UNIVERSITI PUTRA MALAYSIA

EVALUATION OF HEAVY METALS EXPOSURE THROUGH AIR USING NAILS AND SALIVARY INTERLEUKIN-6 AMONG CHILDREN LIVING CLOSE TO SOLID WASTE LANDFILLS IN MALAYSIA

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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May 2018

Chairman: Sharifah Norkhadijah binti Syed Ismail, PhD
Faculty: Medicine and Health Sciences

Prolonged exposure to particulate matter (PM_{10}) pollution from municipal solid waste (MSW) landfills may produce some health effects especially in children. This study evaluates heavy metals exposure through air using nails and salivary interleukin-6 as a biomarker among children living close to solid waste landfills in Malaysia. This cross-sectional study was conducted from May to July 2014 among children living close to solid waste landfills in four states of Peninsular Malaysia. The operating municipal solid waste (MSW) landfill sites in this study were selected based on the landfill type through levels classification which is landfill Level 1; a non-sanitary landfill with daily soil covering, landfill Level 2; a non-sanitary landfill with ban and daily soil covering and landfill Level 3; a non-sanitary landfill with leachate collection pond. Three sub-studies include; 1) environmental assessment, 2) biomarker analysis and, 3) health risk assessment was performed to meet the study objectives. In sub-study 1, heavy metals concentration in PM_{10} collected in the MSW landfill sites, exposed residential areas (within 3-km radius from MSW landfills) and unexposed residential areas (beyond 3-km radius from MSW landfills) from the air samples were determined. Heavy metals concentrations were compared with the international and national air quality standards. The heavy metals in PM_{10} were analysed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The highest mean concentration among all the heavy metals in the MSW landfills and residential areas was Al with the mean ± SD of 117.25 ± 23.43 $\mu g/m^3$ particularly in landfill type-level 1. Only three elements were found significantly higher; Al ($p<0.001$), Cd ($p<0.05$), and Ni ($p<0.05$), particularly in landfill type-Level 1, when compared to other landfill types. In the sub-study 2, the presence of these heavy metals in fingernails and IL-6 in saliva as biomarker samples of the exposed and unexposed children were determined and compared. Questionnaire forms were distributed among 342 children aged 7 to 12 years. An adapted Children Health Questionnaire form (CHQ) was applied in the survey. The heavy metals in fingernail samples were analysed using an inductively coupled plasma mass spectrometry (ICP-

MS). The IL-6 level was analysed using an enzyme-linked immunosorbent assay (ELISA) method. The heavy metals in fingernails of the exposed children were significantly higher compared to those in the unexposed group. The IL-6 level also was significantly higher ($p<0.05$) among exposed children with the mean ± SD of 5.52 ± 1.31pg/ml compared to the unexposed children (5.19 ± 1.17pg/ml). In the sub-study 3, the association of PM_{10} heavy metals in air, heavy metals accumulation in fingernails and IL-6 level with reported health symptoms are determined and children health risks were calculated. Results had showed that runny nose and sneezing were significant difference among the exposed and unexposed group respondents with $p<0.05$. Children without pets had lesser risk of the respiratory symptoms. High levels of heavy metals in PM_{10} and in fingernails were associated with higher risks of reported respiratory symptoms. Heavy metals in PM_{10} and fingernails were associated with potential risk factors of respiratory health. Non-carcinogenic and carcinogenic health risk showed that no risk exists via ingestion, inhalation and dermal route for both groups in the study areas. In conclusion, children living less than 3-km radius from MSW landfills are likely to experience potential health risks due to exposure to the PM_{10} heavy metals.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN PENDEDAHAN LOGAM BERAT MELALUI UDARA MENGGUNAKAN KUKU DAN INTERLEUKIN- 6 DALAM AIR LIUR PADA KANAK-KANAK YANG TINGGAL BERDEKATAN TAPAK PELUPUSAN SAMPAH SISA PEPEJAL DI MALAYSIA

Oleh

DORA ESPHYLIN BINTI JAMALUDDIN

Mei 2018

Pengerusi: Sharifah Norkhadijah binti Syed Ismail, PhD
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Pendedahan yang berpanjangan kepada pencemaran partikulat (PM_{10}) dari tapak pelupusan sisa pepejal perbandaran (SPP) boleh mengakibatkan kesan kesihatan terutama pada kanak-kanak. Kajian ini menilai pendedahan logam berat melalui udara menggunakan kuku dan air liur interleukin-6 sebagai biomarker di kalangan kanak-kanak yang tinggal berhampiran dengan tapak pelupusan sisa pepejal di Malaysia. Kajian keratan rentas ini dijalankan dari Mei hingga Julai 2014 di kalangan kanak-kanak yang tinggal berhampiran tapak pelupusan sisa pepejal di empat negeri di Semenanjung Malaysia. Tapak-tapak pelupusan sisa pepejal perbandaran (TPSPP) yang beroperasi di dalam kajian ini telah dipilih berdasarkan jenis tapak pelupusan melalui tahap-tahap klasifikasi iaitu Tahap 1; tapak pelupusan tidak sanitari dengan penutupan tanah harian, Tahap 2; tapak pelupusan tidak sanitari dengan larangan dan penutupan tanah harian dan tapak pelupusan Tahap 3; tapak pelupusan tidak sanitari dengan kolam pengumpulan leachate. Tiga sub-kajian termasuk; 1) penilaian alam sekitar, 2) analisis biomarker dan, 3) penilaian risiko kesihatan dilakukan untuk memenuhi objektif kajian. Dalam sub-kajian 1, kepekatan logam berat dalam PM_{10} yang dikumpul di tapak perlupusan SPP, kawasan kediaman yang terdedah (dalam lingkungan radius 3 km dari tapak pelupusan SPP) dan kawasan kediaman yang tidak terdedah (di luar radius 3 km dari tapak pelupusan SPP) dari sampel udara, ditentukan. Kepekatan logam berat dibandingkan dengan piawaian kualiti udara antarabangsa dan kebangsaan. Logam berat dalam PM_{10} dianalisis menggunakan spektrometri jisim plasma induktif (SJPI). Kadar kepekatan tertinggi di kalangan semua logam berat di tapak pelupusan SPP dan kawasan kediaman adalah Al dengan purata ± SD 117.25 ± 23.43 $\mu g/m^3$ terutamanya di tapak pelupusan Tahap 1. Hanya tiga elemen yang didapati lebih tinggi iaitu; Al ($p < 0.001$), Cd ($p < 0.05$), dan Ni ($p < 0.05$), terutamanya di tapak perlupusan Tahap 1, berbanding dengan jenis tapak perlupusan (SPP) tahap lain. Dalam sub-kajian 2, kehadiran logam berat dalam kuku dan IL-6 dalam air liur sebagai sampel biomarker

bagi kanak-kanak yang terdedah dan tidak terdedah ditentukan dan dibandingkan. Borang soal selidik diedarkan di kalangan 342 kanak-kanak berumur 7 hingga 12 tahun. Borang Soal Selidik Kesihatan Kanak-kanak (CHQ) yang telah disesuaikan digunakan dalam kaji selidik ini. Logam berat dalam sampel kuku telah dianalisis dengan menggunakan spektrometri jisim plasma induktif (SJPI). Paras IL-6 dianalisis dengan menggunakan kaedah imunosorbent berkaitan enzim (ELISA). Logam berat di kuku pada kanak-kanak yang terdedah adalah jauh lebih tinggi berbanding dengan golongan yang tidak terdedah. Paras IL-6 juga jauh lebih tinggi ($p < 0.05$) di kalangan kanak-kanak yang terdedah dengan ± SD ± 5.51 ± 1.31 pg/ml berbanding dengan kanak-kanak yang tidak terdedah (5.19 ± 1.17 pg/ml). Dalam sub-kajian 3, perkaitan logam berat PM_{10} di udara, pengumpulan logam berat dalam kuku dan paras IL-6 dengan gejala kesihatan yang dilaporkan ditentukan dan risiko kesihatan kanak-kanak dikira. Keputusan telah menunjukkan bahawa hidung berair dan bersin mempunyai perbezaan yang signifikan antara responden kumpulan terdedah dan tidak terdedah dengan $p < 0.05$. Kanak-kanak tanpa haiwan peliharaan mempunyai risiko gejala pernafasan yang lebih rendah. Tahap logam berat yang tinggi dalam PM_{10} dan kuku telah dikaitkan dengan risiko yang lebih tinggi daripada gejala pernafasan yang dilaporkan. Logam berat dalam PM_{10} dan kuku dikaitkan dengan faktor-faktor risiko yang berpotensi untuk kesihatan pernafasan. Risiko kesihatan tidak karsinogenik dan karsinogenik menunjukkan bahawa tiada risiko wujud melalui pengingesan, penyedutan dan laluan derma bagi kedua-dua kumpulan di kawasan kajian. Kesimpulannya, kanak-kanak yang tinggal kurang daripada 3 km radius dari tapak pelupusan (SPP) mungkin mengalami potensi risiko kesihatan akibat pendedahan kepada logam berat PM_{10}.

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

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LIST OF ABBREVIATIONS

ADD	Average Daily Dose
ATSDR	Agency for Toxic Substances and Disease Registry
AOR	Adjusted Odd Ratio
Cd	Cadmium
Al	Aluminium
cm	centimeter
Co	Cobalt
Cr	Chromium
Cr (VI)	Chromium Hexavalent
Cu	Copper
DOE	Department of Environment
EPA	Environmental Protection Agency
g	gram
GDP	gross domestic product per capita
HI	Hazard Index
HQ	Hazard Quotient
HRA	Health Risk Assessment
IARC	International Agency for Research on Cancer
IL-6	Interleukin 6
IPCC	Intergovernmental Panel on Climate Change
Mn	Manganese
µg	microgram
MOH	Ministry of Health
MHLG	Ministry of Housing and Local Government
MSW	municipal solid waste
NEHAP	National Environmental Health Action Plan
NHANES	National Health and Nutrition Examination Survey
Ni	Nickel
pg	picogram
Pb	Lead
RfD	Reference Dose
RAIS	Risk Assessment Information System
SWPCMC	Solid Waste and Public Cleansing Management Corporation
SF	Slope Factor
SPM	suspended particulate matter
PM	particulate matter
PEMANDU	Performance Management And Delivery Unit
SW	schedule waste
US EPA	United States Environmental Protection Agency
WHO	World Health Organization
Zn	Zinc

CHAPTER 1

INTRODUCTION

1.1 Research Background

Elements having a specific density of more than 5 g/cm^3 are defined as heavy metals. Heavy metals are associated with the main threats to human health: for example, from exposure to mercury (Hg), lead (Pb), cadmium (Cd) and arsenic (As). Heavy metals that are contained in solid waste disposals have already been known to affect human health. In the past decade, numerous studies were carried out to investigate the behaviour of municipal solid waste (MSW) landfills and their emissions (Chalvatzaki et al., 2010; Durmusoglu et al., 2010; Gębicki & Dymerski et al., 2017; Goorah et al., 2005; Laner et al., 2009). Municipal solid waste (MSW) is defined as rubbish or garbage or unwanted everyday items such as food wastes, textiles, scrap metal, rubber, bottles, plastics, papers etc. (Ismail et al., 2015).

Solid waste in landfills is a diverse waste category, generated from different sources, each of which is itself heterogeneous (Dixon & Jones, 2005). The heterogeneity of the solid waste composition may consist of thousands of complex mixtures of substances, even some hazardous ones which may increase the health risk of the residents nearby (Gouveia & Prado, 2010). These mixtures of chemical and hazardous substances from the MSW landfills can be major threats to drinking water sources and the surrounding air (Gouveia & Prado, 2010). Furthermore, chemical or hazardous substances that are retained in a landfill will gradually affect human health especially that in the most susceptible groups i.e. children, pregnant women and the elderly who live in the vicinity of the landfill (Wigle et al., 2006).

In Malaysia, solid waste landfill sites are mainly controlled dumping sites with soil covering or open dumping, like most of the developing countries (Johari, Ahmed, Hashim, Alkali, & Ramli, 2012). Non-sanitary landfill facilities in Malaysia have triggered a lot of issues, including fire incidents due to landfill gas (LFG) emission and pollution due to leachate discharge. Lack of expertise and financial constraint have prevented proper sanitary landfill concepts to be fully implemented (Johari et al., 2012).

Compared to the engineering design of modern sanitary landfills, a system barrier is built to prevent leachate leakage contaminants from rainwater and other liquids flowing over the site of a landfill. The system is built up with a leachate collection system with a single or double liner below the waste to prevent it from seeping through. The liner can either be hard plastic, clay or some other composites (Rowe, 2011). Modern sanitary landfills are now set up with pipes to collect methane gas, together with other bio-economical systems to convert methane gas to energy (Alghni, 2010).

Elements such as copper (Cu), lead (Pb), cadmium (Cd), chromium (Cr) which are sourced from car battery disposals, NiCd batteries, food cans, electro-plating, plastics, metals, electrical disposals, pesticides and old residual paints (ATSDR, 2008) are some heavy metal elements that are commonly produced in the landfills. These elements or some form of them are commonly found in nature (Duruibe, et. al, 2007). These metals are necessarily in very minute amounts to sustain our life, but they can reach a toxic level if accumulated into bigger quantities. This is because; heavy metals have the ability to slowly accumulate in all human organs, causing a myriad of symptoms from fatigue to cancer (Jean, 2011). Cadmium, for example, can accumulate in the human body, especially the kidneys, and may contribute to organ dysfunction with impaired re-assimilation of proteins, glucose and amino acids (Kah et. al, 2012; Llop et. al, 2013; Nawrot et al., 2008; Satarug et.al, 2000) .

The content of toxic elements in the landfill is primarily a consequence of chemicals in products that we use every day such as toys, furniture, plastic containers, fabric, newspapers and books, batteries, televisions and electronic gadgets, water bottles, medical supplies, and personal products like hairspray, shampoo, perfume etc. (Slack et al, 2005). At the end of their useful life, all products will end up as waste and they are in our soil, food, and water, and in the air we breathe.

A completed route must exist for exposure to pollutants to occur. This route exists when all of the following five elements are present: i) a source of contamination; ii) an environmental medium through which the contaminant might be transported; iii) a point or area of human exposure; iv) a route or process of human uptake (such as ingestion, inhalation, and dermal contact); and v) an exposed population (one or more individuals) (Elliott et al., 2001; Kah et al., 2012). Children living in the vicinity of municipal solid waste landfills had been earmarked for the study. Their fingernails and saliva had been used as biomarkers of the heavy metal exposure.

1.2 Problem Statement

Living in the vicinity of municipal solid waste (MSW) landfills may expose the residents to various types of pollutants. Occupants near to landfill are continuosly exposed to gas and particulare matter (PM) produced from the waste dumping process through several routes of exposure especially inhalation and ingestion (Davoli et al., 2010). Landfills are complex settings reported with variety of exposures involving a multiplicity of agents with different and partly unknown toxicological profiles. Increase of land prices and the scarcity of land in highly developed states had caused residential areas being developed one kilometer or less from a landfill area (Anupam et al, 2010). This problem has negatively affected residents living in the vicinity of landfills especially to elderly, pregnant women and children. The United States Environmental Protection Agency has identified solid waste landfills as one of the hazardous air pollutant sources (USEPA, 1999). This had warranted a high risk of health problems such as skin allergy, asthma and eye allergy to the occupants in the area. In addition, without proper waste landfill

facilities such as liners and leachate collection ponds, this area can be a sink of diseases (USEPA, 2011).

Previous studies had reported potential health effects living in the proximity of less than 3 km from landfill to infants and children. Among the potential health effects reported were skin and eye allergy, respiratory problem, a high accumulation of blood lead levels that contributed to the cognitive problem, low birth weight (<2500g) in infants, infants borned with congenital anomalies, and also the growth of certain types of cancer and leukemia (Dolk et al., 1998; Vrijheid et al., 2002; Vrijheid, 2000, ATSDR, 1992; Comba et al., 2006; Elliott et al., 2006; Jarup et al., 2002; Redfearn and Roberts, 2002; Davoli et al., 2010). Hassan et al., (2002) also highlighted that heavy metals retained in a MSW landfill may cause respiratory symptoms and increase the risk of certain birth defects (Al-Delaimy et al., 2014), especially for those living less than one kilometer from the landfill area. Windblown of PM from the landfill can affect children with asthma since their breathing rate is faster than an adult, which can accumulate more PM from the air to their lungs (Cynthia, 1995). A study from Agamuthu & Fauziah (2002), also found that the surrounding soil of post-closure waste landfills in Selangor was heavily contaminated with heavy metals, especially arsenic and mercury, which might contribute to neurodevelopment effect, kidney failure and lung cancer to children (Llop et al., 2013; Sun et al., 2013).

Children are vulnerable to toxic elements because they are still young and at the development stage of physical and biological growth (Salvi, 2007; Schwenk et al., 2003). Children are also physically smaller than an adult which make their metabolic rate are higher, thus consuming more oxygen and consequently, more prone to higher air pollution in the surrounding areas (Suwanwaiphatthana et al., 2010). Children also eat more food and drink more water in the proportion of their body weights (Suwanwaiphatthana et al., 2010; Zeliger, 2008).

Comprehensive written reports that define the health outcome of children living in the vicinity of landfills are few and far between. In Malaysia, limited studies have been carried out in terms of the series of health effect in children and heavy metal exposure associated from their living in the vicinity of MSW landfills. Previous researches are mainly focused on waste treatment or waste generation and its impact on the environment and researchers often determined health problems associated with hazardous landfills in developing regions rather than the less hazardous ones (MSW landfills) (Caravanos et. al, 2013; El & Shahawy, 2011; Liu et al., 2009).

Therefore, this research was designed to evaluate the heavy metals exposure through air using nails and salivary Interleukin-6 as a biomarker among children living close to solid waste landfills in Malaysia. Children who lived in the proximity of less than a 3-km radius from municipal solid waste landfill areas were classified as the exposed group while those lived beyond these km radiuses were classified as non-exposed group in several parts of Peninsular Malaysia. A three-kilometer radius from the MSW landfill is used as an investigation barrier because the findings of health

outcome of residents were reported to be within this distance. A questionnaire was used to obtain an overall measure of the socio-demographic data, past and current history of health symptoms, and additionally, it is a cost-effective research tool in the collection of data (Jack & Clarke, 1998; Marshall, 2005; Rattray et al., 2007). Questionnaires that include queries on socio-demographic, other health symptoms, lifestyles, and food consumption are given to respondents' parents to be answered. Fingernails as a biomarker sample from children were sampled for the analysis of heavy metal accumulation in children's bodies. These are chosen as a biomarker sample because of their easy storage, cost effectiveness, are less invasive, and additionally, are made of a metabolic product that subsumes metals into the growth process (Kim et. al, 2011; Sisodia et. al, 2014). Saliva is another sample to be collected from the children to measure the level of the biomarker, interleukin-6 (IL-6). Saliva is chosen to be collected because it is non-invasive, cheap, and an acceptable method to obtain data (Hibel et al., 2007; Williamson et al., 2012). Inflammatory effects in the respiratory system will show a high level of IL-6 reading of the saliva.

The intended outcome of this study able to model the relationship of health effects on the bodies of children through heavy metals in PM_{10} from MSW landfills, level of IL-6 concentration in saliva and heavy metal accumulation in children's fingernails. Through the comprehensive analysis, a statistical modelling through this study could help resolve the current situation.

1.3 Research Questions

This study is classified into three sub-studies; Sub-study 1) environmental assessments, Sub-study 2) biomarker assessments, and Sub-study 3) health assessments. First sub-study focusing on evaluation of heavy metal concentrations in PM_{10} around the MSW landfills and residential areas; and their comparison to the International and National Air Quality Standards. Second sub-study assessing the level of heavy metals accumulation in fingernails and interleukin 6 (IL-6) in saliva of exposed and unexposed children. The third sub-study examing on health symptoms, factors associated with reported health symptom and health risks for heavy metal exposure in PM_{10} occurring among exposed and unexposed children. The research questions for each sub-study are listed below;

Sub-study 1: Environmental Assessments

1) What are the levels of heavy metal concentrations in PM_{10} around the MSW landfills, in exposed and unexposed residential areas and does it exceed the International and National Air Quality Standards?

Sub-study 2: Biomarker Assessments

2) What are the levels of heavy metal accumulations in the fingernails and interleukin 6 (IL-6) in saliva of exposed and unexposed children?
3) What are the levels of heavy metal accumulations in the fingernails and interleukin 6 (IL-6) in saliva of exposed and unexposed children when compared to previous studies?

Sub-study 3: Health Assessments

4) What are the reported health symptoms occurring among exposed and unexposed children in this study?
5) What are the factors associated with reported health symptoms in exposed and unexposed children?
6) What are the health risks for heavy metal exposure in PM_{10} among exposed and unexposed children?

1.4 Research Aim and Objectives

The aim of this study is to explore the potential association of living near MSW landfills with health effects, using the IL-6 concentration in saliva and heavy metal accumulations in the fingernails of children. Specific objectives are established to answer the research questions in three sub-studies as listed below;

1.4.1 Specific objectives

Sub-study 1: Environmental assessments

1) To determine and compare heavy metal concentrations in PM_{10} around the MSW landfills, in exposed and unexposed residential areas.
2) To compare heavy metal concentrations of PM_{10} around the MSW landfills, in exposed and unexposed residential areas to the International and National Air Quality Standards

Sub-study 2: Biomarker assessments

3) To determine and compare the levels of heavy metal accumulations in fingernails and interleukin-6 (IL6) in saliva of exposed and unexposed children

4) To compare the levels of heavy metal accumulations in fingernails and interleukin-6 (IL6) in saliva of exposed and unexposed children to previous studies

Sub-study 3: Health assessments

5) To determine and compare reported health symptoms occurring among exposed and unexposed children
6) To determine factors associated with reported health symptom in exposed and unexposed children
7) To assess health risks for heavy metal exposure in PM_{10} among exposed and unexposed children

1.5 Research Hypotheses

The research hypotheses are as follow;

Sub-study 1: Environmental assessments

1) Heavy metal concentrations in PM_{10} around the MSW landfills are significantly higher than those of residential areas, but are lower when compared to the International and National Quality Standards

Sub-study 2: Biomarker assessments

2) Heavy metal accumulations in fingernails and interleukin-6 (IL6) in saliva of exposed children are significantly higher when compared to those of unexposed ones
3) Heavy metal accumulations in fingernails and interleukin-6 (IL6) in saliva of exposed children and unexposed children are significantly lower when compared to previous studies

Sub-study 3: Health assessment

4) Reported health symptoms occurring among the exposed children are significantly higher compared to those of the unexposed ones
5) Factors associated with reported health symptoms are significantly higher in exposed children when compared to those of the unexposed ones
6) The heavy metal exposures in PM_{10} are significantly associated with health risks present in exposed and unexposed children

1.6 Conceptual Framework

The conceptual framework in Figure 1.1 illustrates the exposure of MSW landfills to children. This study consists of three major assessments: 1) environmental assessment; exposure of PM_{10} heavy metals from landfills to residential area; 2) biomarker assessment of children as respondents, and 3) health assessment of respondents. The major focus of exposure in this study is on air exposure through PM_{10}. Multiple heavy metals are reported present in the PM_{10} is one of concern. Heavy metals in PM_{10} from MSW landfills and residential areas are captured using several air sampling pumps.

The exposure can exist through inhalation, dermal contact and ingestion. Children are susceptible to these exposures which produce significant effects to their health. The risk to children health can be assessed through a bio-indicator or biomarker such as saliva and fingernails. The saliva biomarker IL-6 illustrates the inflammation of the respiratory system while the accumulation of heavy metals in the fingernails indicates the accumulation in the respondents' bodies. Meanwhile, respiratory and skin allergy symptoms are also obtained in this study and the non-carcinogenic and carcinogenic estimates from the heavy metal exposures are calculated. Respondents' socio-demographic information, health history, daily food consumption and lifestyle are the associated factors relating to the health risks and are also studied.

This study provides a comprehensive assessment to illustrate the potential association of living near MSW landfill with the health effect to the children.

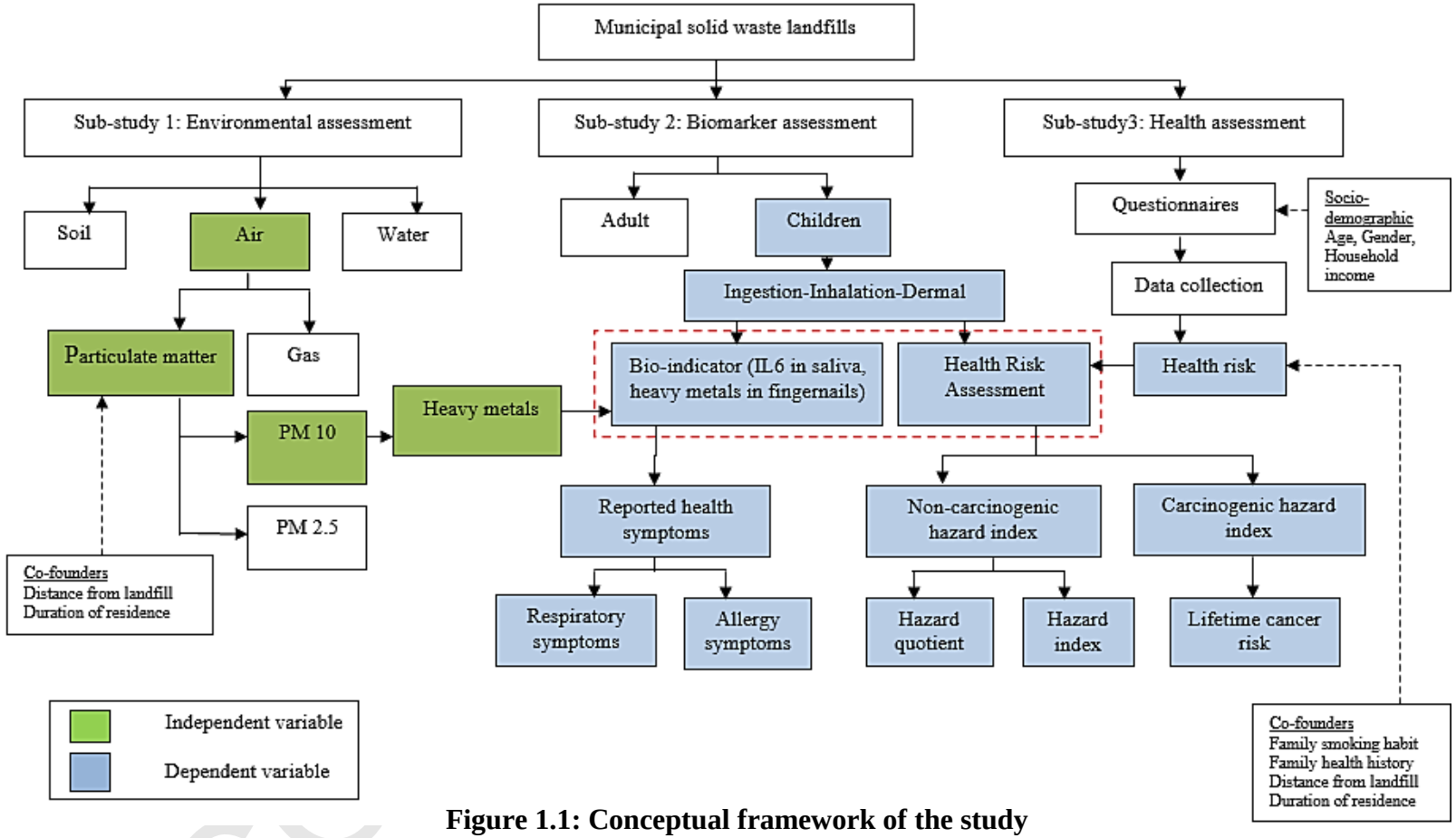

Figure 1.1: Conceptual framework of the study

1.7 Research Justification

This study contributes in terms of providing the exposure of heavy metals in children living in the vicinity of a MSW landfill and its associated health effects in Malaysia. It also shows the association between environmental contamination and the health symptoms in children living near a MSW landfill area, as well as to measure the extent of pollution in selected MSW landfills in Malaysia.

This study is carried out in conjunction with the objective of the National Solid Waste Department (NSWD), and the Ministry of Housing and Local Government (MHLG) Malaysia. This objective would ensure that the environment and public health are conserved from landfilling practices.

1.8 Thesis organization

This thesis contains six chapters which intentionally to provide data on MSW landfill exposure through PM_{10} as well as their potential health symptoms and health risk to children in four states of Peninsular Malaysia. Each of the chapter has been organized as follows:

Chapter 1 describes the research background, problem statements and the objectives of the study, research hypothesis, conceptual framework research justification and thesis organization.

Chapter 2 consists of an introduction to the solid waste categories, act and regulations, disposal method of waste treatment, current status of MSW landfills in Malaysia, environmental pollution from MSW landfill, biomarker identification and literature review that is associated with the health effects to population and children in and outside of Malaysia.

Chapter 3 provides detail description of heavy metals in PM_{10} assessment in selected MSW landfills and the study areas. The chapter starts with a brief introduction about emission from MSW landfills to children. In methodology section, study design, study location, sampling method, data collection and data analysis were described. The results and discussion of PM_{10} heavy metals assessment were provided on the last chapter.

Chapter 4 presents biomarker assessment of fingernails and IL-6 in saliva in respondent's starts with a brief introduction about biomarker identification. The study design, study population, study location, sample size calculation, sampling method, data collection and data analysis were described in methodology section. The results section includes the description of the socio-demografic, determination of

heavy metals accumulation in fingernails and level of IL-6 in saliva and comparison of the the result with previous study. Finally, the discussion of biomarker assessment was provided on the last chapter.

Chapter 5 provides an assessment of health symptoms, factors associated with reported health symptom health risk assessment via ingestion, inhalation and dermal contact of PM_{10} heavy metals among respondents. The chapter begins with a brief introduction about socio-demographic of respondents, reported health symptoms, and health risk assessment (via ingestion, inhalation and dermal exposure) for non-carcinogenic and carcinogenic elements. Data collection, socio-demographic factors associated, calculation and analysis are provided in the methodology part. The findings of reported health symptoms and health risk assessment are discussed and concluded in the last section.

Chapter 6 describes the conclusions from each sub-study. In this last chapter, the study limitation and future recommendations are included.

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LIST OF PUBLICATIONS

Esphylin, D., Ismail, S. N. S., Abidin, E. Z, Praveena, S. M & Hashim, Z. (2018). Exposure to airborne heavy metals in the vicinity of municipal solid waste landfills: An assessment of the health risks on children (Submitted to *Malaysian Journal of Public Health Medicine* on 4 Jan 2018)

Esphylin, D., Ismail, S. N. S., Abidin, E. Z, Praveena, S. M & Hashim, Z (2018). The Association between Airborne Metal Dust in Municipal Solid Waste Landfills and Respiratory Health among Children in Malaysia. (Submitted to *Malaysian Journal of Medicine and Health Sciences: Special Issue on Advancement in Health Sciences* on 7 Dec 2017)

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Ismail, S. N. S., Othman, M. S., **Jamaluddin, D. E**., Praveena, S. M., Bin, H. Y., Abidin, E. Z., ... & Haryati, A. (2015). Assessing Respiratory Inflammation among Children Living near a Non-sanitary Landfill using Interleukin-6 (IL-6). *Advances in Research*, *3*(4), 404-416.

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