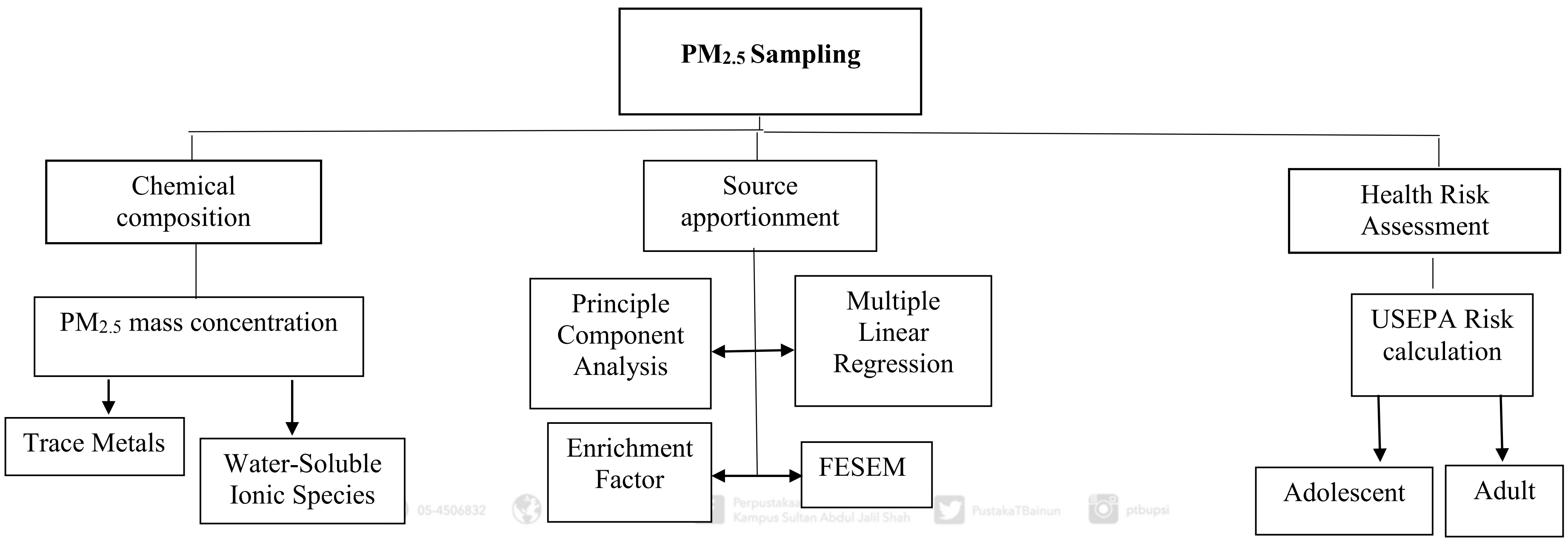

Figure 1.1. Conceptual framework design for the study

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.