EFFECTS OF HEAVY METALS IN BAUXITE FROM SCHOOL ENVIRONMENT ON RESPIRATORY HEALTH AND BIOMARKERS OF EXPOSURE AMONG PRIMARY SCHOOL CHILDREN IN PAHANG, MALAYSIA

By

NUR AZALINA SUZIANTI BINTI FEISAL

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

July 2020

FPSK (p) 2020 28

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

EFFECTS OF HEAVY METALS IN BAUXITE FROM SCHOOL ENVIRONMENT ON RESPIRATORY HEALTH AND BIOMARKERS OF EXPOSURE AMONG PRIMARY SCHOOL CHILDREN IN PAHANG, MALAYSIA

By

NUR AZALINA SUZIANTI BINTI FEISAL

July 2020

Chair : Prof. Juliana Jalaludin, PhD
Faculty : Medicine and Health Sciences

Mining activities pose a serious threat to human health and the general environmental ecosystem in Malaysia and globally. This study was to determine the relationships between heavy metals in school environments with reported health symptoms, lung function, and biomarkers among primary students. A comparative cross-sectional study was carried out on 148 students in the studied group and 122 students in the comparative group. Heavy metals in the air (n=48), dust (n=32), and soil (n=28) of school environments monitored using Gillian personal sampling pump and 400W vacuum cleaner. Reported health symptoms were gathered using questionnaire. Chestgraph HI-105 was used for lung function measurement. Heavy metals were analysed using Inductively Coupled Plasma Mass Spectrometry. Data analysis was carried using SPSS analysis. The concentration of PM_{10} and heavy metals in environment was significantly higher in the studied area. The highest heavy metal concentration in all school environments was Ni in the studied area. Highest reported symptoms among students in the studied area were cough with flu (48.0%) followed by nasal congestion (45.9%), runny nose (42.6%) and headache (41.2%). While in comparative group was cough with flu (35.9%) and cough only (35.2%) for the past 3 months. Symptoms such as headache, dizziness, diagnosed asthma, runny nose, nasal congestion, sore throat, dry throat, chest tightness after outdoor activities and itchiness showed significant differences between two groups. This study also showed students in studied area have significantly lower lung functions ratio with 68.2% FEV_1 abnormalities followed by 50% of FEV_1/FVC and 38.5% of FVC. All heavy metals accumulated in hair and toenails were significantly higher in studied group than the comparative group. Pb accounted for the highest heavy metal accumulation detected in hair with 18.14 μg/g while Ni accounted for the highest heavy metal accumulation detected in toenails with 6.13 μg/g. Higher pollutants concentration of PM_{10} and heavy metals

concentrations in indoor air, window dust and corridor dust were significantly associated with all reported health symptoms except for cough and chest tightness at night. PM_{10} and heavy metals exposure in school environments especially air, window dust and corridor dust were significantly associated with reduction of lung functions. Findings showed there was significant relationship between heavy metals in environment with heavy metals accumulation in biomarkers. This study indicated the association of heavy metals concentration in biomarkers with all reported health symptoms. Lower values of lung functions were found significantly associated with runny nose, nasal congestion, dry throat, chest tightness, chest tightness at night and chest tightness after outdoor activities. Logistic regression showed increasing exposure to heavy metals in indoor air and dust to health symptoms and lung function. Increasing exposure to heavy metals in environment increase the concentrations of heavy metals in biomarkers. This study found that school location to mining area and Ni concentrations in indoor air and dust were the two risk factors for health outcomes among students. Since it is near the school location, proper zoning implemented for school location, mining companies should have appropriate standard operating procedures (SOP) and cleanliness should be emphasized.
.
Keywords: Students; Mining; Bauxite; Health symptoms; Lung function; Biomarkers; Heavy metals

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

KESAN LOGAM BERAT DALAM BAUKSIT DARIPADA PERSEKITARAN SEKOLAH TERHADAP KESIHATAN RESPIRATORI DAN PETUNJUK BIOLOGI DALAM KALANGAN MURID SEKOLAH DI PAHANG, MALAYSIA

Oleh

NUR AZALINA SUZIANTI BINTI FEISAL

Julai 2020

Pengerusi : Prof. Juliana Jalaludin, PhD
Fakulti : Perubatan dan Sains Kesihatan

Aktiviti perlombongan menimbulkan ancaman serius terhadap kesihatan manusia dan ekosistem alam sekitar di Malaysia dan seluruh dunia. Kajian in dijalankan untuk menentukan hubung kait di antara kandungan logam berat di persekitaran sekolah dengan laporan simptom kesihatan, fungsi paru-paru dan petunjuk biologi di kalangan pelajar sekolah rendah. Kajian keratan rentas perbandingan dijalankan terhadap 148 murid kumpulan kajian dan 122 sebagai kumpulan perbandingan. Logam berat dalam udara (n=48), debu (n=32) dan tanah (n=28) di persekitaran sekolah dipantau menggunakan pam persampelan Gillian dan 400W pembersih vakum. Simptom kesihatan diperolehi menggunakan borang soal selidik. Chestgraph HI-105 digunakan untuk ujian fungsi paru-paru. Kandungan logam berat dalam dianalisa menggunakan Spektrometri Jisim Plasma Gandingan Teraruh (ICP-MS). Data analisis dalam kajian ini menggunakan SPSS analisis. Kandungan PM_{10} dan logam berat dalam persekitaran lebih tinggi di kawasan kajian. Kepekatan logam berat yang tertinggi di semua sampel persekitaraan sekolah adalah Ni. Simptom tertinggi yang dilaporkan di kumpulan kajian adalah batuk dan selsema (48.0%) diikuti dengan hidung tersumbat (45.9%), hidung berair (42.6%) dan sakit kepala (41.2%). Manakala kumpulan perbandingan, simptom batuk dan selsema (35.9%) dan batuk sahaja (35.2%) dilaporkan dalam masa 3 bulan terakhir. Simptom seperti sakit kepala, hidung berair, hidung tersumbat, sakit tekak, kering tekak, sesak nafas selepas aktiviti luar dan gatal menunjukkan perbezaan signifikan antara dua kumpulan. Kajian ini juga mendapati bahawa pelajar di kawasan kajian mempunyai signifikan abnormal fungsi paru-paru yang rendah dengan 68.2% FEV_1 diikuti dengan 50% FEV_1/FVC dan 38.5% FVC. Kepekatan logam berat dalam petunjuk biologi adalah signifikan lebih tinggi dalam kumpulan kajian. Pb merupakan yang tertinggi dalam rambut manakala Ni merupakan tertinggi dalam kuku kaki, 6.13 μg/g. Kepekatan tertinggi PM_{10} dan logam berat dalam udara, debu tingkap dan debu koridor mempunyai hubungkait

yang signifikan dengan simptom kesihatan yang dilaporkan kecuali simptom batuk dan sesak nafas pada waktu malam. PM_{10} dan logam berat di persekitaran sekolah terutama udara, debu tingkap dan debu koridor mempunyai hubungkait yang signifikan dengan keupayaan fungsi paru-paru. Hasil menunjukkan hubungkait yang signifikan antara logam berat di persekitaran dengan pengumpulan logam berat dalam petunjuk biologi. Kajian ini menunjukkan kaitan peningkatan kepekatan logam berat dalam petunjuk biologi dengan simptom kesihatan yang dilaporkan. Terdapat hubungkait antara penurunan fungsi paru-paru dengan hidung berair, kering tekak, sesak nafas, sesak nafas pada waktu malam dan sesak nafas selepas melakukan aktiviti luar. Regresi logistik menunjukkan pendedahan terhadap logam berat di udara dan debu mempengaruhi simptom kesihatan dan fungsi paru-paru. Manakala, pendedahan terhadap logam berat dalam semua sampel mempengaruhi kepekatan logam berat dalam petunjuk biologi. Kajian ini mendapati bahawa lokasi sekolah dan kepekatan Ni di udara dan debu merupakan dua faktor risiko dalam kalangan pelajar. Oleh kerana berdekatan dengan lokasi sekolah, zon penyangga harus dilaksanakan, syarikat perlombongan harus mempunyai prosedur operasi standard yang sesuai dan kebersihan harus dititikberatkan.

Kata kunci: Pelajar; Perlombongan; Bauksit; Simptom kesihatan; Fungsi paru-paru; Petunjuk biologi; Logam berat

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful.

Alhamdulillah, all praises to the Almighty Allah for granting me His blessings in every beat of my heart, good health and great vitality in completing my PhD journey. I would like to acknowledge and extend my gratitude to Prof. Dr. Zailina bin Hashim as the Main Supervisor who retired just before the thesis was submitted. She has guided and advised me from the beginning till the study completion, thesis submission and viva. Appreciation to Associate Prof. Dr. Juliana bin Jalaludin as the new Main Supervisor together with Dr. Vivien How and Dr. Saliza bin Elias as the Supervisory Committee Members for their assistance and valuable guidance, critics as well as encouragement.

My special gratitude also goes to Dr. Rafiza, Dr. Zurahanim, Miss Wan Nurul Farah, and staff from the Environmental Health Research Centre (EHRC), Institute of Medical Research (IMR) for the study sample preparation and analysis. Besides that, I am indebted to these bodies for monetary support; the Ministry of Education (MOE), the Ministry of Higher Education (MOHE) for the scholarship, and UPM for financing my PhD study under the Putra Research Grant (GP-IPS/2016/9509700).

Moreover, I would like to give my deepest appreciation to all dear students, their parents and guardians, the school teachers, and the management of primary schools for their willingness to cooperate in this research. Last, but not least, I am very grateful to my beloved family members who have been very understanding with my commitments, showering me with eternal love, praying to Allah for my success, lending me a shoulder to cry on and ear to open up my pain, constantly motivating me throughout my life; my beloved husband Mohd Syazwan bin Mohd Rosli, my dear son Adam Naufal bin Mohd Syazwan, my mother Wan Nuraizzass binti Wan Napi, my late father Feisal bin Dato Hj Mustapha, my parents-in-law Noraliza binti Idris and Mohd Rosli bin Daud, my dear siblings, and sibling-in-law. Not to forget, my sincere gratitude to those individuals who contributed either directly or indirectly to my research. May Allah bless all of you!

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:

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

Vivien How, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

Saliza binti Elias, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

_____
ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 08 October 2020

Declaration by the Graduate Student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and the copyright of the thesis are fully-owned by Universiti Putra Malaysia, as stipulated in the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from the supervisor and the office of the Deputy Vice-Chancellor (Research and innovation) before the thesis is published in any written, printed or electronic form (including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials) as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld in accordance with the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2015-2016) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: _____ Date: _____

Name and Matric No.: Nur Azalina Suzianti Binti Feisal

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	Percent
<	Less than
>	More than
^{o}C	Degree Celsius
As	Arsenic
ATS	American Thoracic Society
Cd	Cadmium
CI	Confidence Interval
EHRC	Environmental Health Research Centre
EPA	Environmental and Protection Agency
FEV_1	Forced Expiratory Volume in 1 Seconds
FVC	Forced Vital Capacity
GDP	Gross Domestic Product
H_2O_2	Hydrogen Peroxide
HNO_3	Nitric Acid
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
IMR	Institute of Medical Research
ISAAC	International Standard Asthma and Allergies in Childhood
km	Kilometre
μg/g	Microgram per gram
$\mu g/m^3$	Microgram per cubic meter
mg/kg	Milligram per kilogram
mL	Millilitre
Ni	Nickel

Pb	Lead
Ppb	Part per billion
PM_{10}	Particulate matter 10
PTFE	Polytetrafluoroethylene
SD	Standard deviation
SK	Sekolah Kebangsaan
SPSS	Statistical Package for Social Science
UPM	Universiti Putra Malaysia
UPSR	Ujian Penilaian Sekolah Rendah
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Mining is an exploration of minerals from the earth which is important because it is one of the main material sources. For example to convert a raw material like bauxite ore to aluminium oxide in order to make aluminium metal (Cablik, 2007; Khan, 2015). Bauxite mining is one of the upstream operations of primary aluminium production except for alumina refining. Rock that contains aluminium hydroxide which is one of the principle ore of aluminium is called bauxite and is found closely at the ground surface (0.8 to 2 metres deep) depending on the geography structure of the region meant for exploitation (Lad & Samant, 2015). Tin resources and tin-associated minerals (bauxite, coal, carbonate rocks, clays, copper, gold, iron ore, crude petroleum, and silica) and tin placer deposits (ilmenite, monazite, struverite and zircon) are minerals that are mainly produced by Malaysia since 2000 (Tse, 2015).

Aluminium industry is one of the largest industrial by-products in our modern society. Malaysia had resorted to many kinds of activities to exploit natural resources like mining to achieve rapid economic development. In Figure 1.1, the three countries that are the most dominant in bauxite mine production that generate 81 million, 47 million, and 32.5 million metric tons of bauxite are Australia, China, and Brazil (Kearney, 2013). Bauxite mining in Pahang started in the year 2013 where started with small-scale mining at Balok then expand to Bukit Goh and Bukit Sagu (ASM, 2016; Mohd Taminzi et al., 2019). However, bauxite mines nowadays are springing up in Malaysia which only supplied just about 1.27 million tonnes in the first nine months and increasing the amounts of the raw material used for aluminium to China since Indonesia banned bauxite mining export in 2014 (Anuradha & Melanie 2014). Meanwhile, there was rapid expansion from 343, 000 tonnes in January 2015 to 3.72 million tonnes in September 2015 according to the Malaysia Statistics Department the mining sector contributed around 12.5% to Malaysia's gross domestic product (GDP) compared with 6.7% before (Rahman, 2011; Khan, 2015; ASM, 2016; Mohd Taminzi et al., 2019). Due to the environmental impact of bauxite production, government authorities decided to hold a moratorium on mining early in 2016 (Cecilia, 2019).

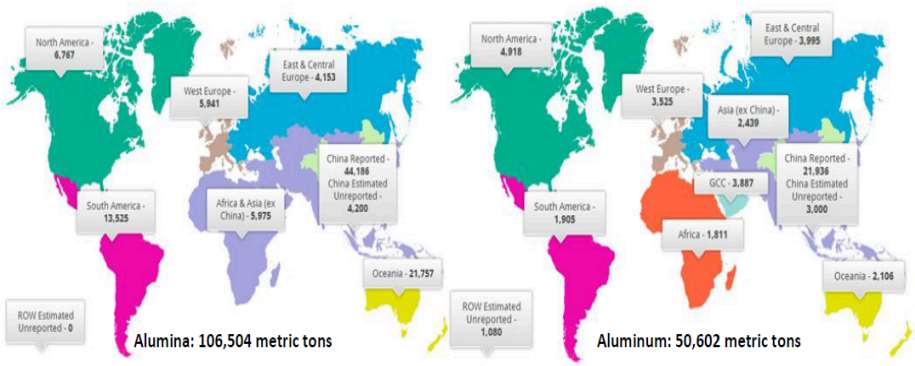

Figure 1.1: Global Bauxite Production
(Source: Nappi, 2013)

1.2 Problem Statement

Mining activities are absolutely necessary for our country due to the economic benefits which that involved in the extraction of mineral resources. However, several economic companies have lost sight of the environmental and health effects associated with mining activity. Additionally, the declining quality trend of Chinese bauxite has increase demand for imported bauxite which caused an increased in bauxite prices that attracted new independent bauxite projects. Moreover, ahead of the Indonesian ban, it conducted Malaysia increased bauxite production from a token of 100,000 to 200,000 in 2013 to 3.3 million tons in 2014 and a possible of 15 – 20 million tons in 2015 (ASM, 2016; Mohd Taminzi et al., 2019). In order to accomplish the increase in Malaysia's capacity there are many new mines that have been start-ups, especially in Kuantan, Pahang areas. As Malaysian bauxite is gibbsite bauxite the quality of bauxite is high in moisture and iron this can cause several impacts when transporting the bauxite towards health and the environment (Edison Investment Research, 2015). Due to the environmental and health impact on the communities nearby, the government had to lift up the moratorium on the bauxite mining activities that started on January 2016 (The Malaysian Insider, 2016).

Bauxite mining activities nowadays gave more harm than benefit to communities in surrounding areas (Noor Hisham et al., 2016). Based on the latest study done in Pahang where there mining activities will cause acute, intermediate, and long-term health impacts on people living nearby (Noor Hisham et al., 2016). It mentioned that the children who are admitted are among communities that live nearby to bauxite mining. Long-term exposure to bauxite can affect our health either by acute or chronic effects because it contains heavy metals.

School children approximately spend 180 days or 30% (Fromme et al., 2006; Francess & Nachinaab, 2018) of their daytime in a year and seven hours long in a school. Most of the students arrive at school early and stay late for school

activities. During this time, they are prone to exposure from the ambient concentrations, air exchange rate, penetration factor, deposition, and resuspension mechanism (Fromme et al., 2006; Ronald et al., 2016; Francess & Nachinaab, 2018). Besides, due to their body systems being still in the growing phase, they are vulnerable to the risk of mining exposure because the location of the school is near to mining area which is the point source of pollutants that could penetrate into the school environment.

There are numerous studies carried out on the association of particle mass (PM) concentration outside with the occurrence of health problems (WHO, 2013; Nomsa et al., 2014; Wen et al., 2015) However, there are fewer studies done on heavy metals concentration in biomarkers that caused an effect on health especially in children schooling near mining area in Malaysia, most of the studies done among communities living nearby (Muhammad Hafizz, 2016; Nurul Hidayah et al., 2016). Hence, data is needed in order to assume that children are more vulnerable to health hazards as they spend more time in classrooms.

Previous studies conducted in other countries such as Portugal, Egypt, and China had shown that heavy metals concentration in children's biomarkers has been studied thoroughly well (Cimi et al., 2014; Blaurock-Busch et al., 2012; Pnuwa et al., 2012). However, there is still a deficiency of proof that heavy metals in biomarkers such as hair and toenails are associated with health impacts among students schooling in exposed mining areas, especially in Malaysia. To detect chronic metal exposure, blood, and urine are not the best diagnostic tool for analysis due to heavy metals in urine remaining for a period of weeks or months which did not contribute to long-term exposure (Eleoner et al., 2011; John et al., 2018).

Respiratory illnesses such as asthma, allergy, and respiratory infections among children are high and increasing by the day. Because of this health problem, International Study on Asthma and Allergy in Childhood (ISAAC) developed a standardized case definition, questionnaire, methodology, and established databases for asthma and allergy. In Malaysia, there are no specific studies that found the effect of health symptoms among children exposed to mining activity. Nevertheless, there are abundant studies done among workers in Malaysia (Abuh et al., 2013; Yahaya et al., 2014; Thomas et al., 2017).

These environmental and health impacts of bauxite mining activities have attracted public attention mostly from communities that live in Kuantan, Pahang and outsiders. Hence these issues need to be addressed through research on the current environment and health impacts of schools and communities of bauxite mining on communities that live in Felda Bukit Goh, Kuantan which is one of the main areas of mining in Malaysia. Indeed, concerns towards children where are more susceptible to toxic exposure than adults because they have a more proportionally intake of food contaminants, active developmental

processes, multiple exposure pathways, and socio-behavioral activities (WHO, 2004).

1.3 Study Justification

This research was conducted to determine the health implications due to exposure to heavy metal pollutants in school environments among students. This study related exposure to school environments with reported health symptoms, lung function, and biomarkers among school children in mining areas. The target heavy metals in school environments and biomarkers were Pb, Cd, As, and Ni. Short-term heavy metal exposure can cause effects on health. On the other hand, chronic heavy metal toxicity remained largely unknown and therefore there is a void that needs to be performed for more studies.

Recent studies done on perceptions of residents in the mining area of Pahang found that 90% of the respondents stated that mining activities especially dust pollution gave negative impacts while 43.2% of the respondents reported medium scores of psychosocial impacts due to mining activities (Muhammad Hafizz, 2016; Nurul Hidayah et al., 2016). Nevertheless, a study done by Nurul Amalina (2017) found that the bauxite mining activities gave a positive impact in terms of finances despite the health effects. Meanwhile, a study done by Noor Hisham and friends (2016), found that uncontrolled bauxite mining activities will give indirect and direct issues to the health of people nearby and environmental pollution.

Hence, this research study helped to convey facts to fulfill the gap of knowledge on the effects of health and biomarkers related to exposure to heavy metals. Moreover, this finding would be beneficial to policy maker to make policy and to the government in order to find proper management to minimize bauxite exposure to reduce environmental pollution and health risks.

1.4 Objectives and Hypothesis

1.4.1 General Objective

To determine the relationships between the heavy metals in school environments (air, soil, and dust) with reported health symptoms, lung function, and biomarkers (hair and toenails) among primary students.

1.4.2 Specific Objectives

1. To determine and compare the heavy metal concentrations in the two schools environments (air, dust, and soil).
2. To determine and compare the reported health symptoms between two groups of students.
3. To determine and compare the lung function between two groups of students.
4. To determine and compare the heavy metals concentrations in biomarker samples (hair and toenails) between the two groups of students.
5. To determine the association between heavy metals in school environments with the reported health symptoms, biomarkers, and lung functions among students.
6. To determine the association between reported health symptoms with lung functions and biomarkers among students.
7. To determine the selected risk factors (personal; residential and school environments) that significantly contributed to the reported health symptoms among the studied group.
8. To determine the selected risk factors (personal; residential and school environments) that significantly contributed to lung functions among the studied group.
9. To determine the selected risk factors (personal; residential and school environments) that significantly contributed to heavy metals in biomarkers (hair and toenails) among the studied group.

1.4.3 Research Hypothesis

1. There are significant differences in heavy metal concentration between the two schools environments (air, dust, and soil).
2. There are significant differences in the reported health symptoms between the two groups of students.
3. There are significant differences in lung functions between the two groups of students.
4. There are significant differences in the heavy metal concentrations in the biomarker samples (hair and toenails) between the two groups of students.
5. There are significant associations between heavy metals in school environments with the reported health symptoms, lung functions, and biomarkers in the two groups of students.
6. There are significant associations between reported health symptoms, lung function, and biomarkers in the students of the studied group.
7. The school environment (air and dust) is the risk factor that contributed to the reported health symptoms among the studied group.
8. School environment (air and dust) is the risk factor that contributed to lung functions among the studied group.
9. School environments (air and dust) is the risk factors that contributed to the heavy metals concentration in biomarkers (hair and toenails) among the studied group.

1.5 Conceptual Definition of Terms

1.5.1 Primary School

In Malaysia, there are two types of schools which are primary and secondary. Primary school is a school for students from the aged 7 to 12 years old while secondary school is for students aged 13 to 17 years old. There are certain primary schools that include pre-primary in the same school area for children aged 5 and 6 years old. Malaysia Education Department has set a broad and general education schooling in public schools and private sector schools. *Sekolah Kebangsaan* is the most public which is a government school while *Sekolah Jenis Kebangsaan* is a public-funded national type school (Malaysia Education Blueprint 2013 – 2025: Preschool to Post-Secondary Education, 2013).

1.5.2 Health Symptoms

Health is a state of complete physical, mental, and social well-being and not just the absence of illness or infirmity by the World Health Organization (WHO, 1946). The respiratory system is a biological system that consists of specific organs and structures used for the process of respiration in an organism (Maton et al., 2010). Respiratory health problem is a diseases that affect the air passages including nasal passages, bronchi, and lungs. The diseases range from acute infections such as pneumonia and bronchitis to chronic such as asthma and chronic obstructive pulmonary disease (NHCHIS, 2008). The usual respiratory symptoms which are common in humans are cough, sore throat, runny nose, nasal congestion, headache, low-grade fever, facial pressure, and sneezing (Eccles et al., 2007). General symptoms are defined as those that have common and basic symptoms such as headache, fever, dizziness, and diarrhea (Zahid, 2015). Dermal or skin health symptoms can be temporary or permanent. There are many different types of skin disorders such as acne, cold sore, blister, hives, actinic keratosis, rosacea, carbuncle, latex cellulitis measles, allergy, eczema, psoriasis, and others (Katherine, 2016).

1.5.3 Lung Function

Lung function or pulmonary function are breathing tests to find the movement of air in and out of the lungs and how well oxygen enters the bloodstream (ATS, 2019). Spirometry tests are important to help diagnosed suspected lung disease and in planning treatments (Lung Foundation Australia, 2017). The FEV_1 is the maximum volume of air exhaled in the first second of a forced expiration from the position of full inspiration, expressed in litres of body temperature and ambient pressure saturated with water vapor (ATS, 2005). The FVC refers to the maximum volume of air exhaled with a maximally forced effort from a maximum

expiration, expressed in litres at body temperature and ambient pressure saturated with water vapor (ATS, 2005).

1.5.4 Heavy Metals

Chemical elements with a specific gravity that occur naturally in the earth's crust and the contents in the environment that vary between different regions with densities of greater than 5 g/cm^3 are called heavy metals or other words toxic metals (Jaishankar et al., 2014; Tchounwou et al., 2014). There are 92 naturally occurring elements where 30 are metals and metalloids which are potentially toxic to humans (WHO, 2007; Morais et al., 2012). As, Pb, Cd, and Ni have been listed by an agency called United State Environmental Protection Agency as the targets to be analyzed in the environmental assessment program (USEPA, 2014).

1.5.5 Biomarkers

Biomarkers or other word called biological marker is defined as an indication observed from outside that can be measured accurately and reproducibly (Kyle & Jorge, 2010). While Gil and Hernandez (2009) explained that biomarkers are a tool for an exposure assessment to harmful substances and evaluation of temporal changes in a population exposed to environmental contaminants are biomarkers.

1.6 Operational Definition of Terms

1.6.1 Primary School

Any primary school located in a mining activities area was considered a study school while any primary school located not in a mining activities area was considered a comparative school.

1.6.2 Health Symptoms

Health symptoms are the dependent variable in this study and presented with the symptoms are reported through parents or guardians via questionnaires and lung function. The data is taken by a modified questionnaire from The International Study of Asthma and Allergies in Childhood (ISAAC) based on related symptoms that appear in children over the past three months for respiratory symptoms. Headache and dizziness for general symptoms and itchiness, skin rashes, and eczema for dermal symptoms.

1.6.3 Lung Functions

A spirometry device is used in this study which to measure how much air we inhale and how quickly can be exhaled. The spirometer will record the amount and rate of air breathed in and out over a period. The normal value for lung function tests is based on age, height, ethnicity, and gender. The value that is usually considered abnormal is approximately less than 80% of the predicted value. FEV_1% is done by calculated dividing the measured FEV_1 value (obtained from the spirometry) by its normal value (derived from a standard equation) and then multiplying it by 100. While FVC% is calculated by dividing the measured FEV_1 value (obtained from the spirometry) by its normal value (derived from the standard equation) and then multiplying it by 100. FEV_1 will be lessened if there is an obstruction to the trachea tract and bronchi while FVC will be lessened if there is a restriction of lung volume and maximum expiration by the subject.

1.6.4 Heavy Metals

As, Cd, Ni, and Pb are 4 types of heavy metals that are being analyzed in school environments (indoor air, soil, and dust) and biomarkers (hair and toenails) in this research. The heavy metals concentration is analyzed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

1.6.5 Biomarkers

Biomarkers used in this study are hair and toenails. The sampling of hair and toenails are non-invasive methods that can easily be collected, stored, and transported. Heavy metals concentration that is analyzed in these biomarkers is As, Cd, Ni, and Pb.

1.7 Conceptual Framework

Figure 1.2 shows the conceptual framework of this study by estimating heavy metals in biomarkers (hair and toenails), health symptoms reported, and lung function through school environmental pollutants. The environment and its compartment in mining areas are severely polluted by heavy metals. This changes the environment to undesirable and unintended changes in soil, water, and air of physical, chemical, and biological properties (Vhahangwele and Khatutshelo, 2017; Wenhao et al., 2018; Yixian et al., 2018). School children are hypothesized to be exposed to the heavy metals pollutant through micro-environment and macro-activity.

To recent date, previous research findings for toxicity in biomarkers and lung function exposed to mining in children are inchoately compared to other studies among workers (Safrudin et al., 2014; Alphonsus et al., 2016; Ritta et al., 2016; Matilda et al., 2018). Human biomarkers are analyzed to provide evidence of human exposure to a school environment's pollutants, while lung function can provide a simple for assessing how well the lungs work in the body.

In Malaysia, this is the first research that use biomarkers such as hair and toenails of mediator and health variables to assess lung function among students schooling near mining area. This study was conducted on the entire assessment process of student exposure from the evaluation of school environments, a survey on reported health symptoms, lung function tests, and biomarkers sample collection, and laboratory analysis to statistical analysis. The findings of this work can be used to increase awareness of hazards they face because of constant exposure to the students of mining operations and to inform that children are a human vulnerability as one of the prevention components. Therefore, from the findings of the study, it is expected that parents and guardians will be more attentive to the health effects their children face when they are exposed to contaminants from mining. In addition, this study suggests measures for parents, guardians, and school administrators to ensure that the school and residences provide students with a clean environment. As for the other researchers, there are even more differences to understand the lung function processes and the health effects of exposure to pollution from mining. Still, more gaps in order to understand the mechanisms of lung function and health symptoms exposure to mining pollutants. Therefore, the findings of this study should provide rooms for improvement to be made.

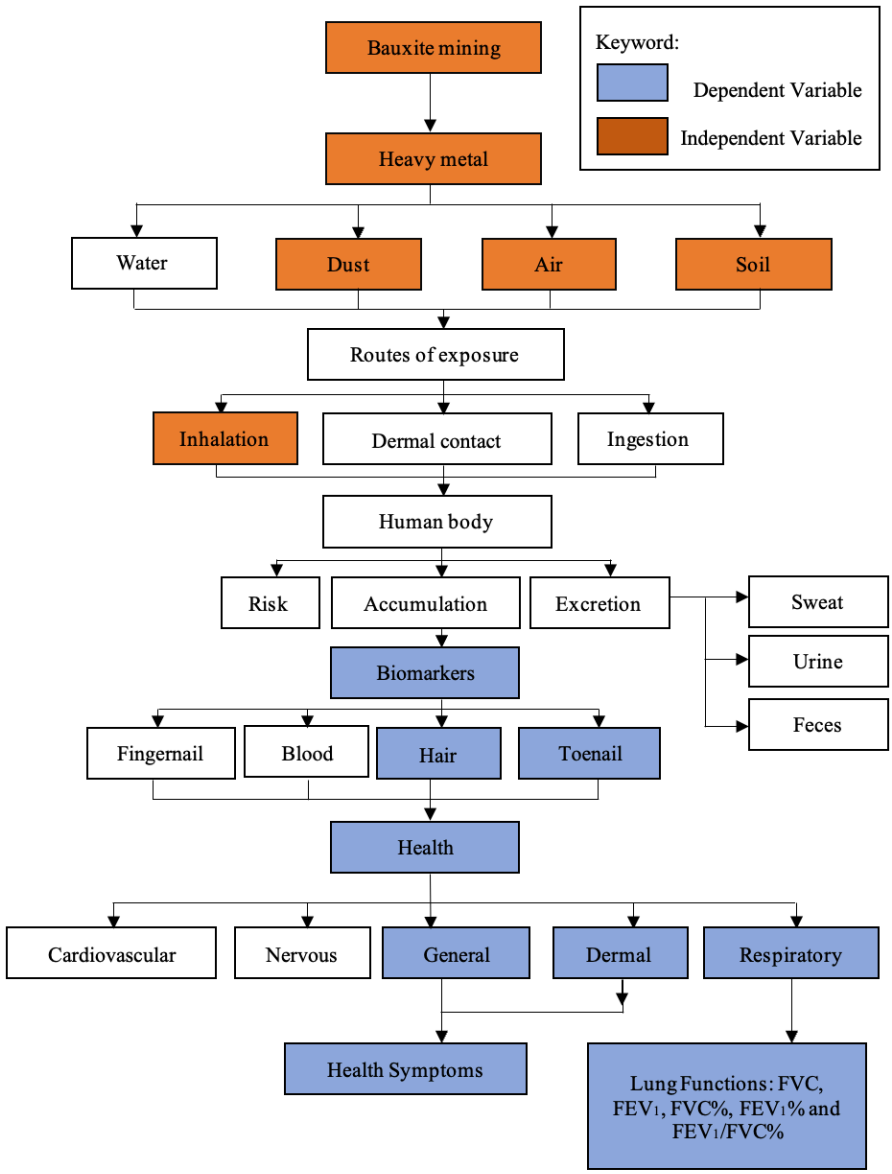

Figure 1.2: Conceptual Framework

REFERENCES

Abdulrahman, F.I., Akan, J.C., Chellube, Z.M. & Waziri, M. (2012). Levels of Heavy metals in Human Hair and Nail Samples from Maiduguri Metropolis, Borno State, Nigeria. *World Environment*, *2(4).* 81 - 89.

Abuh, M., Sphiwe, E.M., Olukoga, A., Confidence, M. & Matamela, M. (2013). Potential Implications of Mine Dusts on Human Health: A Case Study of Mukula Mine, Limpopo Province, South Africa. *Journal of Medical Science, 29(6).* 1444 – 1446.

Afaq, H., Vineeth, A.R., Soumya, K., Tapendu, S., Raja, S., Debnath, P. & Jayasri, D.S. (2018). Mechanisms of Arsenic-Induced Toxicity with Special Emphasis on Arsenic-Binding Proteins. *Analytical and Toxicological Studies, 10.5772.*

Agency for Toxic Substances and Disease Registry (ATSDR). (2008). Aluminium.

Ahanger, F.A., Sharma, H,K., Rather, M.A. & Rao, R.J. (2014). Impact of Mining Activities on Various Environmental Attributes with Specific Reference to Health Impacts in Shaabdipuram, Gwalior, India. *International Research Journal of Environment Sciences*, *3(6),.* 81 - 87.

Ahmad, Q., Rusli, N., Krystal, Y., Ho, H., Tan, H., Tham, Y., Shum, L. & Thayaparan, P. (2017). A Review of The Occupational and Environmental Health Hazards of Bauxite Mining in Malaysia. *Proceeding of the 3rd International Conference on Public Health, 3.* 1-14.

Ah Young, L., Se Kyu, K., Joon, C., Young Ae, K., Young Sam, K., Moo Suk, P., Song Yee, K., Eun Young, K., Kyung Soo, C. & Ji Ye, J. (2015).Relationship between Blood Levels of Heavy Metals and Lung Function Baased on the Korean National Health and Nutrition Examination Survey IV-V. *International Journal of COPD, 10.* 1559-1570.

Ahmed Al Hejami, (2014). Heavy Metals in Indoor Settled Dusts in Toronto, Canada.

Ain Nihla, K., Yee Shan, W. & Mohd Faizal, A.J. (20170. Distribution and Analysis of Heavy Metals Contamination in Soil, Perlis, Malaysia. *CENVIRON, 34(02040).*

Airi, A. & Takeo, F. (2018). Association of Low Family Income with Liung Function Among Children and Adolescents: Results of the J-SHINE Study. *Journal of Epidemiology, 29(2).* 50 – 56.

American Throcacic Society (ATS). (2014). Pulmonary Function Tests. *American Journal Respiratory Critical Care Medical, 189*. 17 – 18.

Ami, R.Z., Adrienne, E., Anne, R. & Laurel, S. (2015). Associations Between Metals in Residnetial Environmental Media and Exposure Biomarkers Over Time in Infants Living Near a Mining-Impacted Site. *Journal of Exposure Science and Environmental Epidemiology, 26(5).* 1 - 10.

Al-Ramadi, M.A., Al-Askar, N.A. & Mostafa, G.A.E. (2017). Simultaneous Determination of Some Heavy Metals in Nail Samples of Saudi Arabian Smokers by Inductive Coupled Plasma Mass Spectrometry. *Biomedical Research, 28(10).* 4568-4574.

Alesia, C.F., Jennifer, C.B., Isaac, B.S., Jennifer, N.W., Samir, M.E., Kendra, E.G., Mark, H. & Helena, M.S.G. (2018). Risk Assessment for Children Exposed to Arsenic on Baseball Fields with Contaminated Fill Material. *International Jpurnal of Environmental Research and Public Health.* 15(67). 1 – 23.

Alison, P.S., Sloane, K.M., Viet, N., Jonathan, B.K. & Rebecca, C.F. (2014). Toxic Metal Levels in Children Residing in A Smelting Craft Village in Vietnam: A Pilot Biomonitoring Study. *BMC Public Health, 14(114),* 1 – 8.

Alphonsus, R.I., Vincent, Y.A., Adesuwa, Q.A. & Innocent O.A. (2016). Respiratory Symptoms and Ventilatory Functions among Quarry Workers in Edo State, Nigeria. *Pan African Medical Journal*, *23(212).* 1 – 9.

Anna, B., Kuan-Yung, L., Heng-Hsin, L., Przemyslaw, N., Lukasz, K., Bersilav, M., Magdalena, J.C., Rajmund, M., Andrzej, P., Jaroslaw, J. & Ryszard, K. (2017). Alterations of hair and Nail Content of School of Selected Trace Elements in Nonoccupationally Exposed Patients with Chronic Depression from Different Geogrphical Regions. *Hindawi biomed Research International.*

Anna, T., Kinga, W. & Wojciech, M.W. (2019). Digestion Procedure and Determination of Heavy Metals in Sewage Sludge – An Analytical Problem. *Sustainability, 11(1753).*

Andrea, H., Anna, C.C., Jane, H., Peter, M. & Peter, D.S. (2014). Children's Personal Exposure to PM_{10} and Associated Metals in Urban, Rural and Mining Activtiy Area. *Elsevier: Chemosphere, 108.* 125 – 133.

AOAC. (2016). Guidelines for Standard Method Performance Requirements. *AOAC Official Methods of Analysis.*

Awad, A.M., Mohammed Awad, A.K., Malik Abdalla, e. & Dafaalla, M.H.A. (2015). Trace Elements in Scalp Hair and Fingernails as biomarkers in Clinical Studies. *Journal of Health Specialities, 3(1).* 28-34.

Azizul, A. A., Juliana, J., Nur Hazirah, H. (2019). Air Pollutants Exposure with Respiratory Symptoms and Lung Function among Primary School

Children nearby Heavy Traffic Area in Kajang. *Asian Journal of Atmospheric Environment, 13(1).* 21 – 29.

Balomenos, E., Panias, D. & Paspaliaris, I. (2011). Energy and Exergy Analysis of The Primary Aluminium Production Processes: A Review on Current and Future Sustainability. *Mineral Processing and Extractive Metallurgy Review: An International Journal.*

Bruce, J.K., Rebecca, N., Corina, D.J., Levicatus, M., Qingyu, M., Gilbert, A., Sian, W., Hellen, A.T., Moses, K., Stephan, S., Thys, V.D.M. & Vahid, M. (2018). Lung Fucntion of Children at Three Sites of Varying Ambient Air Pollution Levels in Uganda: A Cross Sectional Comparative Study. *International Journal of Environmental Research and Public Health*. 15(2653). 1 – 13.

Cablik, V. (2007) Characterization and Applications of Red Mud from Bauxite Processing.

Caspah, K., Manny, M. & Morgan, M. (2016). Health Risk Assessment of Heavy Metals in Soils from Witwatersrand Gold Mining Basin, South Africa. *International Journal of Environmental Research and Public Health, 13(663).* 1 – 11.

Cecilia, J. (2019). Malaysia Puts Bauxite Mining Ban on Hold Until Impact Studies Competed. *Mining[dot]com.* https://www.mining.com/malaysia-extends-bauxite-mining-ban-impacts-study-completed/

Clain, J., Jeff, K. & Kathrin, O.R. (2014). Soil Sampling and Laboratory Selection. *Nutrient Management, 1.* 4449-1.

Counter, S.A. & Buchanan, L.H. (2004). Mercury Exposure in Children: A Review. *Toxicology and Applied Pharmacology, 198*. 209-230.

David, K.E. (2009). Levels of Arsenic in Human Hair as Biomarkers of Arsenic Exposure in A Mining Community in Ghana. *Bulletin Chemical Society of Ethiopia, 23(2).* 275 – 280.

Dennis, S.K. (1971). The Evidentiary Uses of Neutron Activation Analysis. *California Law Review, 59(4)*.

Donoghue, A.M., Frisch, N. & Olney, D. (2014). Bauxite Mining and Alumina Refining. *American College of Occupational and Environmental Medicine, 56*. (55).

Dora, E., Sharifah, N.S.I., Sarva, M.P., Zailina, H. & Emilia, Z. A. (2018). The Association of Reported Respiratory Symptoms among Children in Malaysia with Particulate Matter Exposure in Municipal Solid Waste Landfills. *Malaysian Journal of Medicine and Health Sciences, 2(11)*. 1 – 11.

Eleonor, B.B., Omnia, R.A. & Thanaa, R. (2011). Heavy Metals and Trace Elements in Hair and Urine of A Sample of Arab Children with Autistic Spectrum Disorder. *A Journal of Clinical Medicine, 6(4).* 247-257.

Elvir, B., Zehra, S., Alisa, B., Milan, S. & Miodrag, J. (2014). Qualitative Characteristics of Bauxite Ostrelj, Near Bosanka Krupa. *Archives for Technical Science, 10(1)*, 1 - 8.

Environmental and Protection Agency (EPA). (1984). Bauxite Mining in The Jarrah Forrest. Steering Committee for Research on Land Use and Water Supply.

Environmental and Protection Agency (EPA). (2007). Mining and Extractive Industries. Protocal for Environmental Management, State Environment Protection Policy (Air Quality Management).

Environmental and Protection Agency (EPA). (2010). Air Pollution and Children's Respiratory Health.

Environmental and Protection Agency (EPA). (2016). Aquatic Life Ambient Water Quality Criteria Update for Cadmium.

Esther, A., Yan, L., Jiali, y. & Chunhui, N. (2017). Occupational Respiratory Diseases of Miners from Two Gold Mines in Ghana. *International Journal of Environmental Research and Public Health, 14(337*). 1 – 14.

Evrenoglou, L., Partsinevelou, A.S. & Nicolopoulou-Stamati, P. (2017). Correlation between Concentrations of Heavy Metals in Children's Scalp Hair and The Environment. A Case Study from Kifissos River in Attica, Greece. *Global NEST Journal, 19(4).* 592 – 600.

Fabiana, S.S.D.A., Renato, C.T., Diego, A.A., Thayrine, R.B., Fabianne, J.D.S. & Rafael, V.C. (2017). Lung Function and Functional Capacity in School Age Children. *Fisioteraphy Movement, 30 (1).* 77 – 84. doi: 10.1590/1980-5918.030.001.A008.

Farida, E.B.M., Eman, A.Z., Adel, B. E.S., Reham, M.E., Sally, S.Z., Waleed, S. E., Walaa, Y.Y., Rania, A.K.& Azza, M.Y. (2015). Assessment of Hair Aluminium, Lead, and Mercury in A Sample of Autistic Egyptian Children: Environmental Risk Factors of Heavy Metals in Autism. *Behavioural Neurology*. doi: 10.1155/2015/545674.

Feng, W., Huang, X., Zhang, C., Liu, C., Cui, X., Zhou, Y., Sun, H., Qiu, G., Guo, H., He, M., Zhang, X., Yuan, J., Chen, W. & Wu, T. (2015). The Dose-Response Association of Urinary Metals with Altered Pulmonary Function and Risks of Restrictive and Obstructive Lung Diseases: A Population-Based Study in China. *BMJ Open*, *5(5).*

Flynn, E., Matz, P., Woolf, A. & Wright, R. (2000). Indoor Air Pollutants Affecting Child Health.

Francess, D.A. & Nachinaab, J.O. (2018). The Effects of Illegal Gold Mining on The Education of Children: A Case Study of Aniamoah Community in the Atwima Mponua District, Ashante Region-Ghana. *International Journal of Innovative Research and Advanced Studies (IJRAS), 5(2).* 66-72.

Gfycat. (2018). A Child's Guide to Hospital: Spirometry – Lung Function. *https://gfycat.com/gloriousinfantileleafhopper*

Ghose, M.K. & Majee, S.R. (2001). Air Pollution due to Opencast Coal Mining and It's Control in Indian Context. *Journal of Scientific & Industrial Research, 60*. 786-797.

Gilio, A.D., Farella, G., Marzocca, A., Giua, R., Assennato, G., Tutino, M. & Gennaro, G.D. (2017). Indoor / Outdoor Air Quality Assessment at School Near the Steel Plant in Taranto (Italy). *Hindawi Advance in Meteorology.*

Giuseppe, G., Alessia, C., Graziantonio, L., Maria, S.S. & Alessia, C. (2020). Nickel: Human Health and Environmental Toxicology. *International Journal of Environmental Research and Public Health. 17(679).*

Godwill, A.E., Paschaline, U.F., Friday, N.N. & Marian, N.U. (2019). Mechanism and Health Effects of Heavy Metal Toxicity in Humans. *Intechopen. 82511.*

Gordana, O., Dragica, L., Branko, S., Jelena, P.S., Slavica, S., Dragana, K. & Dragana, B. (2014). Chemical-Mineralogical Characterization of Bauxite from Different Deposits.

Guha, M. (2000). Diagnosis and Treatment of Chronic Arsenic Poisoning.

Guina, Z., Xijin, X., Bin, L., Kusheng, W., Taofeek, A.Y. & Xia, H. (2013). Association Between Lung Function in School Children and Exposure to Three Transition Metals From an E-Waste Recycling Area. *Journal of Exposure Science and Environmental Epidemiology, 23.* 67 – 72.

Habashi, F. (1995). Bayer's Process for Alumina Production: A Historical Perspective.

Habiba, A.B., Kipchu, T. & Mir, M. (2015). Estimation of arsenic in Nail using Silver Diethyldithiocarbamate Method. *Bangladesh Journal of Pharmacology, 10.* 513-517.

Hao, X., Leung, K., Wang, R., Sun, W. & Li, Y. (2010). The Geomicrobiology of Bauxite Deposits. *Geosicience Frontiers, 1.* 81 - 89.

Hair Tissue Mineral Analysis, (HTMA). (2018). Instructions: How To Cut A Hair Sample. *htmaexperts.com/instructions-how-to-cut-a-hair-sample/*

Ines, P., Joao, C.R., Diana, S., Carla, M., Francisca, M., Tiago, R., Ana, R., Joana, M., Luis, D., Eduardo, D.O.F., Patricia, P., Pedro, M., Milton, S.,

Maria, F.P., Joao, P.T., Henrique, B., Lasse, R., Tari, H. & Andre, M. (2019). School Environment Associates with Lung Function and Autonomic Nervous System Activity in Children: A Cross-Sectional Study. Scientific Reports. *Nature Research*.

Irena, B., Samuel, K. & Alvaro, R.O.V. (2006). The Effects of Air Pollution on The Health of Children. *Paediatric Children Health, 11(8).*

Iqhlima, N., Haryati, A., Ramadhansyah, P.J. & Mohamad Idris, A. (2019). A Comparative Study of Kuantan Bauxite Mineralogy as Potential Material in Civil Engineering. *IOP Conference Series: Earth and Environmental Science, 244.*

Janaina, C.S., Rafaela, C.M., Camila, I.S.S. (2017). Spirometry in SchoolChildren for Fields Studies: Does Testing on Different Days Change the Result of the Exam? *Revista Paulidta de Pediatria, 36(1).* 25-30.

Jane, K., Vassiliki, B., Sooky, L., Angie, W. & Janet, S. (2016). Natural Variability of Lung Function in young Health School Children. *Paediatric Pulmonology and Lung Function, 48.* 411-419.

John, A.M.M., Zainab, S.K. & Kessy, F.K. (2018). Levels of Heavy Metals in Urine Samples of School Children from Selected Industrial and Non-Industrial Areas in Dar es Salaam, Tanzania. *African Health Sciences, 18(4).* 1226-1235.

Joyce, S.T., Michael, R.G., Vanessa, P. & Ellen, T.C. (2015). Low-level Arsenic Exposure and Developmental Neurotoxicity in Children: A Systematic Review and Risk Assessment. *Toxicology*, *337*. 91-107.

Kangmo, A. (2014). The Role of Air Pollutants in Atopic Dermatitis. *Clinical Reviews in Allergy and Immunology, 134 (5).* 993 – 999.

Karla, Y., Stephanie, M.M., Sergio, A.A.O. & Jose, K. (2015). Exposure to Fine Particles by Mine Tailing and Lung Function Effects in A Panel of Schoolchildren, Chanaral, Chile. *Journal of Environmental Protection, 6.*

Klender, S.J. (2014). Evaluation of Airborne Particles at a Local High School. *Journal of Environmental Protection, 6.* 118 – 128. doi: 10.4236/jep.2015.62014

Kloprogge, J.T., Ruan, H.D. & Frost, R.L. (2002). Thermal Decomposition of Bauxite Minerals: Infrared Emission Spectroscopy of Gibbsite, Boehmite and Diaspore.

Krejpdo, Z., Olejnik, D., Wojciak, R.W. & Gawecki, J. (1999). Comparison of Trace Elements in The Hair of Children Inhabiting Areas of Different Environmental Pollution Types. *Polish Journal of Environmental Studies, 8(4)*. 227 – 229.

Krewski, D., Yokel, R.A., Nieboer, E., Borchelt, D., Cohen, J., Harry, J., Kacew, S., Lindsay, J., Mahfouz, A.M. & Rondeau, V. (2007). Human Health Risk Assessment for Aluminium, Aluminium Oxide and Aluminium Hydroxide. *National Institutes of Health*.

Kuan-Wen, S., Chih-Yung, C., Ming-Han, T., Sui-Lin, L., Li-Chen, C., Man-Chin, H., Tsung-Chieh, Y., Jing-Long, H. & Kuo-Wei, Y. (2019). Asymptomatic Toddlers with House Dust Mite Sensitization at Risk of Asthma and Abnormal Lung Functions at Age & Years. *World Allergy Organization Journal*, *12*. 1 – 8.

Lad, R.J. & Samant, J.S. (2015) Impact of Bauxite Mining on Soil: A Case Study of Bauxite Mines at Udgiri, Dist-Kolhapur, Maharashtra State, India. *International Research Journal of Environmental Sciences, 4(2)*. 77 - 83.

Laura, A.R.V., Henry, C.O. & Juan, J.R.S. (2012). The Effects of Air Pollution on Respiratory Health in Susceptible Populations: A Multilevel Study in Bucaramanga, Colombia. *28(4).* 749 – 757.

Lauryn, M.F., Aaron, E., Rebecca, S., Michael, K., Lori, B., Vamsi, K., Lauren, B., Aleksandr, B.S., Michael, L.K., James, M.A. & Patti, C.Z.E. (2018). Pulmonary Toxicity and Lung Tumorigenic Potential of Surrogate Metal Oxides in Gas Metal Arc Welding-Stainless Steel Fume: Iron as A Primary Mediator Versus Chromium and Nickel. *PLOS ONE. 10(1371).*

Lee, K.Y., Ho, L.Y., Tham, Y.y>, Ling, S.P., Qureshi, A.M., Ponnudurai, T. & Nordin, R. (2017). Environmental and Occupational Health Impact of Bauxite Mining in Malaysia: A Review. *16(2).* 137 – 150.

Lemeshow, S., Hosmer, D.W., Klar, J. & Lwanga, S. (1990). Adequacy of Sample Size in Health Studies. *World Health Organization.*

Liu, X., Wang, Q., Zhang, Q., Feng, Y. & Cai, S. (2012). Mineralogical Characteristic of The Superlarge Quaternary Bauxite Depositis in Jingxi and Debao Countries, Western Guangxi, China. *Journal of Asian Earth Sciences, 52*. 53 - 62.

Lung Foundation Australia. (2017). Lung Function Tests. *www.lungfoundation.com.au*.

Lyudmila, V.V., Elena, E.M., Tatyana, I.V., Tatyana, A.G. & Kirill, S.G. (2017). Impact of Atmospheric Microparticles and Heavy Metals on External Respiration of Urbanized Territory Population. *Russian Open Medical Journal; Hygiene and Environmental Health, 6(4).*

Mao, J.C., Liu, X.Y., Chen, B., Luo, F.M., Wu, X.D., Jiang, D.H. & Luo, Z.G. (2017). Determination of Heavy Metals in Soil by Inductively Coupled

Plasma Mass Spectrometry (ICP-MS) with Internal Standard Method. *Electronics Science Technology and Application, 4(1).* 23-31.

Marlowe, M. (1988). Hair Element Content of Native American Indian Children. *Journal of Orthomolecular Medicine, 3(1).*

Maryam, Z., Hazrin, A.H., Hizrri, A., Norhidayah, A., Samsuddin, N. & Mohd Shukri, M.A. (2018). Association of Particulate Matter (PM) with Respiratory Symptoms among Children in Selected Primary Schools in Pahang. *Journal Clean WAS, 2(1).* 11 – 15.

Matilda, R., Eugene, M. & Simon, M. (2018). Respiratory Impairment and Personal Dust Exposure among the Underground and Open Cast Gold Miners in Tanzania. *Annals of Global Health, 84(3).* 419 – 428.

Michael, T.K. (2000). The Health Effects of Air Pollution on Children. South Coast Air Quality Management District.

Michael. (2010). Bauxite Mining. Contents of Factory Gate To Factory Gate Life Cycle Inventory Summary.

Miller, M.R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., Crapo, R., Enright, P., Grinten, C.P.M., Gustafsson, P., Jensen, R., Johnson, D.C., Macintyre, N., Mckay, R., Navajas, D., Pedersen, O.F., Pellegrino, R., Viegi, G. & Wanger, J. (2005). Standardisation of Spirometry. *Environmental Respiratory Journal, 26.* 319 - 338.

Miller, M.R., Crapo, R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., Crapo, R., Enright, P., Grinten, C.P.M., Gustafsson, P., Jensen, R., Johnson, D.C., Macintyre, N., Mckay, R., Navajas, D., Pedersen, O.F., Pellegrino, R., Viegi, G. & Wanger, J. (2005). General Considerations for Lung Function Testing. *Environmental Respiratory Journal, 26*. 153 - 161.

Mireia, E.M., Pere, M., Juan, I.M., Xavier, G. & Joan, R. (2018). A Study on Air Quality and Heavy Metals Content of Urban Food Produced in A Mediterranean City (Barcelona). *Journal of Cleaner Production, 195.* 385-395.

Miranda, M.L., Anastasia, S., Nathan, L., Walter, K., Melissa, C., Sarah, T.W., Zhenqiang, L. & Paloma, I.B. (2016). Multimedia Exposures to Arsenic and Lead for Children Near Inactive Mine Tailings and Smelter Site. *Environmental Research, 146*. 331 – 339.

Mohamed, N.R. & Farouk, H. (2007). Heavy Metals in Fingernails and Scalp Hair of Children, Adults and Workers from Environmentally Exposed Areas at Aswan, Egypt. *Environmental Bioindicators, 2(3).* 131 – 145.

Mozhgon, R., Alllson, K.Y., Rachel, N.L., Ellsha, P.R., Thomas, G.R. & Nlladri, B. (2017). Pulmonary Function and Respiratory Health of rural Farmers

and Artisanal and Smale Scale Gold Miners in Ghana. *Environmental Research, 158.* 522-530.

Muhammad Hafizz, M. (2016). Perceptions of Residents in Felda Bukit Goh, Kuantan on the Environmental Impact of Bauxite Mining.

Muhammad, W.A. (2012). Levels of Heavy Metals in Popular Cigarette Brands and Exposure to These Metals via Smoking. *The Scientific World Journal, 2012(729430)*. 1 - 5.

National Health and Nutrition Examination Survey (NHANES). (2008). Respiratory Health ENO Procedures Manual.

National Institute for Health and Care Excellence (NICE). (2014). Measuring Fractional Exhaled Nitric Oxide Concentration in Asthma: NIO, MINO, NIOX VERO and NObreath. *NICE Diagnostics Guidance 12.*

Nomsa, D.L.T., Jacobus, C.E., Caradee. Y.W. & Maria, A.O. (2014). Human Health Risks Posed by Exposure to PM_{10} for Four Life Stages in A Low Socio-Economic Community in South Africa. *Pan African Medical Journal*. 1 – 12.

Noor, H.A., Norlen, M., Lokman, H.S., Thahirahtul, A.Z. & Daud, A.R. (2016). Potential Helath Impacts of Bauxite Mining in Kuantan. Malaysia *Journal Medical Science, May – Jun. 23(3)*. 1 – 8.

Nor Wahidatul A.Z.N., Syakirah, A.M., Saffaatul, H.IS. & Wan Amiza, A.W.A. (2012). Assessment of Heavy Metal in Soil due to Human Activties in Kangar, Perlis, Malaysia. *International Journal of Civil & Environmental Engineering, 12(6).* 28-33.

Nur Azwani, M.N.R., Juliana, J. & Poh, C.C. (2015). Indoor Air Quality and Respiratory Health among Malay Preschool Children in Selangor. *Hindawi Biomed Research International.*

Nurul Amalina, S. (2017). Impacts Assessment of Bauxite Mining Activities on Human and Environment in Bukit Goh.

Nurul Hidayah, H., Zailina, H., Jamal Hisham, H., Norazura, I. & Junaidah, Z. (2016). Psychosocial and Health Impacts of Bauxite Mining among Felda Bukit Goh Communities in Kuantan, Malaysia. *International Journal of Public Health and Clinical Sciences (IJPHCS). 3(5).* 174-189.

Niharranjan, M. & Nabanita, D. (2017). Coal Mining and Local Environment: A Study in Talcher Coalfield of India. *Air, Soil and Water Research. 10*. 1 – 12.

NIOSH. (1998). Particulates Not Otherwise Regulated, Respirable 0600. *NIOSH Manuak of Analytical Methods (NMAM), Fourth Edition.*

O'Connor, B.H., Dononghue, M., Manning, T.J.H. & Chesson, J.J. (2013). Radiological Assessment for Bauxite Mining and Alumina Refining.

Ohlander, j., Huber, s.M., Schomaker, M., Heumann, c., Schierl, R., Michalke, B., Jenni, O.G., Caflisch, J., Moraga, D., Ehrenstein, O.S. & Radon, K. (2013). Risk Factors for Mercury Ecposure of Children in a Rural Mining town in Northern Chile. *PLOSONE.*

Olowoyo, J.O., Mugivhisa, L.L. & Magoloi, Z.G. (2016). Composition of Trace Metals in Dust Samples Collected from Selected High Schools in Pretoria, South Africa. *Applied and Environmental Soil Science*. 1 – 9.

Patricia, A.P. (2000). Bauxite and Alumina. U.S. Geological Survey Minerals Yearbook.

Parvez, F., Chen, Y., Yunus, M., Olopade, C., Segers, S., Slavkovich, V., Argos, M., Hasan, R., Ahmed, A., Islam, T., Akter, M.M., Graziano, J.H.& Ahsan H. Arsenic Exposure and Impaired Lung Function. Findings From A Large Population-Based Prospective Cohort Study. *American Journal Respiratory Critical Care Medicine, 188(7*). 813– 819.

Pellegrino, R., Viegi, G., Brusasco, V., Crapo, R.O., Burgos, F., Casaburi, R., Coates, A., Grinten, C.P.M., Gustafsson, P., Hankinson, J., Jensen, R., Johnson, D.C., Macintyre, N., Mckay, R., Miller, M.R., Navajas, D., Pedersen, O.F. & Wanger, J. (2005). *Interpretative Strategies for Lung Function Tests. Europe Respiratory Journal, 26*. 948 - 968.

Pereira, R., Ribeiro, R. & Goncalves, F. (2004). Scalp Hair Analysis as A Tool in Assessing Human Exposure To Heavy Metals (S. Domingos Mine, Portugal). *Science of Total Environment*, *327*. 81 – 92.

Penradee, C., Seiichiro, H. & Suthipong, S. (2015). Arsenic and Other Metals Presences in Biomarkers of Cambodians in Arsenic Contaminated Areas. *International Journal of Environmental Research and Public Health*, *12*. 14285 -14300.

Pozebon, d., Scheffler, G.L. & Dressler, V.L. (2017). Elemental Hair Analysis: A Review of Procedures and Applications. *Analytica Chimica Acta.* 1-23.

Rachel, G., Jinming, Z., Shona, C.F., Marc, G.W., David, C.C. & Jennifer, M.C. (2015). Toenail Metal Concentration as A Biomarker of Occupational Welding Fume Exposure. *Journal of Occupational and Environmental Hygiene, 11(6).* 397 – 405.

Radomir, S., Cynthia, R.R., Rovnaghi, & Kanwaijeet, J.S. (2015). Methodological Considerations for Hair Cortisol Measurements in Children. *The Drug Monitoring, 37(6).* 812 – 820.

Raed, A.D., Peter, B.B., Serpil, C.E., Charles, G.I., Margaret, W.L., Jon, O.L., Olin, A.C., Alan, L.P. & Taylor, D.R. (2011). An Official ATS Clinical Practice Guideline: Interpretation of Echaled Nitric Oxide Levels (FENO)

for Clinical Applications. *American Thoracic Society Documents, 184.* 602 - 615.

Rahman, H. (2011) Malaysia's Economic Census 2011 and The Strengthening of The Business Register.

Ranjana, C., Sathwara, N.G., Shivgotra, V.K., Shruti, P., Rathod, R.A., Shagufta, S., Idrish Shaikh, M., Shaswar D., Parikh, D.J. & Saiyed, H.N. (2010). Study of Lead Exposure to Children Residing Near A Lead-Zinc Mine. *Indian Journal of Occupational and Environmental Medicine, 14(2).* 58 – 62.

Rajah, S.S. (1986) Bauxite in The Kuantan Area, Peninsular Malaysia. *Geological Society Malaysia Bulletin, 19.* 315 - 325.

Rashed, M.N. & Hossam. F. (2007). Heavy Metals in Fingernails and Scalp Hair of Children, Adults and Workers from Environmentally Exposed Areas at Aswan, Egypt. *Environmental Bioindicators, 2.* 131-145.

Rashid, M.H., Fardous, Z., Chowdhury, M.A.Z., Alam, M.K., Bari, M.L., Moniruzzaman, M. & Siew, H.G. (2016). Determination of Heavy Metals in the Soils of Tea Plantations and in Fresh and Processed Tea Leaves: An Evaluation of six Digestion Methods. *Chemistry Central Journal, 10(7).*

Ratnaike, R.N. (2003). Acute and Chronic Arsenic Toxicity. *Postgrad Medical Journal.* 391 – 396.

Recio-Vega, R., Gonzalez-Cortes, T., Olivas-Calderon, E., Lantz, R.C., Gandolfi, A.J. & Alba, C.G. (2014). In Utero and Early Childhood Exposure to Arsenic Decreases Lung Function in Children. *Journal of Applied Toxicology.*

Rejoice, P.M. (2013). Land Degradation Due to Mining: The Gunda Scenario. *International Journal of Geography and Geology, 2(12)*. 144 - 158.

Richard, F.P., Dean, A.B., Rob, G., Mishelle, C., William, M., Karen, U., Mary, E.D. David, Q. (1998). Preparation of Hair for Measurement of Elements by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). *Biological Trace Element Research*.

Ritta D.C.C.O.B., Jose, C.B.J., Fabricio, B.O., Marisa, A.B., Paulo, R.V.O. (2016). Evaluation of Pulmonary Function and Respiratory Symptoms in Pyrochlore Mine Workers. *Journal Bras Pneumology (JBP), 42(4).* 279 – 285.

Romilda, Z.B., Nel. R. & Paul, T.J.S. (2017). Human Biological Monitoring of Mercury for Exposure Assessment. *AIMS Environmental Science, 4(2).* 251 – 276.

Ronald, H., Katja, R., Ondine, S.V.E., Stella, C., Daniel, M.M. & Ursula, B. (2016). Proximity to Mining Industry and Respiratory Disease in Children in A Community in Northern Chile: A Cross-Sectional Study. *Environmental Health, 15(66).*

Safrudin, T., Moh, R.N., Inne, A.G., James, S., Soedjajadi, K., I Ketut, S., Ririh, Y., Mukono & Azizah, R. (2014). Effect Inhaling of Limestone Dust Exposure on Increased Level of IL- 8 Serum and Pulmonary Function Decline to Workers of Limestone Mining Indsutry. *International Refereed Journal of Engineering and Science (IRJES), 3(8)*. 66 – 72.

Sahu, H.B. & Dash, S. (2011). Land Degradation due to Mining in India and Its Mitigation Measures. *Second International Conference on Environmental Science and Technology*.

Sanna, E., Vargiu, L., Rosetti, I., Vallascas, E. & Floris, G. (2007). Correlation between blood and hair levels in boys and girls of Sardinia (Italy). *Journal of Anthropological Sciences*. 173 - 181.

Sarosh, R.K. (2015) Carribbean Economic Alchemy. Has Magic Returned to Bauxite? Inter-American Development Bank, No. IDB-PB-238.

Saulo, R. P., Ronaldo, L.C., Roberto, C.V., Zuleica, C.C., Allegra, V.Y., Bernhard, P., Debora, M.P., Flavia, M.F. & Luiz, R. (2004). Environmental and Health Assessment in Two Small-Scale Gold Mining Areas – Indonesia Final Report Sulawesi and Kalimantan.

Sensidyne, 2019. Gilian Personal Air Sampling Pumps and Area Air Sampling Pumps. *Retrieved from: https://www.sensidyne.com/air-sampling-equipment/gilian-air-sampling-pumps/*

Shuhui, W., Hong, Z. & Shasha, T. (2019). A Review of Arsenic Exposure and Lung Cancer. *Toxicology Research, 3.* 319-327.

Singer, F., Luchsinger, I., Inci, D., Knauer, N., Latzin, P., Wildhaber, J.H. & Moeller, a. (2013). Exhaled Nitric Oxide in Symptomatic Children at Preschool Age Predicts Later Asthma. *European of Allergy and Clinical Immunology, 68*. 531-538.

Smith, A.H., Yunus, M., Khan, A.F., Ercumen, A., Yuan, Y., Smith, M.H., Liaw, J., Balmes, J., Von Ehrenstein, O., Raqib, R., Kalman, D., Alam, D.S, Streatfield, P.K. & Steinmaus, C. (2013). Chronic Respiratory Symptoms in Children Following in Utero and Early Life Exposure to Arsenic in Drinking Water in Bangladesh. *International Journal of Epidemiology, 42(4).* 1077 – 1086.

Subhabrata, M., Jayashree, G., Janatul, F., Arghya, B., Monojit, M., Jayanta, K.B., Subhashis, S., Soumya, B. & Saibal, M. (2018). Exposure to Heavy Metals Alters the Surface Topology of Alveolar Macrophages and Induces Respiratory Dysfunction among Indian Metal Arc-Welders. *Toxicology and Industrial Health, 34(12).* 908-921.

Society for Miniig, Metallurgy & Exploration (SME). (2015). The Role of Arsenic in The Mining Industry.

Sooky, L., Vassiliki, B., Samatha, S., Angie, W., Tim, J.C., Seeromanie, H., Jonathan, C.K.W., Chris, G., Philip, T., Rachel, B., Jane, K., Simon, L., Emma, R., Sarah, L., Dave, S., Philippa, C., Colin, F. & Janet, S. (2015). Lung function in Children in Relation to Ethnicity, Physique and Socioeconomic Factors. *European Respiratory Journal, 46.* 1662-1671.

Susana, P., EvaTrinidad, G., Africa, M. & Manuel, M.J. (2019). The Relationship between Indoor and Outdoor Levels of PM_{10} and Its Chemical Composition at Schools in Coastal Region in Spain. *Elsevier*. doi: 10.1016/j.heliyon.2019.e02270.

Sutar, H., Mishra, S.C., Sahoo, S.K., Chakraverty, A.P. & Maharana, H.S. (2015). Progress of Red Mud Utilization : An Overview. *American Chemical Science Journal, 4(3)*. 255-279.

Sutar, S. (2015). Review Paper on Bauxite Residue Characteristics, Disposal and Utilization. *International Journal of Innovation in Engineering Research and Technology.* 2394 - 3696.

Suzan, O. (2008). Emerging Issues Paper: Mine Water Population. ISBN No: 978-0-9814178-5-1.

Szynkowska, M.I., Pawlaczyk, A., Wojciechowska, E., Sypniewski, S. & Paryjczak, T. (2009). Human Hair as a Biomarker in Assessing Exposure to Toxic Metals.

Tanja, P.M., Denise, H., Andrew, K., Ian, S., John, M., Jan, B. & Ross, D. (2000). Living Near Opencast Coal Mining Sites and Children's Respiratory Health. *Occupational Environmental Medicine, 57*. 145 – 151.

The Malaysian Insider. (2016). Bauxite Mining Moratorium Could Land Malaysia in Trouble Under TPP, Says Law Professor. https://isds.bilaterals.org/?bauxite-mining-moratorium-could

Thomas, J., Cheryl, R.S. & Donald, R.S. (2018). Determinants of Hair Manganese, Lead, Cadmium and Arsenic Levels in Environmentally Exposed Children. *Toxics, 6(19).* 1-15.

Thomas, M., Thomas, E., PAtrik, S. & Linda, W. (2017). The Local Employment Impacts of Mining: An Econometric of Job Multipliers in Northern Sweden. *Miner Economy Journal, 30.* 53 – 65.

Tong, S., Schimding, Y.E. & Prapamontol, T. (2000). Environmental Lead Exposure: A Public Health Problem of Global Dimensions. *Bulletion of the World Health Organization, 78 (9).*

Tse, P.K. (2015) The Mineral Industry of Malaysia.USGS 2013 Minerals Yearbook Malaysia (Advance Release).

United Nations Conference on Trade and Development (UNCTAD). (1995). Environmental Aspects of Bauxite, Alumina and Aluminium Production in Brazil.

United States Environmental Protection Agency (USEPA). (2016) Health Effects of Exposures to Mercury.

Veronica, Ngure., Noah, S., Silvanus, S., Gelas, S., Geoffrey, K. & Festus, K. (2013). Health Implications of Heavy Metals in Soil, Scalp Hair and Selected Food Crops Within Eldoret Municipality, Kenya. *Journal of Environmental Science, Toxicology and Food Technology, 7(3).* 47 – 55.

Vhahangwele, M. & Khatutshelo, L.M. (2018). Environmental Contamination by Heavy Metals. *Intechopen.* doi: 10.5772/intechopen.76082.

Vicky, Y., Margit, J., Audris, C & Natasha, A.M. (2018). Alopecia and Associated Toxic Agents: A Systematic Review. *Skin Appendage Disorders, 4.* 245 – 260.

Villines, Z. (2019). "What are the best ways to cut an ingrown toenail?". *Medical News Today*. Retrieved from:https://www.medicalnewstoday.com/articles/326025.php.

Viney, P.A., Aaron, I. & Peter, M. (2012). Characterization of Particulate Matter (PM10) Related to Surface Coal Mining Operations in Appalachia. *Atmospheric Environment, 54.* 496 - 501.

Vladimir, S. & Robert, E.M. (2006). Environmental Occurrence and Impacts of Arsenic at Gold Mining Sites in the Western United States. Mine Water and the Environment.

Vusumuzi, N., Janine, W. & Kuku, V. (2014). Mine Dumps, Wheeze, Asthma and Rhinoconjuctivitis among Adolescents in South Africa: any Association?. *International Journal of Environmental Health Research, 25(6).* 583 – 600.

Vusumuzi, N., Janine, W. & Kuku, V. (2017). Indoor and Outdoor PM_{10} Levels at Schools Located Near Mine Dumps in Gauteng and North West Province, South Africa. *BMC Public Health, 17(42).*

Walton, J.R. (2006). A Longitudinal Study of Rats Chronically Exposed To Aluminium at Human Dietary Levels.

Wang, Y., Xing, S., Zhang, Y., Zhang, Z., Ma, Y., Du, X. & Wang, X. (2014). Characteristics of Disseminated Diaspore in the Longzhou Bauxite Deposit, Guangxi Province, China. *88.* 1485 - 1486.

Wan Zuhairi, .W.Y., Abdul Rahim, S. & Esmail, A. (2009). Risk Assessment at Abandoned Tin Mine in Sungai Lembing, Pahang, Malaysia. *EJGE, 14.*

Wen, W., Tao, Y., Pubu, C. & Peng, J. (2015). Assessment of Human Health Impact from PM_{10} Exposure in China based on Satellite Observations. *Journal of applied Remote Sensing, 9(096027)*. 1 - 14.

Wenhao, W., Rui, M., Ziyong, S., Aiguo, Z., Jianwei, B., Xiang, L. & Yunde, L. (2018). Effects of Mining Activities on The Release of Heavy Metals (HMs) in A Typical Mountain Headwater Region, The Qinghai-Tibet Plateau in China. *International Journal of Environmental Research and Public Health, 15(1987).* 1 – 19.

Wheeler, A.J., Chen, L., MacNeill, M., Villeneuve, P.J., Van Ryswyk, K., Xu, X., You, H., Kulka, R., Brook, J.R., Rasmussen, P. & Dales, R. (2008). Personal Air Pollution Monitoring and Lung Health of Asthmatic Children Living in Windsor, Ontario. *Epidemiology, 19(1345).* 275 – 276.

World Aluminium. (2014). Bauxite Residue Management: Best Practice. European Aluminium Association.

World Health Organization (WHO). (2005). Re-defining 'Health'.

World Health Organization. (2007). Health Risks of Heavy Metals from Long-Range Transboundary Air Pollution.

World Health Organization (WHO). (2009). *Levels of Lead in Children's Blood. European Environment and He alth Information System.*

World Health Organization (WHO). (2010). *Exposure to Arsenic: A Major Public Health Concern.*

World Health Organization. (2010). *Air Quality Guidelines: Second Edition*.

World Health Organization. (2013). *Health Effects of Particulate Matter: Policy Implications for Countries in Eastern Europe, Caucasus and Central Asia.*

Wu, C.S. & Liu,D.Y. (2012). Mineral Phase and Physical Properties of Red Mud Calcined at Different Temperatures. Journal of Nanomaterials.

Ying-ju, L., Zhi-kang, W., Fan-xin, Q., Zhi-qing, F., Xin-li, L. & Gang, L. (2018). Potentially Toxic Elements and Health Risk Assessment in Farmland Around High-Concentrated Arsenic Coal Mining in Xingren, China. *Hindawi Journal of Chemistry, 2198176.* doi: 10.1155/2018/2198176.

Yixian, C., Xiaosan, J., Yong, W. & Dafang, Z. (2018). Spatial Characteristics of Heavy Metal Pollution and The Potential Ecological Risk of A Typical Mining Area: A Case Study in China. *Elsevier, Process Safety and Environmental Protection, 113.* 204 – 219.

Yu, F., Tingping, Z., Mengtong, L., Jieyi, H. & Ruixue, H. (2017). Heavy Metal Contamination in Soil and Brown Rice and Human Health Risk

Assessment Near Three Mining Areas in Central China. *Hindawi Journal of Healthcare Engineering, 4124302*. doi: 10.1155/2017/4124302.

Zahari, M.A.F., Ismail, S.A. & Arumugam, U. (2019). Kajian Rentas Pendedahan Partikel Terampai (PM_{10}) Terhadap Fungsi Keupayaan Paru-Paru dan Simptom Masalah Respiratori Dalam Kalangan Pelajar Sekolah di Bukit Mertajam, Pulau Pinang. *MAEH Journal of Environmental Health.*