



**CONTAMINATION AND ASSESSMENTS OF
HEAVY METALS IN THE SOIL OF MUNICIPAL
WASTE FROM BACHOK, TUMPAT AND TANAH
MERAH DUMPSITES IN KELANTAN**

by

AYUNI NAZIHAN BINTI MOHD YA AINON

A report submitted in fulfilment of the requirements for the degree of
Bachelor of Applied Science (Sustainable Science) with Honours

**FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN**

2024

DECLARATION

I declare that this thesis entitled “Contamination and Assessments of Heavy Metals in The Soil of Municipal Waste from Bachok, Tumpat and Tanah Merah Dumpsites in Kelantan” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : AYUNI NAZIHAH BINTI MOHD YA AINON

Date : 29/02/2024

UNIVERSITI
MALAYSIA
KELANTAN

ACKNOWLEDGEMENT

At the very beginning I would like to express my deepest gratitude to Almighty Allah for giving me the strength and the composure to complete this thesis within the scheduled time. During the period of my research, I have received generous help from many quarters, which I like to put on record here with deep gratitude and great pleasure.

First and foremost, I would like to express my appreciation to my supervisor, Ms. Nor Sayzwani binti Sukri for her guidance and constant support to complete my thesis with her patience and knowledge. Without her kind direction and proper guidance this thesis would have been a little success.

Not to forget, a massive thank you to the lecturers and lab assistants of the Faculty of Earth Science who were willing to share their knowledge, Encik Rohanif, Encik Firdaus, Puan Nur Syahida, and Puan Nur Izzati for the help in assisting with the laboratory appliances during the experiments have been conducted. A big thanks also to Majlis Perbandaran Kota Bharu, Majlis Daerah Tumpat, Majlis Daerah Tanah Merah, and Kelantan Utilities Mubaarakan for giving me permission to conduct my research at the dumpsites. I am pleased for giving me the dumpsite data required and helping me to complete my research which subsequently led to the completion of my thesis.

Last but not least, my deepest gratitude to my beloved father Mr. Mohd Ya Ainon bin Jusoh, my beloved mother Mrs. Anisah binti Zakaria and to my dearest siblings for their prayer and encouragement. Special thanks also to all my lovely friends Amiza, Annisa, Fazlin, Suhana, Nurin, Adila, Fatin, and Sarah for their support and help especially at times when things were going tough. Also do not forget to those who indirectly contributed in this research, your kindness means a lot for me. Thank you very much.

Contamination and Assessments of Heavy Metals in The Soil of Municipal Waste from Bachok, Tumpat and Tanah Merah Dumpsites in Kelantan

ABSTRACT

Heavy metals contamination was one of the most important environmental issues and the dumping of municipal waste at the dumpsites led to the contamination. Hence this study concentrated at three dumpsites in Kelantan, which were Tapak Pelupusan Beris Lalang (Bachok), Tapak Pelupusan Kok Bedollah (Tumpat), and Tapak Pelupusan Bukit Che Ros (Tanah Merah). The aims of this study were to determine the concentration of selected heavy metals, to examine the quality of soil using soil assessments, and to examine possible human risk from exposure to heavy metals in soil. A total of nine soil samples were collected at the dumpsites. All soil samples were goes through laboratory analysis and were analysed using Atomic Absorption Spectroscopy (AAS). Besides that, I_{geo} , PLI, and health risk were calculated. This study revealed the mean concentration of heavy metals in soil at Tapak Pelupusan Beris Lalang as following order, Cu (16.00 mgkg^{-1}) > Cr (11.87 mgkg^{-1}) > Zn (10.54 mgkg^{-1}) > Mn (6.69 mgkg^{-1}) > Pb (5.72 mgkg^{-1}), while Tapak Pelupusan Kok Bedollah, Mn (64.86 mgkg^{-1}) > Zn (31.28 mgkg^{-1}) > Cu (18.92 mgkg^{-1}) > Pb (18.59 mgkg^{-1}) > Cr (3.52 mgkg^{-1}) and Tapak Pelupusan Bukit Che Ros, Zn (17.46 mgkg^{-1}) > Cu (13.24 mgkg^{-1}) > Cr (8.60 mgkg^{-1}) > Mn (5.74 mgkg^{-1}) > Pb (4.89 mgkg^{-1}). Meanwhile for soil assessments, the I_{geo} value demonstrated that all the stations were in class 0 except of T2 station for Pb that reached the class 1. This also supported with the PLI value that found none of the three dumpsites categorised as polluted because the PLI values were 0.13 (Tapak Pelupusan Beris Lalang), 0.26 (Tapak Pelupusan Kok Bedollah), and 0.12 (Tapak Pelupusan Bukit Che Ros). Other than that, this study revealed the HQ value from Tapak Pelupusan Beris Lalang and Tapak Pelupusan Bukit Che Ros were in the following order $HQ_{ingestion} > HQ_{dermal} > HQ_{inhalation}$ while from Tapak Pelupusan Kok Bedollah was as followed $HQ_{ingestion} > HQ_{inhalation} > HQ_{dermal}$. According to the findings of this study, if the dumpsite management remains not properly managed, this contamination may continue to have an impact on soil quality in the future. Thus, the data obtained from this study was useful to help authorities managed the dumpsites systematically in order to mitigate environmental risk.

Pencemaran dan Penilaian Logam Berat dalam Tanah Sisa Perbandaran dari Tapak Pelupusan Sampah Bachok, Tumpat dan Tanah Merah di Kelantan

ABSTRAK

Pencemaran logam berat adalah salah satu isu alam sekitar yang paling penting dan pembuangan sisa perbandaran di tapak pelupusan membawa kepada pencemaran. Jadi, kajian ini memfokuskan kepada tiga tapak pelupusan di Kelantan, iaitu Tapak Pelupusan Beris Lalang (Bachok), Tapak Pelupusan Kok Bedollah (Tumpat), dan Tapak Pelupusan Bukit Che Ros (Tanah Merah). Matlamat kajian ini adalah untuk menentukan kepekatan logam berat terpilih, untuk mengkaji kualiti tanah menggunakan penilaian tanah, dan untuk mengkaji kemungkinan risiko manusia terhadap pendedahan kepada logam berat dalam tanah. Sebanyak sembilan sampel tanah telah dikumpul dari tapak pelupusan sampah. Semua sampel tanah telah melalui analisis makmal dan dianalisis menggunakan Spektroskopi Serapan Atom (AAS). Selain itu, I_{geo} , PLI dan risiko kesihatan telah dikira. Kajian ini memdedahkan purata kepekatan logam berat dalam tanah di Tapak Pelupusan Beris Lalang seperti berikut, Cu (16.00 mgkg^{-1}) > Cr (11.87 mgkg^{-1}) > Zn (10.54 mgkg^{-1}) > Mn (6.69 mgkg^{-1}) > Pb (5.72 mgkg^{-1}), manakala Tapak Pelupusan Kok Bedollah, Mn (64.86 mgkg^{-1}) > Zn (31.28 mgkg^{-1}) > Cu (18.92 mgkg^{-1}) > Pb (18.59 mgkg^{-1}) > Cr (3.52 mgkg^{-1}) dan Tapak Pelupusan Bukit Che Ros, Zn (17.46 mgkg^{-1}) > Cu (13.24 mgkg^{-1}) > Cr (8.60 mgkg^{-1}) > Mn (5.74 mgkg^{-1}) > Pb (4.89 mgkg^{-1}). Manakala bagi penilaian tanah, nilai I_{geo} menunjukkan bahawa semua stesen berada dalam kelas 0 kecuali stesen T2 untuk Pb yang mencapai kelas 1. Ini juga disokong dengan nilai PLI yang mendapati tiada satu pun daripada tiga tapak pelupusan dikategorikan sebagai tercemar kerana nilai PLInya ialah 0.13 (Tapak Pelupusan Beris Lalang), 0.26 (Tapak Pelupusan Kok Bedollah), dan 0.12 (Tapak Pelupusan Bukit Che Ros). Selain itu, kajian ini memdedahkan nilai HQ daripada Tapak Pelupusan Beris Lalang dan Tapak Pelupusan Bukit Che Ros berada dalam urutan berikut, $HQ_{ingestion} > HQ_{dermal} > HQ_{inhalation}$ manakala daripada Tapak Pelupusan Kok Bedollah adalah seperti, $HQ_{ingestion} > HQ_{inhalation} > HQ_{dermal}$. Mengikut dapatan kajian ini, jika pengurusan tapak pelupusan kekal tidak diuruskan dengan baik, pencemaran ini mungkin akan terus memberi kesan kepada kualiti tanah pada masa hadapan. Oleh itu, data yang diperoleh daripada kajian ini berguna untuk membantu pihak berkuasa menguruskan tapak pelupusan secara sistematik untuk mengurangkan risiko alam sekitar.

MALAYSIA

KELANTAN

TABLE OF CONTENTS

	PAGE
DECLARATION	i
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
ABSTRAK	iv
TABLE OF CONTENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	ix
LIST OF SYMBOLS	x
CHAPTER 1: INTRODUCTION	
1.1 Background of Study	1
1.2 Problem Statement	3
1.3 Objectives	4
1.4 Scope of Study	4
1.5 Significant of Study	5
CHAPTER 2: LITERATURE REVIEW	
2.1 Municipal Waste	7
2.2 Heavy Metals	8
2.3 Geo-accumulation Index (I_{geo})	11
2.4 Pollution Load Index (PLI)	12
2.5 Health Risk Assessment	14
CHAPTER 3: METHODOLOGY	
3.1 Study Area	15
3.2 Soil Sampling	16

3.3	Acid Digestion and Preparation of Sample	17
3.4	Heavy Metal Analysis	18
3.5	Soil Assessment	19
	3.5.1 Determination of Geo-accumulation Index (I_{geo})	20
	3.5.2 Determination of Pollution Load Index (PLI)	20
3.6	Health Risk Assessment	21
CHAPTER 4: RESULTS AND DISCUSSIONS		
4.1	Concentration of Heavy Metals in Soil from different Dumpsites in Kelantan	24
4.2	Comparison with Previous Studies	29
4.3	Geo-accumulation Index	32
4.4	Pollution Load Index	32
4.5	Health Risk Assessment	33
CHAPTER 5: CONCLUSION AND RECOMMENDATION		
5.1	Conclusion	36
5.2	Recommendation	38
REFERENCES		39
APPENDICES		
	Appendix A	44
	Appendix B	45
	Appendix C	46

LIST OF TABLES

No.	TITLE	PAGE
2.1	Daily waste generation in Kelantan.	8
2.2	The heavy metals concentration data from municipal waste dumpsites around the world.	10
2.3	Classification of contamination level I_{geo} .	11
2.4	Classification index of Pollution Load Index (PLI).	12
2.5	Metal pollution indices used in this study	13
3.1	The general information about sampling sites.	15
3.2	Background value of metal concentration.	20
3.3	Description and values of factors used in the risk assessment equation.	21
4.1	Concentration of heavy metals in collected soil samples ($mgkg^{-1}$).	25
4.2	Comparison between the present data of metal concentration in soil with other studies	31
4.3	Geo-accumulation index values of each location.	32
4.4	Pollution Load Index of each location.	33
4.5	Health Risk Assessment values.	35

LIST OF FIGURES

No.	TITLE	PAGE
3.1	Locations of the sampling sites.	16
3.2	Analytical procedure for selected heavy metals in soil.	18
3.3	Research flow chart for this study.	23
4.1	The concentration of copper (Cu) at each station.	26
4.2	The concentration of lead (Pb) at each station.	26
4.3	The concentration of zinc (Zn) at each station.	27
4.4	The concentration of manganese (Mn) at each station.	28
4.5	The concentration of chromium (Cr) at each station.	28

LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
ADD	average daily dose
As	arsenic
Cd	cadmium
CF	contamination factor
cm ² /event	centimetre square per event
Co	cobalt
Cr	chromium
CR	carcinogenic risk
CSF	cancer slope factor
Cu	copper
Fe	iron
gkg ⁻¹	gram per kilogram
HCl	hydrochloric acid
HI	hazard index
HNO ₃	nitric acid
HQ	hazard quotient
I _{geo}	Geo-accumulation Index
kg/mg	kilogram per milligram
mg/cm	milligram per centimetre
mg/cm ³	milligram per centimetre cube
mg/day	milligram per day
mgkg ⁻¹	milligram per kilogram
Mn	manganese
Ni	nickel
Pb	lead
PLI	Pollution Load Index
RfD	reference dose
TCR	total carcinogenic risk
USEPA	United States Environmental Protection Agency
Zn	zinc

LIST OF SYMBOLS

%	percentage
-	until
:	ratio
/	per
°	degree
°C	Temperature (degree Celcius)
Σ	sum of
\times	multiply
<	less than
=	equal to
>	greater than
\leq	less than or equal to
\geq	less than or equal to

UNIVERSITI
MALAYSIA
KELANTAN

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Dumpsites were stated as any location where municipal wastes were discarded, deposited, or spilt in such a way that it caused a nuisance, posed a risk of environmental pollution or released harmful substances that were dangerous to human health. The most common method of municipal waste disposal was dumpsites (Hussein & Mona, 2018). It was due to the fact that dumping was one of the simplest methods of disposing of rubbish and it was the most straightforward approach used in controlling municipal waste.

Meanwhile, municipal waste, also known as domestic waste, referred to the solid waste generated from homes, institutions and industries (USEPA, 2016). This waste included a variety of materials such as food waste, papers, plastics, glass, and so on. Effective municipal waste management was important because improper waste disposal had a negative impact on the environment (Agbeshie et al., 2020). These eventually are deposited in nearby soils and caused pollution. According to Malaysian Investment Development Authority (2021), municipal solid waste was generated

about 2.01 billion metric tonnes in the world every year, 33% of which was not efficiently handled in an environmentally friendly manner. Malaysia's population was quickly growing, resulting in a tremendous amount of waste generated every day equating to 1.17kg of waste per capita, around 30,000 tonnes of municipal solid waste (United States International Trade Administration, 2022).

Soils were principally responsible for ensuring social-ecological stability and safety (Wu et al., 2018). However, soils absorbed the heavy metals that were released from anthropogenic and natural activities into the environment. Heavy metals in soil considerably impeded the biodegradation of organic contaminants. According to Ismat et al. (2019), numerous heavy metals contaminated soil at the dumpsite which were chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), and zinc (Zn). This study only focused on Cu, Pb, Zn, Mn, and Cr because in the previous studies, these heavy metals were mostly found at dumpsites. These heavy metals degraded soil quality and posed serious health risks to people (Ekere et al., 2020). In order to assess the condition of soil quality, soil assessment calculations were needed.

In addition, soil assessment was an important way to analyze soil health at certain places. According to Afolagboye et al. (2020), soil assessments that had been accessed at municipal waste dumpsites were like Contamination Factor (CF), Enrichment Factor (EF), Geo-accumulation Index (I_{geo}), Pollution Load Index (PLI), Ecological risk index (RI), ecological risk factor, Degree of Contamination (DegC), Modified Degree of Contamination (MDC), and Nemerow Integrated Pollution Index (NIPI). This study only focused on I_{geo} and PLI. I_{geo} assessment was proposed by Muller (1969) to determine the level of pollution whether unpolluted to extremely polluted. Besides that, PLI was an index for evaluation of pollution status of heavy

metals (Shirani et al., 2020). PLI assessed pollution load, while I_{geo} targeted heavy metal contamination, compared concentrations with background levels to evaluate pollution extent in sediments or soils. Both assessments provided quantitative data for achieving one of the study's objectives.

The contamination in dumpsites led to human health risk. Assessment of human health risk was an assessment to determine the impact of polluted dumpsites on human health which were the residents lived nearby, with three major exposure routes which were ingestion, inhalation, and dermal. Human health risk assessment evaluated by ingestion exposure due to the flowing of leachate that disturbed the nearby water sources. Residents who utilized the water source had been exposed to polluted water. The inhalation route was resulted by the emission of hazardous substances into the atmosphere from the dumpsite. Polluted air had an impact on the human respiratory system. Workers were exposed to pollution through dermal exposure, which occurred through skin contact when handling municipal waste. Hazard quotients of each exposure route were calculated to know the potential of non-cancer health hazard exposed by heavy metals from dumpsites (Ogundele et al., 2019).

1.2 Problem Statement

The use of open dumping sites as a method of waste disposal was common in many low-income countries and has since become a neglected area by communities (Mansoor et al., 2020). Improper management of waste at the open dumping site has polluted the soil with heavy metals (Ferronato & Torretta, 2019). The reason for this was that dumpsites were regarded as non-sanitary landfills due to lack of liner system, gas control system, leachate collection system, and a treatment system for the leachate

(Imran et al., 2019). Leachate from dumpsites polluted groundwater, soil, surface water, and natural habitats, especially when it was released uncontrollably.

Dumping municipal waste at dumpsites led to heavy metal contamination. Previous studies had discovered that common heavy metals found at municipal waste dumpsites include Cu, Pb, Zn, Mn, and Cr. These heavy metals came from plastics, metals, batteries, glass, and other sources, reduced soil quality and polluted the soil. According to Hamza et al. (2022), the I_{geo} and PLI in Morocco showed that the pollution levels in the area of the municipal dumpsite were moderate to high (PLI = 1.84) due to heavy metals from anthropogenic sources. This caused human health risks such as inhalation due to the unpleasant smell of the waste dumped there, which was damaged human's organs such as lungs, kidney, and liver. Human health was at the high-risk limit and caused cancer. Similar to the findings that conducted in Khamees-Mushait, Saudi Arabia, all metals assessed in the soil posed little risk to adults and children. However, the carcinogenic risk from inhalation for Zn, Co, and Ni was below the acceptable risk limit, while Cr showed a higher risk of cancer in both adults and children than the safe limit (Ismat et al, 2019).

1.3 Objectives

- 1) To determine the concentration of selected heavy metals.
- 2) To examine the quality of soil using soil assessments.
- 3) To examine possible human risk from exposure to heavy metals in soil.

1.4 Scope of Study

This study was focused to determine the heavy metals concentration in soil at selected dumpsites in Kelantan State, which were Tapak Pelupusan Beris Lalang,

Bachok, Tapak Pelupusan Kok Bedollah, Tumpat, and Tapak Pelupusan Bukit Che Ros, Tanah Merah. Soil samples were collected at 0 cm – 20 cm depth for each location at dumpsites using an auger. Soil samples were analyzed in the laboratory and the heavy metals concentration was determined by using Atomic Absorption Spectroscopy (AAS). Next, to examine the soil quality, the I_{geo} and PLI were calculated using the heavy metals concentration results obtained. I_{geo} evaluated contamination or enrichment of elements at the dumpsite, while the PLI determined heavy metal contamination status in soil samples (Jiya et al., 2019). Human health risk was examined by using hazard quotient formula and health guideline for the ingestion exposure due to the flowing of leachate that disturbed nearby water source. Inhalation was caused by the emission of hazardous substances into the atmosphere from the dumpsite, while dermal exposure occurred through skin contact when handling with municipal waste. Polluted air had an impact on the human respiratory system. So, for this study it was to determine the concentration of heavy metals in soil, the soil quality, and the potential of human risk at the selected dumpsites in Kelantan.

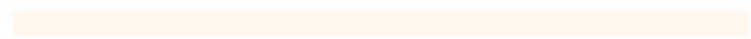
1.5 Significant of Study

This study assisted to analyze the presence of heavy metals in soil at selected dumpsites in Kelantan. It also helped to determine whether the soil quality at the selected dumpsites was at low level or at high level. So, it could assist authorities in controlling and monitoring soil pollution. In addition, government could plan a systematic system that avoided pollution at dumpsites. Apart from that, this study helped to analyze the human health risk that were affected due to the heavy metal contamination especially at the dumpsites where all the wastes were dumped there.

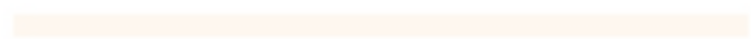
The data obtained from this study could be utilized by the local authorities to handle the municipal solid waste dumpsites properly.



UNIVERSITI



MALAYSIA



KELANTAN

CHAPTER 2

LITERATURE REVIEW

2.1 Municipal Waste

Municipal waste was one of the waste types that frequently discarded at disposal facilities. Nowadays, Malaysia's population was expanding quickly, contributing to a tremendous amount of solid waste, with a daily production rate of 38,427 metric tonnes, 82.5 percent of which was disposed of in landfills (Malaysian Investment Development Authority, 2021). Municipal wastes were also referred to as trash or garbage. These municipal wastes were extremely inhomogeneous mixtures. The volume of municipal waste was rapidly increasing due to urban lifestyles and urbanization development. Typical residential and commercial wastes include papers, plastics, metals, glasses, food wastes, and so on. In Kelantan, there were 12 municipal waste dumpsites and all of them were non-sanitary dumpsites.

The Solid Waste Corporation's 2014 report stated that approximately 990 metric tonnes of waste were produced daily in Kelantan as shown in Table 2.1.

Table 2.1: Daily waste generation in Kelantan.

District	Local Authorities	Production (metric/tonnes)
Kota Bharu	Majlis Perbandaran Kota Bharu	350
Ketereh	Majlis Daerah Ketereh	70
Jeli	Majlis Daerah Jeli	10
Kuala Krai	Majlis Daerah Kuala Krai	20
Machang	Majlis Daerah Machang	100
Tumpat	Majlis Daerah Tumpat	120
Tanah Merah	Majlis Daerah Tanah Merah	50
Pasir Mas	Majlis Daerah Pasir Mas	120
Gua Musang	Majlis Daerah Gua Musang	40
Dabong	Majlis Daerah Dabong	26
Pasir Puteh	Majlis Daerah Pasir Puteh	64
Bachok	Majlis Daerah Bachok	20
Total of waste generated every day		990

(Source: Solid Waste Corporation, 2014)

2.2 Heavy Metals

Heavy metals were the most hazardous environmental contaminants because of their toxicity to the environment. Heavy metals could be found in dumpsites. This was due to the fact that various types of waste were dumped in dumpsite, which caused heavy metal pollution in the environment, including the soil. There were a few types of dumpsites which were electrical, mining, industrial, or municipal. Electrical waste such as refrigerators, mobile phones, televisions, and other electronic devices had led to production of maximum heavy metal concentrations including Cr (219.41 mgkg^{-1}), Cd (178.97 mgkg^{-1}), and Pb (577.64 mgkg^{-1}) (Dutta et al., 2022). Furthermore, previous research had shown that the Cu, Mn, Pb, and Zn elements were found in soil at a copper mining dumpsite in Zambia (Dusengemungu et al.,

2022). Copper and lead elements were discovered in the highest concentrations at an abandoned dumpsite in Ghana. According to that finding, the food chain that this area posed significant risks to the environment and public health (Akanchise et al., 2020). A study that conducted in Lahore recycling centres and dumping sites, found that the mean concentrations of Cu, Pb, Zn, and Cd in surface soil of recycling centres were 722.96 mgkg^{-1} , 446.81 mgkg^{-1} , 378.76 mgkg^{-1} , and 4.11 mgkg^{-1} respectively, where the Cu concentration from dumping sites exceeded World Health Organization permissible limits (Shakil et al., 2023).

Besides that, the concentration of the metals at municipal waste dumpsites ranked as $\text{Fe} > \text{Pb} > \text{As} > \text{Zn} > \text{Cd}$ (Agbeshie et al., 2020). Apart from that, a previous study showed the common heavy metals elements found at municipal waste dumpsite in Ilokun, Ado-Ekiti, Nigeria were Cr, Cu, Pb, Cd, and Mn during dry and wet season (Shittu et al, 2018). As stated from Bienvenu et al. (2022), soil samples showed high metal concentrations, with the average order being Zn, Pb, Cu, Cr, Co, Cd, As, and Hg due to the unregulated public waste disposal in public spaces. Heavy metal toxins, such as lead, were distinguished from other pollutants because they did not biodegrade but accumulated in humans and other living organisms. Furthermore, harmful diseases and illnesses manifested even in low quantities. The rising of metal concentration in soil had alarmed government and regulatory authorities in charge of assessing the risks to the environment and people.

Table 2.2 shows the heavy metals concentration data from municipal waste dumpsites around the world. Based on the previous studies, lead (Pb) was the only heavy metal that was found at every dumpsite area.

Table 2.2: The heavy metals concentration data from municipal waste dumpsites around the world.

Area	Cu	Pb	Zn	Mn	Cr	Reference
(mgkg ⁻¹)						
<i>Nigeria</i>						
Calabar	26.08	1489.32	2123.20	NR	75.30	Ediene, et al. 2017
Uyo						
Rainy season	NR	9.90	137.00	94.00	3.60	Ihedioha, et al. 2017
Dry season	NR	8.70	146.00	91.20	4.05	Ihedioha, et al. 2017
Nigeria, Africa	NR	149.67	224.07	NR	133.50	Nwaougu, et al. 2017
Ado-Ekiti						
Dry season	23.30	75.51	NR	126.60	72.02	Shittu, et al., 2018
Wet season	329.06	263.06	NR	8.29	810.94	Shittu, et al., 2018
Makurdi	NR	7.59	NR	NR	73.3	Egwumah, et al., 2018
Ibadan	7.77	3.79	3.07	7.70	8.36	Ogundele, et al. 2019
Uyo	NR	1.72-2.98	7.22-27.50	NR	0.07-0.39	Essien, et al. 2019
Enugu	NR	34.29	168.44	NR	22.60	Ekere, et al., 2020
Ondo State	19.81	15.25	48.79		41.18	Ogundele, et al., 2020
<i>Other countries</i>						
Tamil Nadu, India	36.52	154.27	NR	130.30	NR	Kanmani and Gandhimathi, 2013
Khamees-Mushait, Saudi Arabia	22.92	38.33	64.21	288.90	53.22	Ismat H. Ali, et al. 2019
Sunyani, Ghana	NR	0.40	0.43	NR	NR	Agbeshie, et al. 2020
Khulna, Bangladesh	NR	67.03	NR	499.91	17.40	Saha, et al. 2022

*NR= Not Reported

2.3 Geo-accumulation Index (I_{geo})

The I_{geo} calculation used to determine the contamination level. This calculation depended on the background value of metals in soil. It was calculated by the formula as follows:

$$I_{geo} = \log_2 \left(\frac{C_i}{1.5 \times C_{background}} \right)$$

where C_i was the metal's concentration in soil samples from a study area. $C_{background}$ was the average of the measured metals' concentrations in soil from the control area. The contamination levels of I_{geo} were classified as follows and Table 2.3 showed the classification of contamination level according to the value of I_{geo} .

Table 2.3: Classification of contamination level I_{geo} .

Index class	I_{geo} value	Level of contamination classification
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 \leq I_{geo} \leq 1$	Uncontaminated to moderately contaminated
2	$1 \leq I_{geo} \leq 2$	Moderately contaminated
3	$2 \leq I_{geo} \leq 3$	Moderately to strongly contaminated
4	$3 \leq I_{geo} \leq 4$	Strongly contaminated
5	$4 \leq I_{geo} \leq 5$	Strongly to extremely contaminated
6	$I_{geo} \geq 5$	Extremely contaminated

(Source: Muller, 1981)

The previous study was conducted at solid waste dumpsite in Osogbo metropolis, Nigeria discovered contamination indices for Ni, Cr, Co, and Pb showed low contaminated status, however geo-accumulation indices for Cd, Zn, and Cu indicate the area was heavily contaminated by these metals (Oladejo et al., 2021). Meanwhile at municipal waste dumpsite in Nigeria, the I_{geo} value for Cr are 5 indicated that the level of contamination was extremely contaminated while Cu, Ni, and Fe had I_{geo} values less than zero (Afolagboye et al, 2020). Furthermore, at a municipal waste dumpsite in Kumasi, Ghana, from the I_{geo} calculation, the Zn element at the Kronum and Amakom sites ranged from uncontaminated to moderately contaminated (Akanchise et al, 2020).

The geo-accumulation index from previous research has found that lead contamination levels range from moderate to highly contaminated at electric dumpsite in Owutu, Nigeria (Sawyerr & Oladeji, 2020) and auto mechanic dumpsite in Makurdi, Nigeria (Ogah et al, 2020). The study discovered the range of level contamination were strong to moderate contamination at Kathmandu Valley, with high concentrations of Pb, Zn, As, and Cd in surface soil, primarily due to anthropogenic activities (Kafle et al., 2022).

2.4 Pollution Load Index (PLI)

The PLI calculation indicated that the degree of pollution in soil based on the potential contribution of heavy metals elements in that particular location. Many researchers used it to determine the contamination level in a location. It was determined by the degree of stress exerted on an ecosystem by physical or chemical pollutants discharged into the atmosphere as a consequence from anthropogenic activities. Table 2.4 shows the classification of the PLI for soil contamination. Hence, the value of PLI was determined based on method proposed from Tomlinson:

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n}$$

Table 2.4: Classification index of the Pollution Load Index (PLI).

Classification index	PLI value	Description of class
1	PLI = 0	Background Concentration
2	$0 < PLI \leq 1$	Unpolluted
3	$1 < PLI \leq 2$	Moderately polluted
4	PLI > 2	Highly polluted

(Source: Rabee, 2011)

Previous study conducted by Ogundele et al. (2019) at industrial waste dumpsite Ibadan, Nigeria showed that the value of PLI was moderate to slightly polluted with a range from 0.7-3.0. Other than that, at Kpone municipal solid waste dumpsite, Ghana, the PLI was 16.48, signifying extreme heavy metals pollution of the

entire site (Obiri-Nyarko, 2021). The PLI calculations showed serious metal accumulation at the electronic waste dumpsites in Lagos and Ibadan, Nigeria which was highly polluted, and the highest value of PLI was 109 (Adeyi & Oyeleke, 2017).

Besides that, based on a case study at a municipal waste dumpsite in Ondo State, Nigeria, found that the reading of PLI indicated that moderate to slightly pollution with a range from 0.7 to 3.0 (Ogundele et al., 2020) meanwhile at a municipal solid waste in Morocco, the value indicated that the soils around the landfill had moderate to high pollution levels (PLI = 1.84), due to Cd and Pb enrichment (Hamza El Fadili et al., 2022). According to Huynh & Nguyen (2022), the pollution load index (PLI) indicated medium and low risks of heavy metal contamination at the Cai Dau and An Cu landfills, respectively and thus it posed low potential ecological risk. The PLI revealed at the studied dumpsites in Southeastern Nigeria also were highly polluted due to vanadium pollution (Eze et al., 2022). In general, Table 2.5 summarised the metal pollution indices used in this study.

Table 2.5: Metal pollution indices used in this study.

Indices	Value and Quality of Soil	Background Value of Element (ppm)	References
I _{geo} – Geo-accumulation index	I _{geo} ≤ 0 Uncontaminated	Cu: 25	Muller, 1981
	0 ≤ I _{geo} ≤ 1 Uncontaminated to moderately contaminated	Pb: 14.8	Hans
	1 ≤ I _{geo} ≤ 2 Moderately contaminated	Zn: 65	Wedepohl, 1995
	2 ≤ I _{geo} ≤ 3 Moderately to strongly contaminated	Mn: 716	
	3 ≤ I _{geo} ≤ 4 Strongly contaminated	Cr: 126	
	4 ≤ I _{geo} ≤ 5 Strongly to extremely contaminated		
	I _{geo} ≥ 5 Extremely contaminated		
PLI- Pollution Load Index	PLI = 0 Background Concentration	-	Ogundele et al., 2020
	0 < PLI ≤ 1 Unpolluted		
	1 < PLI ≤ 2 Moderately polluted		
	PLI > 2 Highly polluted		

2.5 Health Risk Assessment

Health risk assessment measured the exposure of heavy metals towards human health. Contamination of heavy metals at dumpsites was exposed through major pathways like ingestion, inhalation, and dermal. People who lived nearby were affected by the exposure. According to Dutta, et al. (2022), a child's non-carcinogenic risk was larger than adult's but the carcinogenic risk was found to be 1.57×10^{-7} in an adult and 6.1×10^{-7} in children. Previous study from Ismat et al. (2019) found that HI values for non-carcinogenic risk were 0.172 for children and 0.087 for adults. For cancer risk assessment, Cr was at a high risk for both children and adults, with 4.56×10^{-6} and 1.14×10^{-7} respectively while Co, Ni and Zn were within acceptable levels.

Besides that, daily ingestion in Morocco's municipal solid waste dumpsite had higher non-carcinogenic risk, with trace element hazard index values exceeding safe levels for children and acceptable carcinogenic risk of Pb and Cd (Hamza et al., 2022). Heavy metals from abandoned industrial waste dumpsite in Ibadan, Nigeria caused low adverse health impacts on children and adults, with hazard quotients lower than 1 while the carcinogen risks ranged from 2.3×10^{-6} to 6.4×10^{-6} , indicated within acceptable limits (Ogundele et al., 2019). According to Shahla et al. (2021), children's hazard index at Kahrizak landfill in Tehran is 6.5 times higher than adults, but safe for employees and residents. The hazard quotient (HQ) trend for all metals except Ba was observed, with $HQ_{\text{ingestion}} > HQ_{\text{dermal}} > HQ_{\text{inhalation}}$ of soil at industrial waste landfill in Gujranwala, Pakistan (Ahmad et al., 2023). As stated from Rouhani et al. (2023), the study at open landfill site at Kazeran, Iran had resulted of hazard quotient and index values were below threshold limit and indicated non-carcinogenic health risk to humans.

CHAPTER 3

METHODOLOGY

3.1 Study Area

For this study, there were three municipal waste dumpsites were chosen which were Tapak Pelupusan Beris Lalang (Bachok), Tapak Pelupusan Kok Bedollah (Tumpat) and Tapak Pelupusan Bukit Che Ros (Tanah Merah). The description of each sampling sites was shown in Table 3.1 and Figure 3.1.

Table 3.1: The general information about sampling sites.

Location	Tapak Pelupusan Beris Bachok	Tapak Pelupusan Lalang, Kok Tumpat	Tapak Pelupusan Bedollah,	Tapak Pelupusan Bukit Che Ros, Tanah Merah
Information				
Area	76 acres	90 acres		10.280 hectares
Latitude	N05°55'45"	N06°11'41"		N05°47'06"
Longitude	E102°24'45"	E102°08'09"		E102°06'31"
Operation period	13 years	33 years		15 years
Amount of waste	400 tons/day	80 tons/day		51tons/day
Type of waste	Domestic waste	Domestic waste		Domestic waste
Number of workers	Operation:8 workers Machinery:5 workers	Operation:3 workers Machinery:2 workers		6 workers
Workers' average weight	80kg	70kg		80kg

(Source: Solid Waste Corporation, 2023)



(Source: Google Earth, 2023)

Figure 3.1: Locations of the sampling sites.

3.2 Soil Sampling

Three locations of dumpsites were selected for soil samples collection. Soil samples were collected within 0 cm – 20 cm depth from three points at each location of dumpsites using auger (Ismat et al., 2019). It was because heavy metals were likely to be present in the soil at those depth. Then, all the samples were stored in zip lock bags and kept in an ice box to prevent contamination. The soil samples were brought

to the laboratory and stored in a 4 °C freezer to prevent contamination for further analysis.

3.3 Acid Digestion and Preparation of Sample

Soil samples were dried in dry oven at 80 °C for 48 hours. After that, the samples were ground with postal slaved by passing through 500 µm mesh and subjected to acid digestion. 4 g of soil samples were weighed into a 250 ml beaker and were added with enough deionized water to wet the samples. Then, 15 ml of concentrated HNO₃ was added into the sample and the beaker was covered with a watch glass and placed on a hot plate where the temperature maintained at 100 °C. Meanwhile, a digestion blank was prepared by adding the same amount of distilled water and concentrated HNO₃ to a beaker (without sample) and was carried through the entire procedures. The samples were heated at 100 °C for one hour and 5 ml of 30% H₂O₂ was added carefully when the beaker was slightly cool. The watch glass was replaced and the beaker on was set on the hotplate. After the vigorous boiling had subsided, the watch glass was removed and over the period of 1 hour the liquid level was allowed to evaporate until about 10 ml remained.

At the end of two hours, the sample was removed from the hotplate. 25 ml of deionized water was added. The watch glass was replaced and the sample allowed to cool in the hood. While the sample is cooling, a folded No 2 or No 40 Whatman filter paper was folded in a funnel and the paper was rinsed with 10% HNO₃. After that, the sample was filtered into a 100 ml volumetric flask. The residue was rinsed in the beaker with deionized water through the filter. Then, a small amount of deionized water was added into the volumetric flask to the 100 ml mark and mixed well by inverting the flask. Then, the sample was transferred to a clean, dry storage bottle and

labelled properly. The heavy metal contents in the sample were analysed using Atomic Absorption Spectroscopy (AAS).

3.4 Heavy Metals Analysis

Heavy metals concentration was examined by using Perkin Elmer Atomic Absorption Spectroscopy (AAS). AAS detected the elements in that sample solution through electromagnetic radiation from a light source. When light of this particular wavelength was present, the atom absorbed it. The element's concentrations which were Cu, Zn, Mn, Pb, and Cr determined by measuring the amount of light that was absorbed. The result of the sample's heavy metal concentration then be generated by the computer. The analytical procedure for selected heavy metals in soil was shown in Figure 3.2.

Sampling site

- Sampling was carried out at 3 selected dumpsites in Kelantan State which were Tapak Pelupusan Beris Lalang Bachok, Tapak Pelupusan Kok Bedollah Tumpat and Tapak Pelupusan Bukit Che Ros Tanah Merah.



Sample Preservation

- The samples that already been digested were put in falcon tubes and preserved under temperature 4 °C in a freezer for further analysis.



Sample Preparation

- Soil samples were dried in dry oven at 80 °C for 48 hours.
- The sample was ground with postal slaved by passing through 500 µm mesh.



Sample Preservation

- 4.00 g sample was weighed into a 250 ml beaker.
- 15 ml of conc. HNO₃ was added into the sample and placed on a hotplate where temperature maintained at 100 °C.
- The sample heated for one hour, removed from hotplate, cooled slightly and carefully added with 5 ml of 30% H₂O₂.
- After the vigorous boiling had subsided, watch glass was removed and over the period of one hour, the liquid level allowed to evaporate until 10ml remains.
- The sample filtered into a 100 ml volumetric flask through Whatman filter paper.
- The volumetric flask filled to the 100 ml mark with distilled water, mixed well by inverting the flask and transferred to a clean falcon tube.



Analysis of Heavy Metals

- The concentration of Cu, Zn, Mn, Pb, and Cr from the sample's solution determined by Atomic Absorption Spectroscopy (AAS).

Figure 3.2: Analytical procedure for selected heavy metals in soil.

3.5 Soil Assessment

The I_{geo} and PLI determined using the result of heavy metal concentration obtained from the previous step. These methods evaluated the enrichment of a particular element or compound at the dumpsite and analyzed the heavy metal contamination status of soil samples collected by using formulas respectively.

3.5.1 Determination of Geo-accumulation Index (I_{geo})

The I_{geo} was calculated for detecting the contamination of heavy metals in soil samples. I_{geo} was calculated by Eq. (3.1), (Muller, 1969):

$$I_{geo} = \log_2 \left(\frac{C_i}{1.5 \times C_{background}} \right) \quad (3.1)$$

where C_i was the metal's concentration in soil samples from a study area. The $C_{background}$ was the background value for the metal (Hans Wedepohl, 1995).

Table 3.2 showed the background value of metal concentration for each metal that was referred to for this study.

Table 3.2: Background value of metal concentration.

Heavy Metal element	Background value of metal concentration (ppm)
Copper (Cu)	25
Lead (Pb)	14.8
Zinc (Zn)	65
Manganese (Mn)	716
Chromium (Cr)	126

(Source: Hans Wedepohl, 1995)

3.5.2 Determination of Pollution Load Index (PLI)

The PLI assessed the extent to which soil was related to heavy metals, which influenced soil structure (Siddiqui et al., 2020). The PLI was determined for each location by dividing each metal's concentration by the n-root of the nCFs for all metals. (Rabee et al., 2011) according to the Eq. (3.2):

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n} \quad (3.2)$$

Where n represented the quantity of metals present and the CF represented the Contamination Factor, which calculated by dividing value of metal concentration in soil with background value of metal (Chakravarty & Patgiri, 2009).

3.6 Health Risk Assessment

The potential health risk of heavy metals exposure in surface soil samples to adults and children's bodies was examined. Average daily dose (ADD) via three major exposure pathways, including ingestion, dermal and inhalation was considered. ADDs were calculated using Eq. (3.3) – (3.5), (USEPA, 2002):

$$ADD_{\text{ingestion}} = C_{\text{soil}} \times \left(\frac{IngR \times ExFr \times ED}{BW \times AT} \right) \times CF \quad (3.3)$$

$$ADD_{\text{inhalation}} = C_{\text{soil}} \times \left(\frac{InhR \times ExFr \times ED}{PEF \times BW \times AT} \right) \quad (3.4)$$

$$ADD_{\text{dermal}} = C_{\text{soil}} \times \left(\frac{SA \times AF \times DAF \times ExFr \times ED}{BW \times AT} \right) \times CF \quad (3.5)$$

where C_{soil} was the concentration of the heavy metals in soil (mg/kg). Table 3.3 (United States Department of Energy, 2011) listed all factor acronyms and values used for this assessment. To estimate potential of non-carcinogenic risk from each route, hazard quotient (HQ) was determined using Eq. (3.6). HQ was the ratio of ADD for each metal through the three routes.

$$HQ = \frac{ADD}{RfD} \quad (3.6)$$

where RfD was the reference dose which indicated the risk of non-carcinogenic adverse effects to human health.

Table 3.3 showed the description and the values of each factor that used in the human health risk assessment equation.

Table 3.3: Description and values of factors used in the risk assessment equation.

Factor	Unit	Description	Value for children	Value for adults
IngR	mg/day	Ingestion rate	200	100
InhR	mg/cm ³	Inhalation rate	7.6	20
ExFr	day	Exposure frequency	350	350

ED	year	Exposure duration	6	24
BW	kg	Body weight	15	70
AT	day	Averaging time	365×6	365×24
SA	cm ² /event	Surface area of the skin contacting surface soil	5700	2800
AF	mg/cm	Skin adherence factor for surface soil	0.02	0.07
CF	kg/mg	Conversion factor	1×10^{-6}	1×10^{-6}
PEF	m ³ /kg	Particle emission factor	1.36×10^9	1.36×10^9
DAF	Unitless	Dermal absorption factor	0.001	0.001

(Source: USEPA,2002)

Overall, the research summary for this study was summarized in the form of a research flow chart as shown in Figure 3.3.

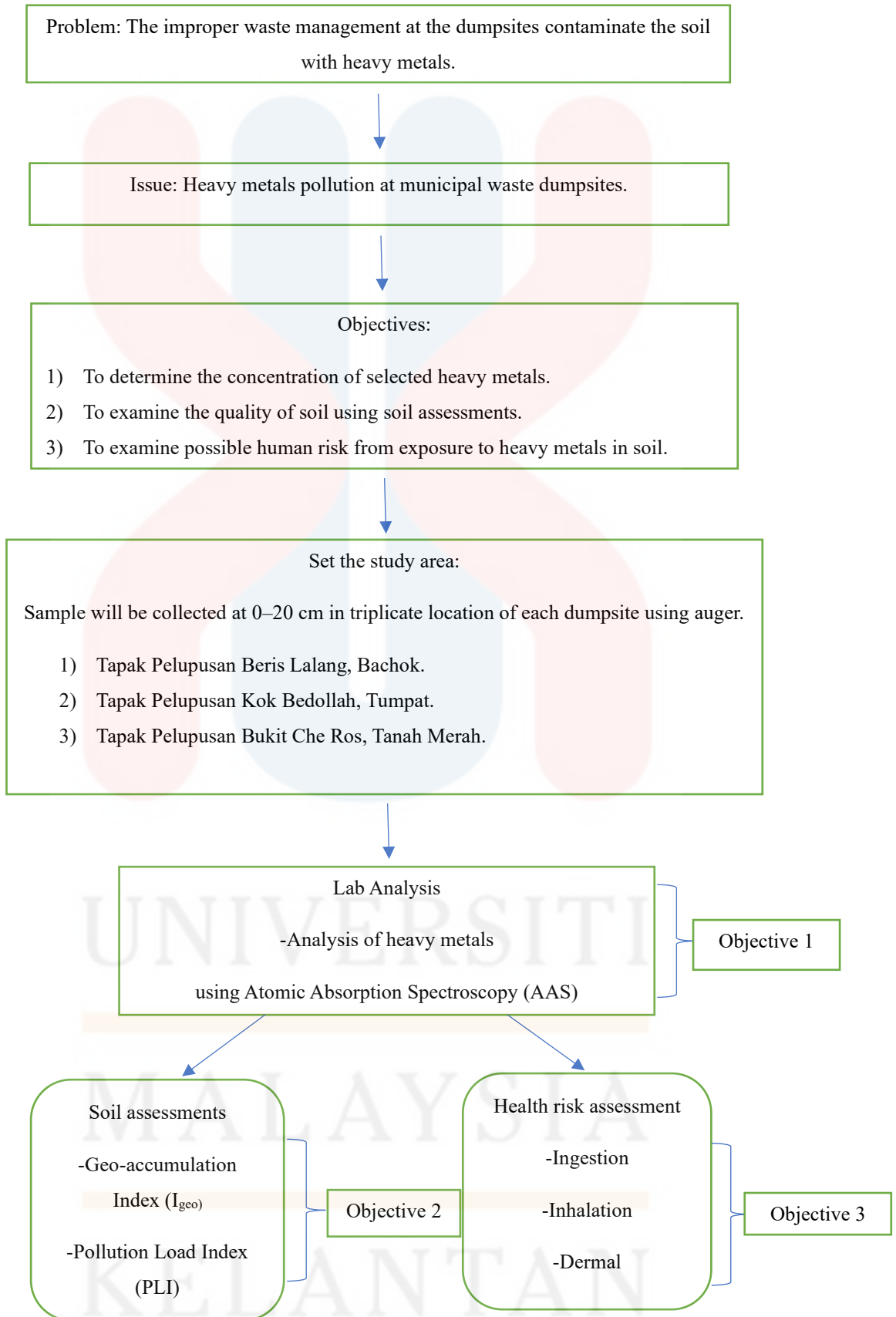


Figure 3.3: Research flow chart for this study.

RESULT AND DISCUSSIONS

4.1 Concentration of Heavy Metals in Soil from Different Dumpsites in Kelantan

In this study, three dumpsites involved which were Tapak Pelupusan Beris Lalang, Bachok, Tapak Pelupusan Kok Bedollah, Tumpat, and Tapak Pelupusan Bukit Che Ros, Tanah Merah. For the Tapak Pelupusan Beris Lalang, Bachok revealed the mean concentration as followed, Cu (16.00 mgkg^{-1}) > Cr (11.87 mgkg^{-1}) > Zn (10.54 mgkg^{-1}) > Mn (6.69 mgkg^{-1}) > Pb (5.72 mgkg^{-1}), with the range Cu (14.60 mgkg^{-1} - 16.88 mgkg^{-1}), Cr (7.75 mgkg^{-1} - 14.49 mgkg^{-1}), Zn (4.76 mgkg^{-1} - 18.64 mgkg^{-1}), Mn (4.49 mgkg^{-1} - 9.00 mgkg^{-1}), and Pb (4.30 mgkg^{-1} - 7.39 mgkg^{-1}). Meanwhile for the Tapak Pelupusan Kok Bedollah, Tumpat revealed the mean concentration as followed, Mn (64.86 mgkg^{-1}) > Zn (31.28 mgkg^{-1}) > Cu (18.92 mgkg^{-1}) > Pb (18.59 mgkg^{-1}) > Cr (3.52 mgkg^{-1}), with the range Mn (54.64 mgkg^{-1} - 70.74 mgkg^{-1}), Zn (15.91 mgkg^{-1} - 39.11 mgkg^{-1}), Cu (14.78 mgkg^{-1} - 23.95 mgkg^{-1}), Pb (14.16 mgkg^{-1} - 26.36 mgkg^{-1}), and Cr (2.95 mgkg^{-1} - 3.93 mgkg^{-1}) while for the Tapak Pelupusan Bukit Che Ros, Tanah Merah revealed the mean concentration as followed, Zn (17.46 mgkg^{-1}) > Cu (13.24

$\text{mgkg}^{-1}) > \text{Cr} (8.60 \text{ mgkg}^{-1}) > \text{Mn} (5.74 \text{ mgkg}^{-1}) > \text{Pb} (4.89 \text{ mgkg}^{-1})$, with the range Zn (5.64 mgkg^{-1} - 32.45 mgkg^{-1}), Cu (8.24 mgkg^{-1} - 19.00 mgkg^{-1}), Cr (5.40 mgkg^{-1} - 12.63 mgkg^{-1}), Mn (4.55 mgkg^{-1} - 7.71 mgkg^{-1}), and Pb (3.23 mgkg^{-1} - 6.74 mgkg^{-1}).

From this study, Tapak Pelupusan Kok Bedollah, Tumpat revealed the highest mean concentration for all elements except for Cr element that show the lowest mean concentration at Tapak Pelupusan Kok Bedollah, Tumpat as shown in Table 4.1. This demonstrated that because Tapak Pelupusan Kok Bedollah, Tumpat was 33 years old compared to Tapak Pelupusan Bukit Che Ros, Tanah Merah 15 years old, and Tapak Pelupusan Beris Lalang, Bachok 13 years old.

Table 4.1: Concentration of heavy metals in collected soil samples (mgkg^{-1}).

Station	Cu	Pb	Zn	Mn	Cr
B1	16.88	5.46	8.23	4.49	13.38
B2	16.51	7.39	18.64	9.00	7.75
B3	14.60	4.30	4.76	6.59	14.49
Mean	16.00 ± 1.22	5.72 ± 1.56	10.54 ± 7.22	6.69 ± 2.26	11.87 ± 3.61
Range	14.60-16.88	4.30-7.39	4.76-18.64	4.49-9.00	7.75-14.49
T1	14.78	14.16	38.81	69.21	3.93
T2	23.95	26.36	15.91	54.64	3.68
T3	18.04	15.24	39.11	70.74	2.95
Mean	18.92 ± 4.65	18.59 ± 6.75	31.28 ± 13.31	64.86 ± 8.89	3.52 ± 0.51
Range	14.78-23.95	14.16-26.36	15.91-39.11	54.64-70.74	2.95-3.93
TM1	19.00	6.74	32.45	4.96	12.63
TM2	12.48	4.69	14.28	7.71	5.40
TM3	8.24	3.23	5.64	4.55	7.76
Mean	13.24 ± 5.42	4.89 ± 1.76	17.46 ± 13.68	5.74 ± 1.72	8.60 ± 3.69
Range	8.24-19.00	3.23-6.74	5.64-32.45	4.55-7.71	5.40-12.63

B= Tapak Pelupusan Beris Lalang, Bachok ; T= Tapak Pelupusan Kok Bedollah, Tumpat ;
TM= Tapak Pelupusan Bukit Che Ros, Tanah Merah

Figure 4.1 showed the concentration of Cu in the soil at each station. The highest Cu concentration was 23.95 mgkg^{-1} at T2. It was because of T2 was an old place that many wastes were dumped there while the lowest Cu concentration was 8.24 mgkg^{-1} at TM3. It was because of TM3 was an area that had been levelled for new garbage pile and still not disposed of garbage.

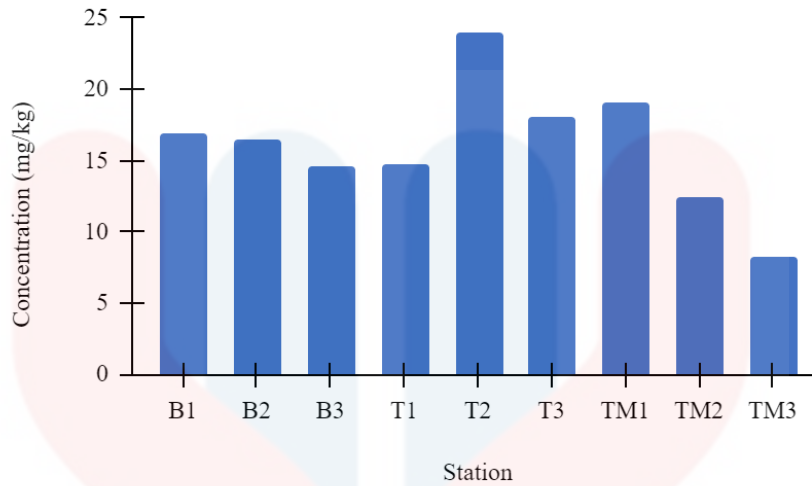


Figure 4.1: The concentration of copper (Cu) at each station.

Figure 4.2 showed the concentration of Pb in the soil at each station. The highest Pb concentration was 26.36 mgkg^{-1} at T2. It might be because of the presence of Pb from certain building materials like asbestos and concrete or from Pb-acid battery that landed at the dumpsite (Alam et al., 2021). Meanwhile the lowest Pb concentration was 2.95 mgkg^{-1} at TM3. It was because TM3 was an area that still not piled up with garbage.

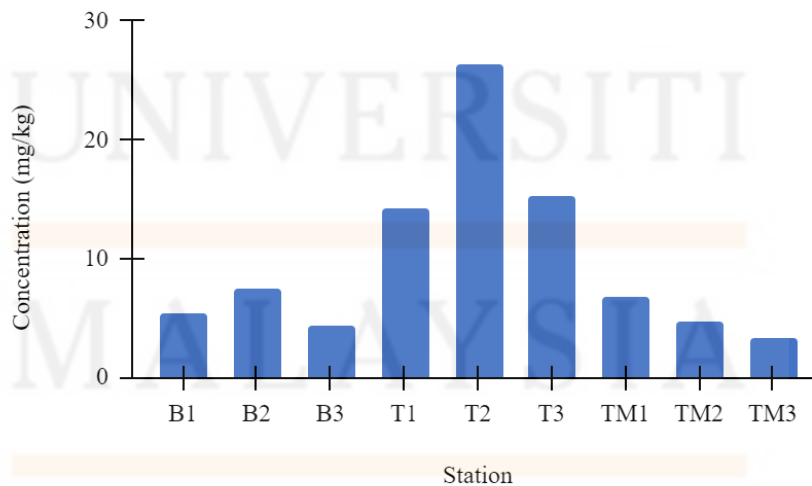


Figure 4.2: The concentration of lead (Pb) at each station.

Figure 4.3 showed the concentration of Zn in the soil at each station. The highest Zn concentration was 39.11 mgkg^{-1} at T3. It might be due to the presence of zinc from food waste such as meat, fish and seafood discarded at the dumpsite (Scutarasu & Trinca, 2023). Meanwhile the lowest Zn concentration was 3.23 mgkg^{-1} at TM3. It was because of TM3 was a newly levelled area for new waste dump.

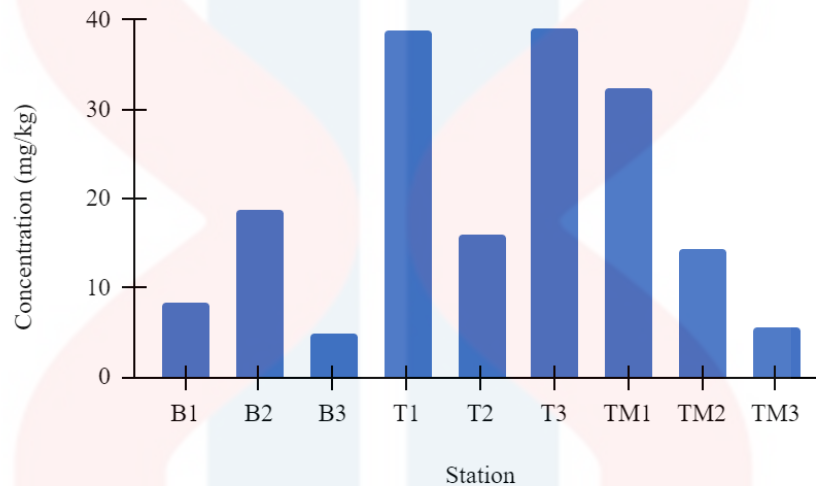


Figure 4.3: The concentration of zinc (Zn) at each station.

Figure 4.4 showed the concentration of Mn in the soil at each station. The highest Mn concentration was 70.74 mgkg^{-1} at T3. It might be derived from steel or food wastes such as clams, green vegetables, oysters, almonds, and so on. Meanwhile, the lowest Mn concentration was 4.49 mgkg^{-1} at B1. It was because of this station only disposed of a small amount of new garbage compared to the others.

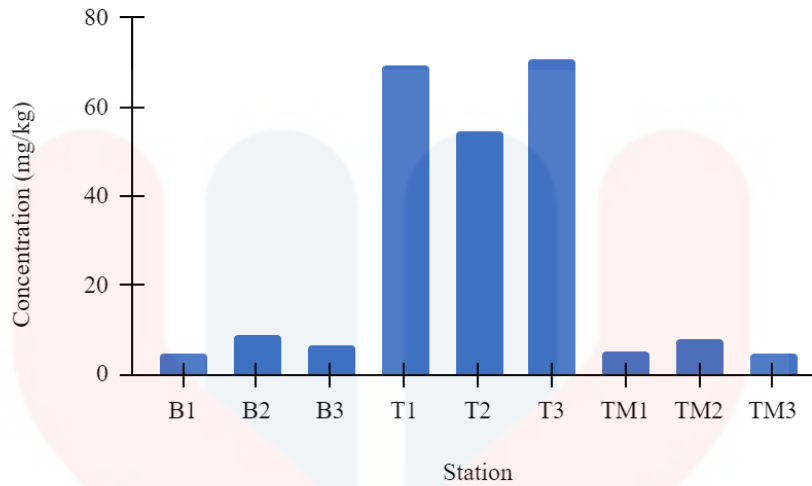


Figure 4.4: The concentration of manganese (Mn) at each station.

Figure 4.5 showed the concentration of Cr in the soil at each station. The highest Cr concentration was 14.49 mgkg^{-1} at B3. It might be due to the presence of chromium from industrial processes, such as metal plating, leather tanning, and textile manufacturing (Bielak & Marcinkowska, 2022) while the lowest Cr concentration was 2.95 mgkg^{-1} at T3. It might because of the station didn't dump with any wastes and located outside the dumpsite.

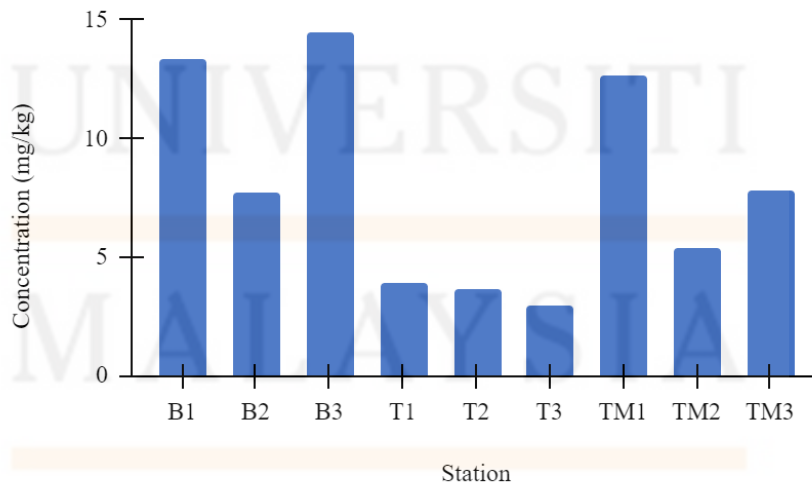


Figure 4.5: The concentration of chromium (Cr) at each station.

4.2 Comparison with Previous Studies

A comparative study of heavy metals concentrations in surface soil samples from the study area with those in soils from other areas in the world was conducted as shown in Table 4.2. The highest concentration of Cu was from Ado Ekiti, Nigeria which was at 329.06 mgkg^{-1} during wet season while in this study, the highest concentration was 23.95 mgkg^{-1} from T2 at Tapak Pelupusan Kok Bedollah. It was due to the presence of Cu in electronic appliances or organic matters that disposed at the dumpsite.

The highest concentration of Pb was from Calabar, Nigeria which was at $1489.32 \text{ mgkg}^{-1}$. It was due to the high quantities of dumped scraped lead proof pipes, batteries, and paint materials in the dumpsite. Lead-acid batteries commonly found in vehicles which contain lead in both the electrodes and the electrolyte (Baca & Vanysek, 2023). Compared to the finding of this study, the highest concentration of Pb was 26.36 mgkg^{-1} from T2 at Tapak Pelupusan Kok Bedollah which mostly came from the municipal wastes which had been disposed of 33 years ago.

The highest concentration of Zn was $2123.20 \text{ mgkg}^{-1}$ which was also from Calabar, Nigeria. The major anthropogenic sources of zinc include wastes from non-ferrous metal industry, construction industry, and agriculture practices while the highest concentration from this study was 39.11 mgkg^{-1} came from T3 at Tapak Pelupusan Kok Bedollah. It might be because of the presence of zinc from food waste that full of zinc like meat, fish, and seafood (Scutarasu & Trinca, 2023).

Other than that, the highest concentration of Mn was 499.91 mgkg^{-1} at Khulna, Bangladesh while in this study, the highest concentration was 70.74 mgkg^{-1} from T3 at Tapak Pelupusan Kok Bedollah. They were contributed by the industrial and house

hold wastes that dumped at the dumpsite. For example, manganese compounds present in household cleaning products.

The highest concentration of Cr was 810.94 mgkg^{-1} at Ado Ekiti, Nigeria. It came from assorted waste ranging from domestic, commercial, and industrial wastes. Some wastes were from certain industrial processes, such as metal plating, chrome plating, and the production of alloys that generate waste that containing chromium compounds. In this study, the highest concentration of Cr was 14.49 mgkg^{-1} from B3 at Tapak Pelupusan Beris Lalang, but it was lower than the value obtained from dumpsite at Ado Ekiti, Nigeria because of the operational period of this dumpsite was only 13 years ago compared to Ado Ekiti dumpsite that had been active for close to two decades.

Table 4.2: Comparison between the present data of metal concentration in soil with other studies.

Area	Cu	Pb	Zn (mgkg ⁻¹)	Mn	Cr	Reference
<i>Kelantan, Malaysia</i>						
Tapak Pelupusan Beris Lalang, Bachok	16.00	5.72	10.54	6.69	11.87	Present study
Tapak Pelupusan Kok Bedollah, Tumpat	18.92	18.59	31.28	64.86	3.52	Present study
Tapak Pelupusan Bukit Che Ros, Tanah Merah	13.24	4.89	17.46	5.74	8.60	Present study
<i>Nigeria</i>						
Calabar	26.08	1489.32	2123.20	NR	75.30	Ediene, et al. 2017
Uyo						
Rainy season	NR	9.90	137.00	94.00	3.60	Ihedioha, et al. 2017
Dry season	NR	8.70	146.00	91.20	4.05	Ihedioha, et al. 2017
Nigeria, Africa	NR	149.67	224.07	NR	133.50	Nwaougu, et al. 2017
Ado-Ekiti						
Dry season	23.30	75.51	NR	126.60	72.02	Shittu, et al., 2018
Wet season	329.06	263.06	NR	8.29	810.94	Shittu, et al., 2018
Makurdi	NR	7.59	NR	NR	73.3	Egwumah, et al., 2018
Ibadan	7.77	3.79	3.07	7.70	8.36	Ogundele, et al. 2019
Uyo	NR	1.72-2.98	7.22-27.50	NR	0.07-0.39	Essien, et al. 2019
Enugu	NR	34.29	168.44	NR	22.60	Ekere, et al., 2020
Ondo State	19.81	15.25	48.79		41.18	Ogundele, et al., 2020
<i>Other countries</i>						
Tamil Nadu, India	36.52	154.27	NR	130.30	NR	Kanmani and Gandhimathi, 2013
Khamees-Mushait, Saudi Arabia	22.92	38.33	64.21	288.90	53.22	Ismat H. Ali, et al. 2019
Sunyani, Ghana	NR	0.40	0.43	NR	NR	Agbeshie, et al. 2020
Khulna, Bangladesh	NR	67.03	NR	499.91	17.40	Saha, et al. 2022

*NR= Not Reported

4.3 Geo-accumulation Index

Based on Table 4.3 below, all the stations revealed that I_{geo} class value was 0 due the measured I_{geo} values were less than 0. It showed that the soil quality was uncontaminated. Meanwhile, only one station revealed the I_{geo} class value at 1 which was at T2 station. Its I_{geo} value was 0.25 and showed that the soil there was uncontaminated to moderately contaminated.

It was same with the previous study from Kronum sampling sites at abandoned dumpsite in Kumasi, Ghana. The I_{geo} values for As, Cd, Cr, Cu, Ni, Pb, and Hg there showed generally no pollution. However, the I_{geo} values of Zn ranged from 0.11 to 1.58 indicating no pollution to moderate pollution. It might due to the disposal of metal scraps, electronic waste, and cosmetics at the dumpsite (Akanchise et al., 2020).

Table 4.3: Geo-accumulation index values at each station.

Station	Measured I_{geo} value					I_{geo} class value				
	Cu	Pb	Zn	Mn	Cr	Cu	Pb	Zn	Mn	Cr
B1	-1.15	-2.02	-3.57	-7.90	-3.82	0	0	0	0	0
B2	-1.18	-1.59	-2.39	-6.90	-4.61	0	0	0	0	0
B3	-1.36	-2.37	-4.36	-7.35	-3.71	0	0	0	0	0
T1	-1.34	-0.65	-1.33	-3.96	-5.59	0	0	0	0	0
T2	-0.65	0.25	-2.62	-4.30	-5.68	0	1	0	0	0
T3	-1.06	-0.54	-1.32	-3.92	-6.00	0	0	0	0	0
TM1	-0.98	-1.72	-1.59	-7.76	-3.90	0	0	0	0	0
TM2	-1.59	-2.24	-2.77	-7.12	-5.13	0	0	0	0	0
TM3	-2.19	-2.78	-4.11	-7.88	-4.61	0	0	0	0	0

4.4 Pollution Load Index

According to Table 4.4, measured PLI value for Tapak Pelupusan Beris Lalang, Tapak Pelupusan Kok Bedollah, and Tapak Pelupusan Bukit Che Ros were 0.13, 0.26, and 0.12 respectively. So, they were classified under class 2 which was unpolluted. Among the three dumpsites, PLI value at Tapak Pelupusan Bukit Che Ros was the lowest because of the amount of waste dumped there every day was the least among the dumpsites which was 51 tons/day while the highest PLI value was at Tapak

Pelupusan Kok Bedollah because of it was the oldest dumpsite among the three dumpsites.

Table 4.4: Pollution Load Index of each location.

Location	Measured PLI value	PLI class
Tapak Pelupusan Beris Lalang	0.13	2
Tapak Pelupusan Kok Bedollah	0.26	2
Tapak Pelupusan Bukit Che Ros	0.12	2

4.5 Health Risk Assessment

According to Table 4.5 below, the readings of average daily dose (ADD) at Tapak Pelupusan Beris Lalang, Bachok, Tapak Pelupusan Kok Bedollah, Tumpat, and Tapak Pelupusan Bukit Che Ros, Tanah Merah were all in the following order $ADD_{\text{ingestion}} > ADD_{\text{dermal}} > ADD_{\text{inhalation}}$. The $ADD_{\text{ingestion}}$ was the highest among others. It might due to the ingestion exposure when the flowing of leachate from the dumpsites disturbed the nearby water sources. While the dermal exposure might because of the exposed through skin contact when handling the wastes especially for the workers there. $ADD_{\text{inhalation}}$ was the lowest because the exposure of hazardous substances from heavy metals not easily spread through the air circulation.

For the $ADD_{\text{ingestion}}$, the highest value was from Cr at Tapak Pelupusan Bukit Che Ros, Tanah Merah. It might due to the huge amounts of municipal wastes that contained Cr was dumped at the dumpsite such as metal plating, and the production of alloys from domestic and commercial wastes. While for the ADD_{dermal} and $ADD_{\text{inhalation}}$, the highest value revealed from Mn at Tapak Pelupusan Kok Bedollah, Tumpat. It might come from the household cleaning products that disposed there and also because of the dumpsites was the oldest among the other two dumpsites.

Compared to the health risk assessment of heavy metals in the soil samples from abandoned industrial waste dumpsite in Ibadan, Nigeria, the average daily dose was in the following order $ADD_{inhalation} > ADD_{dermal} > ADD_{ingestion}$. The largest possible dose of inhalation exposure by air breathing. A significant percentage of breath-in air might contain heavy metals emitted from the dumpsite that enter the human body via inhalation route (Ogundele et al., 2019). Meanwhile through dermal contact, people might potentially be exposed to heavy metals simply by failing to wash hands before eating after regular activities.

Other than that, from this study, the HQ value from Tapak Pelupusan Beris Lalang, Bachok and Tapak Pelupusan Bukit Che Ros, Tanah Merah were in the following order $HQ_{ingestion} > HQ_{dermal} > HQ_{inhalation}$ while from Tapak Pelupusan Kok Bedollah, Tumpat was as followed $HQ_{ingestion} > HQ_{inhalation} > HQ_{dermal}$. The highest value of $HQ_{ingestion}$ from each location revealed that the exposure through ingestion route could pose significant health risks towards people due to the hazardous substances from the heavy metals in soil.

From the previous study at dumpsites in Khamees-Mushait, Saudi Arabia, the value of hazard quotient also as follow $HQ_{ingestion} > HQ_{dermal} > HQ_{inhalation}$. $HQ_{ingestion}$ was the highest due to the exposure when consuming water from the source that contaminated with heavy metals (Ismat et al., 2019). So, the hazardous substances in the water could enter the parts of human body and led to the potential exposure on toxicity and gave adverse effect towards human's health.

Table 4.5: Health risk assessment values

Location	Metals	Mean metal concentration (mgkg ⁻¹)	Ingestion			Inhalation			Dermal		
			ADD	RfD	HQ	ADD	RfD	HQ	ADD	RfD	HQ
Tapak	Cu	16.00	1.92E-05	4.00E-02	4.80E-04	2.82E-09	4.02E-02	7.01E-08	3.76E-08	1.20E-02	3.13E-06
Pelupusan Beris	Pb	5.72	6.86E-06	3.50E-03	1.96E-03	1.01E-09	3.52E-03	2.87E-07	1.34E-08	5.25E-04	2.55E-05
Lalang, Bachok	Zn	10.54	1.26E-05	3.00E-01	4.20E-05	1.86E-09	3.00E-01	6.20E-09	2.48E-08	6.00E-02	4.13E-07
	Mn	6.69	8.02E-06			1.18E-09			1.57E-08		
	Cr	11.87	1.42E-05	3.00E-03	4.73E-03	2.09E-09	2.86E-05	7.31E-05	2.79E-08	6.00E-05	4.65E-04
Tapak	Cu	18.92	2.59E-05	4.00E-02	6.48E-04	3.81E-09	4.02E-02	9.48E-08	5.08E-08	1.20E-02	4.23E-06
Pelupusan Kok	Pb	18.59	2.55E-05	3.50E-03	7.29E-03	3.74E-09	3.52E-03	1.06E-06	4.99E-08	5.25E-04	9.50E-05
Bedollah,	Zn	31.28	4.28E-05	3.00E-01	1.43E-04	6.30E-09	3.00E-01	2.10E-08	8.40E-08	6.00E-02	1.40E-06
Tumpang	Mn	64.86	8.88E-05			1.31E-08			1.74E-07		
	Cr	3.52	4.82E-06	3.00E-03	1.61E-03	7.09E-10	2.86E-05	2.48E-05	9.45E-09	6.00E-05	1.58E-04
Tapak	Cu	1324	1.59E-05	4.00E-02	3.98E-04	2.33E-09	4.02E-02	5.80E-08	3.11E-08	1.20E-02	2.59E-06
Pelupusan Bukit	Pb	4.89	5.86E-06	3.50E-03	1.67E-03	8.62E-10	3.52E-03	2.45E-07	1.15E-08	5.25E-04	2.19E-05
Che Ros, Tanah	Zn	17.46	2.09E-05	3.00E-01	6.97E-05	3.08E-09	3.00E-01	1.03E-08	4.10E-08	6.00E-02	6.83E-07
Merah	Mn	5.74	6.88E-06			1.01E-09			1.35E-08		
	Cr	8.60	1.03E-05	3.00E-03	3.43E-03	1.52E-09	2.86E-05	5.31E-05	2.02E-08	6.00E-05	3.37E-04

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, all the objectives had been achieved. The first objective was to determine the concentration of selected heavy metals. Heavy metals that were analysed in this study were Cu, Pb, Zn, Mn, and Cr. The mean concentration of heavy metals in soil at Tapak Pelupusan Beris Lalang as following order, Cu (16.00 mgkg^{-1}) > Cr (11.87 mgkg^{-1}) > Zn (10.54 mgkg^{-1}) > Mn (6.69 mgkg^{-1}) > Pb (5.72 mgkg^{-1}), while Tapak Pelupusan Kok Bedollah, Mn (64.86 mgkg^{-1}) > Zn (31.28 mgkg^{-1}) > Cu (18.92 mgkg^{-1}) > Pb (18.59 mgkg^{-1}) > Cr (3.52 mgkg^{-1}) and Tapak Pelupusan Bukit Che Ros, Zn (17.46 mgkg^{-1}) > Cu (13.24 mgkg^{-1}) > Cr (8.60 mgkg^{-1}) > Mn (5.74 mgkg^{-1}) > Pb (4.89 mgkg^{-1}). The findings revealed that Tapak Pelupusan Kok Bedollah, Tumpat exhibited the highest concentration readings for most heavy metals, indicating its status as the most contaminated site among the three selected dumpsites. The presence of heavy metals in the soil was attributed to uncontrolled dumpsite management.

Second objective was to examine the quality of soil using soil assessments. There were two assessments used in this study which were Geo-accumulation Index

and Pollution Load Index. All the I_{geo} value for every element Cu, Pb, Zn, Mn, and Cr were at class 0 which was stated as uncontaminated at each station in this study except of the class of Pb at T2 station was at class 1 which was uncontaminated to moderately contaminated while the measured PLI values of all the study locations were at class 2 which were unpolluted.

The third objective was to examine possible human risk from exposure to heavy metals in soil. The study delved into potential of human health risks associated with exposure to heavy metals. The value of $ADD_{ingestion}$ was the highest from Tapak Pelupusan Bukit Che Ros, Tanah Merah while for the $ADD_{inhalation}$ and ADD_{dermal} , the highest value was from Tapak Pelupusan Kok Bedollah, Tumpat. Meanwhile for the value of hazard quotient, the highest value of $HQ_{ingestion}$ and HQ_{dermal} recorded from Tapak Pelupusan Bukit Che Ros, Tanah Merah and for the $HQ_{inhalation}$ was from Tapak Pelupusan Kok Bedollah, Tumpat. This underscored the importance of addressing and rectifying the environmental issues arising from municipal waste dumping, as they pose a direct threat to the well-being of the local population.

The implications of this research highlighted the critical need for immediate interventions in dumpsite management, including regular monitoring and decontamination processes. Without modifications to current practices, the contamination identified in this study could persist, further jeopardizing soil quality and increasing the potential for adverse health effects on the surrounding population. This study served as a call to action, emphasizing the necessity for comprehensive waste management policies and practices to address the pressing issue of heavy metals contamination in municipal solid waste dumpsites.

5.2 Recommendation

After completing this study, some improvements can be taken action in order to make it more reliable for future research. The first recommendation is to increase the number of sampling stations at a specific dumpsite. Instead of the three sampling stations used in this study, the number of sampling stations can be increased in accordance to the size of the dumpsite. Aside from that, more soil assessments can be carried out to determine the quality of soil at specific dumpsites. Examples of soil assessments are enrichment factor (EF), contamination factor (CF), or potential ecological risk index (PERI).

REFERENCES

- Adeyi, A. A., & Oyeleke, P. (2017). Heavy metals and Polycyclic Aromatic Hydrocarbons in soil from e-waste dumpsites in Lagos and Ibadan, Nigeria. *Journal of Health and Pollution*, 7(15), 71–84.
- Afolagboye, L. O., Ojo, A. A., & Talabi, A. O. (2020). Evaluation of soil contamination status around a municipal waste dumpsite using contamination indices, soil-quality guidelines, and multivariate statistical analysis. *SN Applied Sciences*, 2, 1864.
- Agbeshie, A. A., Adjei, R., Anokye, J., & Banunle, A. (2020). Municipal waste dumpsite: Impact on soil properties and heavy metal concentrations, Sunyani, Ghana. *Scientific African*, 8, e00390.
- Ahmad, W., Zubair, M., Ahmed, M. et al. (2023). Assessment of potentially toxic metal(loid)s contamination in soil near the industrial landfill and impact on human health: An evaluation of risk. *Environmental Geochemistry and Health*, 45(7), 4353-4369.
- Akanchise, T., Boakye, S., Borquaye, L. S., Dodd, M., & Darko, G. (2020). Distribution of heavy metals in soils from abandoned dump sites in Kumasi, Ghana. *Scientific African*, 10.
- Alam, A., Chaudhry, M. N., Mahmood, A., Ahmad, S. R., & Butt, T. E. (2021). Development & application of Conceptual Framework Model (CFM) for environmental risk assessment of contaminated lands. *Saudi J. Biol. Sci.* 11, 6167–6177.
- Baca, P. & Vanysek, P. (2023). Issues concerning manufacture and recycling of lead. *Energies*, 16(11), 4468.
- Bielak, E. & Marcinkowska, E. (2022). Heavy metals in leathers, artificial leathers, and textiles in the context of quality and safety of use. *Scientific Reports*, 12, 5061.
- Bienvenu K. M., Periyasamy S., Amandine L., Crispin K. M., Gregory G., Pius T. M., & John P. (2022). Evaluation of heavy metal content and potential ecological risks in soil samples from wild solid waste dumpsites in developing country under tropical conditions. *Environmental Challenges*, 7, 100461.
- Chakravarty, M., & Patgiri, A. D. (2009). Metal pollution assessment in sediments of the Dikrong River, N.E. India. *Journal of Human Ecology*, 27(1), 63–67.
- Dutta D., Goel S., & Kumar S. (2022). Health risk assessment for exposure to heavy metals in soils in and around E-waste dumping site. *Journal of Environmental Chemical Engineering*, 10(2).
- Dusengemungu, L., Mubemba, B., & Gwanama, C. (2022). Evaluation of heavy metal contamination in copper mine tailing soils of Kitwe and Mufulira, Zambia, for

- reclamation prospects. *Scientific Reports*, 12, 11283.
- Ediene, V. F., & Umoetok, S. B. A. (2017). Concentration of heavy metals in soils at the municipal dumpsite in Calabar metropolis. *Asian Journal of Environment & Ecology*, 3(2), 1-11.
- Egwumah, A. J., S Eneji, I., & A Wuana, R. (2018). Assessment of heavy metal and selenium levels in leachates and soils of Central Bank of Nigeria Dumpsite Makurdi. *Asian Journal of Applied Chemistry Research*, 1(2), 1-12.
- Ekere N. R., Ugbor, M. C. J., Ihedioha, J. N., Ukwueze, N. N., & Abugu, H. O. (2020). Ecological and potential health risk assessment of heavy metals in soils and food crops grown in abandoned urban open waste dumpsite. *Journal of Environmental Health Science and Engineering*, 18, 711-721.
- Essien, J. P., Inam, E. D., Ikpe, D. I., Udofia, G. E., & Benson, N. U. (2019). Ecotoxicological status and risk assessment of heavy metals in municipal solid wastes dumpsite impacted soil in Nigeria. *Environmental Nanotechnology, Monitoring & Management*, 11, 100215.
- Eze, V. C., Okeke, D. O., Nwabudike, A. R., & Aduaka, C. N. (2022). Assessment of vanadium pollution and ecological risk in some selected waste dumpsites in Southeastern Nigeria. *Health and Environment*, 3(1), 169-175.
- Ferronato, N., & Toretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health*, 16(6), 1060.
- Hamza El Fadili, Mohammed Ben Ali, Nouredine Touach, Mohammed El Mahi, & El Mostapha Lotfi. (2022). Ecotoxicological and pre-remedial risk assessment of heavy metals in municipal solid wastes dumpsite impacted soil in Morocco. *Environmental Nanotechnology, Monitoring & Management*, 17.
- Hans Wedepohl, K. (1995). The composition of the continental crust. *Geochimica et Cosmochimica Acta*, 59(7), 1217–1232.
- Hussein I. Abdel-Shafy, & Mona S. M. Mansour (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum*, 27(4), 1275–1290.
- Huynh, T. H. N. & Nguyen, T. G. (2022). Assessment of pollution levels and ecological potential risk of the soil influenced by landfilling in a Vietnamese Mekong Delta province. *Science of The Total Environment*, 845.
- Ihedioha, J. N., Ukoha, P. O., & Ekere, N. R. (2017). Ecological and human health risk assessment of heavy metal contamination in soil of a municipal solid waste dump in Uyo, Nigeria. *Environmental Geochemistry Health*, 39, 497-515.
- Imran Ahmad, Chelliapan, S., Norhayati Abdullah, & Mohd Danish Ahmad (2019). Sanitary landfill is a solution in solid waste management or a silent threat to

- environment: Malaysian scenario soil and groundwater view project microalgae view project. *Open International Journal of Informatics (OIJI)*, 7.
- Ismat H. Ali, Saifeldin M. Siddeeg, Abubakr M. Idris, Eid I. Brima, Khalid A. Ibrahim, Sara A. M. Ebraheem, & Muhammad Arshad (2019): Contamination and human health risk assessment of heavy metals in soil of a municipal solid waste dumpsite in Khamees-Mushait, Saudi Arabia. *Toxin Reviews*, 40(1), 102–115.
- Jiya, M. J., Bala, J. D., Mustapha, H. I., Kuti, I. A., Musa, E. T., Yerima, Y. I., Daniel, E. S., & Akos, M. P. (2019). Heavy metals concentration in the dumpsite soils using Geo-accumulation Index and Ecological Risk Assessment. *Agricultural Engineering International: CIGR Journal*, 21(3), 7–17.
- Kafle, H., Khadgi, J., Ojha, R. et al. (2022). Concentration, sources, and associated risks of trace elements in the surface soil of Kathmandu Valley, Nepal. *Water, Air & Soil Pollution*, 233(46).
- Kanmani, S. & Gandhimathi, R. (2013). Assessment of heavy metal contamination in soil due to leachate migration from an open dumping site. *Applied water science*, 3, 193-205.
- Malaysian Investment Development Authority. (2021). Waste to energy for a sustainable future. Retrieved June 24, 2023 from <https://www.mida.gov.my/waste-to-energy-for-a-sustainable-future/>.
- Mansoor Ali., Cotton, A., & Westlake, K. (2020). Waste disposal in developing countries. Retrieved July 11, 2023 from <https://www.lboro.ac.uk/media/wwwlboroacuk/external/content/research/wedc/well/pdf/factsheets/Waste%20disposal%20in%20developing%20countries.pdf>
- Muller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. *GeoJournal*, 2, 108-118.
- Muller, G. (1981). The heavy metal pollution of the sediments of Neckars and its tributary: A stocktaking. *ChemikerZeitung*, 105, 157-164.
- Nwaogu, C., Ogbuagu, H. D., Abrakasa, S., Olawoyin, M. A., & Pavlu, V. (2017). Assessment of the impacts of municipal solid waste dumps on soils and plants. *Chemistry and Ecology*, 33(7), 589-606.
- Obiri-Nyarko, F., Duah, A. A., Karikari, A. Y., Agyekum, W. A., Manu, E., & Tagoe, R. (2021). Assessment of heavy metal contamination in soils at the Kpone landfill site, Ghana: Implication for ecological and health risk assessment. *Chemosphere*, 282.
- Ogah, E., Egah, G. O., Neji, P. A., Samoh, F. T., Dodo, J. D., Anidobu, C. O., Ameer, S. K., & Bwede, D. D. (2020). Analysis of heavy metal concentration in auto-mechanic dumpsites in Makurdi Metropolis. North Central Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, 12(1), 65-71.

- Ogundele, L. T., Adejoro, I. A., & Ayeku, P. O. (2019). Health risk assessment of heavy metals in soil samples from an abandoned industrial waste dumpsite in Ibadan, Nigeria. *Environmental Monitoring Assess.* 191,290.
- Ogundele, L. T., Ayeku, P. O., Adebayo, A. S. et al. (2020). Pollution indices and potential ecological risks of heavy metals in the soil: A case study of municipal wastes site in Ondo State, Southwestern, Nigeria. *Polytechnica*, 3, 78-86.
- Oladejo, O. F., Ogundele, L. T., Inuyomi, S. O. et al. (2021). Heavy metals concentrations and naturally occurring radionuclides in soils affected by and around a solid waste dumpsite in Osogbo metropolis, Nigeria. *Environmental Monitoring Assess*, 193, 730.
- Rabee, A. M., Al-Fatlawy, Y. F., Abd, A.-A.-H. N., & Nameer, M. (2011). Using Pollution Load Index (PLI) and Geoaccumulation Index (I-Geo) for the assessment of heavy metals pollution in Tigris River Sediment in Baghdad Region. *Journal of Al-Nahrain University Science*, 14(4), 108-114.
- Rouhani, A., Shadloo, S., Naqibzadeh, A. et al. (2023). Pollution and health risk assessment of heavy metals in the soil around an open landfill site in a developing country (Kazerun, Iran). *Chemistry Africa*, 6(4), 2139-2149.
- Saha, T. R., Khan, M. A. R., Kundu, R., Naime, J., Karim, K. M. R., & Ara, M. H. (2022). Heavy metal contaminations of soil in waste dumping and non-dumping sites in Khulna: Human health risk assessment. *Results in Chemistry*, 4,100434.
- Sawyerr, H. O., & Oladeji, F. O. (2020). Evaluation of the distribution of heavy metals in soil around electronic dumpsite in Owutu, Ikorodu, Lagos State, Nigeria. *Asian Journal of Chemical Sciences*, 8(3), 24–31.
- Scutarasu, E. C., & Trinca, L.C. (2023). Heavy metals in foods and beverages: Global situation, health risks and reduction methods. *Foods*, 12(18), 3340.
- Shahla K., Sakine S., & Gholamreza M. (2021). Health and ecological risk assessment and simulation of heavy metal-contaminated soil of Tehran landfill. *RSC Advances*, 11, 8080.
- Shakil, S., Nawaz, K. & Sadeq, Y. (2023). Evaluation and environmental risk assessment of heavy metals in the soil released from e-waste management activities in Lahore, Pakistan. *Environmental Monitoring and Assessment*, 195(89).
- Shirani, M., Afzali, K. N., Jahan, S. et al. (2020). Pollution and contamination assesment of heavy metal in the sediments of Jazmurian Playa in Southeast Iran. *Scientific Reports*, 10, 4775.
- Shittu, O. S., Ayodele, O. J., Ilori, A. O., Filani, A. O., & Afuye, A. T. (2018). Heavy metal contamination of a dumpsite environment as assessed with pollution

indices. *International Journal of Agricultural and Biosystems Engineering*, 12(1), 1-7.

- Siddiqui, Z., Khillare, P. S., Jyethi, D. S., Aithani, D., & Yadav, A. K. (2020). Pollution characteristics and human health risk from trace metals in roadside soil and road dust around major urban parks in Delhi city. *Air Quality, Atmosphere and Health*, 13(11), 1271-1286.
- Solid Waste Corporation (2014), Pengurusan bencana banjir Kelantan 2015, Retrieved April 27, 2023 from https://cgss.usm.my/images/Sisa_Serpihan_-_En._Azman_Mohamad.pdf
- U.S. Department of Energy. (2011). The Risk Assessment Information System (RAIS). U.S. Department of Energy's Oak Ridge Operations Office, Washington, DC. Retrieved May 10, 2023 from <https://rais.ornl.gov/>
- U.S. International Trade Administration. (2022). Malaysia waste management solutions. U. S. Department of Commerce, Washington, DC. Retrieved June 4, 2023 from <https://www.trade.gov/market-intelligence/malaysia-waste-management-solutions>
- U.S. Environmental Protection Agency. (2002). Supplemental guidance for developing soil screening levels for Superfund Sites. Environmental Protection Agency, Washington, DC. Retrieved April 29, 2023 from <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=91003IJK.TXT>
- U.S. Environmental Protection Agency. (2016). Municipal solid waste. Environmental Protection Agency, Washington, DC. Retrieved April 30, 2023 from <https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/>
- Wu, J., Lu, J., Li, L., Min, X., & Luo, Y. (2018). Pollution, ecological-health risks, and sources of heavy metals in soil of the northeastern Qinghai-Tibet Plateau. *Chemosphere*, 201, 234–242.

APPENDIX A

The sampling Data Sheet

Station	Coordinate	Description	Date & Time	pH	Moisture content
B1	N 05°55'37" E 102°24'43"	New 3months Soil near the new garbage pile	9/8/2023 12.11PM	4.0	8.0
B2	N 05°55'43" E 102°24'41"	Old 5years Soil near the old garbage pile	9/8/2023 11.58AM	5.4	3.0
B3	N 05°55'46" E 102°24'42"	Control Soil near the canteen in the landfill area	9/8/2023 12.27PM	5.8	4.5
T1	N 06°11'37" E 102°08'01"	New 5months Soil where new garbage was dumped	23/8/2023 11.50AM	4.4	8.0
T2	N 06°11'39" E 102°08'02"	Old 5years Soil where old trash was dumped	23/8/2023 11.45AM	3.0	8.0
T3	N 06°11'41" E 102°08'10"	Control Soil outside the landfill area	23/8/2023 12.05PM	5.0	7.0
TM1	N 05°47'06" E 102°06'33"	New 7months Soil of the recently garbage was disposed	23/8/2023 3.25PM	5.0	6.0
TM2	N 05°47'06" E 102°06'26"	Old Soil of garbage heaps that had burned out	23/8/2023 3.10PM	4.6	8.0
TM3	N 05°47'01" E 102°06'30"	Control Soil near the hill that levelled before garbage was disposed of	23/8/2023 2.45PM	6.2	2.0

UNIVERSITI
MALAYSIA
KELANTAN

FYP FSB

APPENDIX B

Heavy Metals Concentration Data (Raw Data)

Location	Station	Cu	Pb	Zn	Mn	Cr
mgL ⁻¹						
Tapak Pelupusan	B1	1.350	0.437	0.658	0.359	1.070
Beris Lalang,	B2	1.321	0.591	1.491	0.720	0.620
Bachok	B3	1.168	0.344	0.381	0.527	1.159
Tapak Pelupusan	T1	1.182	1.133	3.105	5.537	0.314
Kok Bedollah,	T2	1.916	2.109	1.273	4.371	0.294
Tumpat	T3	1.443	1.219	3.129	5.659	0.236
Tapak Pelupusan	TM1	1.520	0.539	2.596	0.397	1.010
Bukit Che Ros,	TM2	0.998	0.375	1.142	0.617	0.432
Tanah Merah	TM3	0.659	0.258	0.451	0.364	0.621

The Formula for Conversion (mgL⁻¹ to mgkg⁻¹)

$$\frac{\text{concentration of metal } \left(\frac{\text{mg}}{\text{L}}\right) \times \text{volume of sample (L)}}{\text{sample weight (kg)}}$$

Location	Station	Cu	Pb	Zn	Mn	Cr
mgkg ⁻¹						
Tapak Pelupusan	B1	16.88	5.46	8.23	4.49	13.38
Beris Lalang,	B2	16.51	7.39	18.64	9.00	7.75
Bachok	B3	14.60	4.30	4.76	6.59	14.49
Tapak Pelupusan	T1	14.78	14.16	38.81	69.21	3.93
Kok Bedollah,	T2	23.95	26.36	15.91	54.64	3.68
Tumpat	T3	18.04	15.24	39.11	70.74	2.95
Tapak Pelupusan	TM1	19.00	6.74	32.45	4.96	12.63
Bukit Che Ros,	TM2	12.48	4.69	14.28	7.71	5.40
Tanah Merah	TM3	8.24	3.23	5.64	4.55	7.76

The Sample Volume and Weight Data

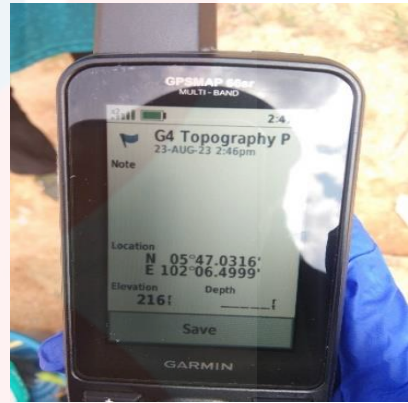
Station	Volume of sample (L)	Sample weight (kg)
B1	0.05	0.004
B2	0.05	0.004
B3	0.05	0.004
T1	0.05	0.004
T2	0.05	0.004
T3	0.05	0.004
TM1	0.05	0.004
TM2	0.05	0.004
TM3	0.05	0.004

APPENDIX C

Photographs taken throughout the research



1. Sampling location was selected at the dumpsite



2. The coordinate of the location was taken



3. The pH and moisture content were measured



4. The soil was dug at the depth of 20cm



5. Soil was dug using the soil auger



6. Sample was put into the ziplock bag



7. Soil samples were prepared in the aluminium foil for 48 hours



8. Samples were dried in the oven at 80°C



9. Samples were sieved through 500micron sieve



10. Samples were weighed for 4g in the beaker

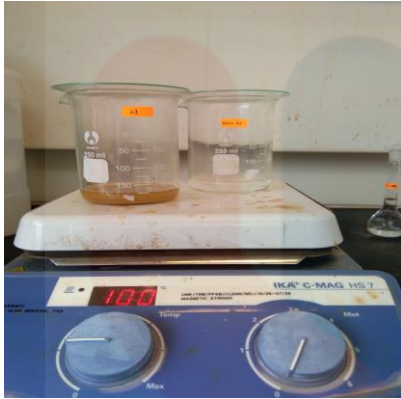


11. Deionized water were added into each sample to wet it



12. 15ml of HNO₃ was added into each sample

KELANTAN



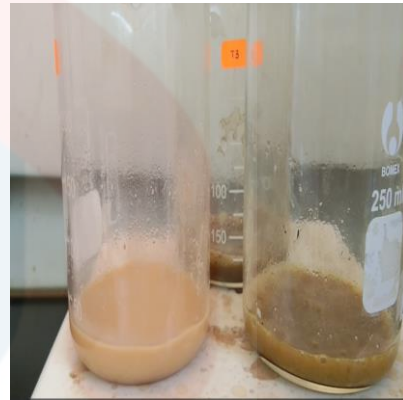
13. Beakers were placed on the hot plate



14. Samples were heated at 100°C for an hour



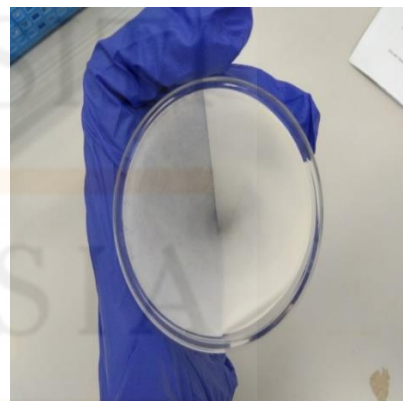
15. 5ml of 30% H₂O₂ was added into the each sample



16. Samples were heated for next one hour



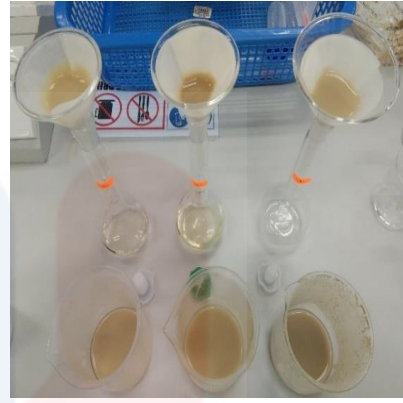
17. Samples were allowed to evaporated until 10ml remained and 25ml of deionized water was added



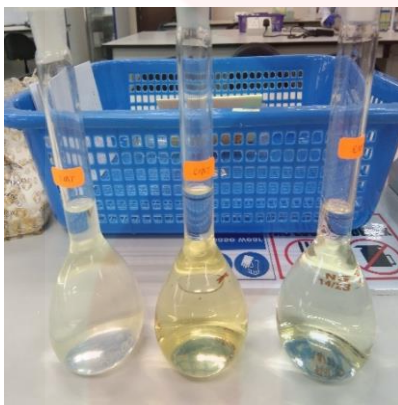
18. Filter paper was folded in the funnel



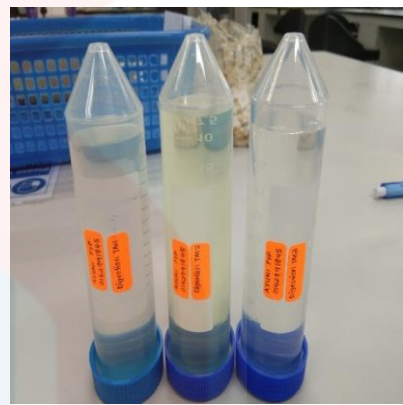
19. Samples were filtered into 100ml flasks



20. The residues were rinsed with deionized water



21. Samples were inverted and mixed well



22. Samples were transferred into the tubes



23. Samples were kept into the chiller for further analysis

UNIVERSITI
KELANTAN



UNIVERSITI

MALAYSIA

KELANTAN