# PRELIMINARY ASSESSMENT ON THE DISTRIBUTION OF HEAVY METAL WITHIN CHENAAM ESTUARY USING GIS

HARSHAAN ARUMUGAM

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA

2022

PRELIMINARY ASSESSMENT ON THE DISTRIBUTION OF HEAVY METAL WITHIN AIR ITAM ESTUARY

BY

HARSHAAN ARUMUGAM

This dissertation is submitted to

**UNIVERSITI SAINS MALAYSIA**

As partial fulfilment of requirement for the degree of

**BACHELOR OF ENGINEERING (HONS.)**
**(CIVIL ENGINEERING)**

School of Civil Engineering
Universiti Sains Malaysia

2022

**SCHOOL OF CIVIL ENGINEERING**
**ACADEMIC SESSION 2020/2021**

**FINAL YEAR PROJECT EAA492/6**
**DISSERTATION ENDORSEMENT FORM**

Title: **Preliminary Assessment on the Distribution of Heavy Metal Within Chenaam Estuary Using GIS**

Name of Student: Harshaan Arumugam

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

______________________

Date: 10 August 2022

Endorsed by:

Dr. Fatehah Mohd Omar (Ph.D.,UniGe)
Lecturer in Environmental Engineering
School of Civil Engineering
Universiti Sains Malaysia
Engineering Campus
14300 Nibong Tebal
Pulau Pinang, MALAYSIA

______________________
(Signature of Supervisor)

**Name of Supervisor**: Ts. Dr. Fatehah Mohd Omar

**Date**: 11-08-2022

Approved by:

______________________
(Signature of Examiner)

**Name of Examiner:** Dr. Rosnani Alkarimiah

**Date:** 11-08-2022

# ACKNOWLEDGEMENT

It is my pleasant duty to express my gratitude to all the kind people who have been a source of great help and encouragement from the time I began this study till its completion. First and foremost, I want to express my gratitude to my family for supporting me in all of my endeavors and for motivating me to pursue my goals. I want to express my gratitude to my parents, Mr. Arumugam and Mrs. Vasanthi, who helped me both financially and emotionally. I've always known you had faith in me and had my best interests in mind. I'm grateful that you taught me that knowing and understanding oneself was the first step toward knowing and understanding others.

I also owe a great deal to my supervisor, Ts. Dr. Fatehah Mohd Omar and co-supervisor, Sr. Dr. Abdul Hakim Salleh who were able to offer invaluable suggestions for my thesis's improvement. Their encouragement and guidance have made this thesis stronger and more effective than I imagined possible.

I also owe a great debt to my mentors, Miss. Siti Nurwajihah Binti Abu Bakar and Mr. Muhammad Fitri Bin Mohd Akhir who shared ideas, suggested topics and offered materials for my thesis.

I would also like to thank the residents of Kampung Sungai Chenaam for their kind gestures by helping me during sampling and made my work easier.

At last, I acknowledge immense debt to my friends, especially Miss. Sarmila Nagarajan who helped me a lot during my lab work.

# ABSTRAK

Pencemaran air memberi kesan negatif kepada organisma manusia dan akuatik. Oleh itu, penilaian dan pemerhatian kritikal terhadap pencemaran air dan akibatnya menjadi penting. Sungai Air Itam menerima sisa daripada pelbagai sumber seperti aktiviti pertanian, aktiviti berperahu, akuakultur dan sisa pepejal perbandaran. Akibatnya, air dan sedimen Sungai Air Itam tercemar dengan logam berat. Penilaian awal telah dijalankan ke atas kepekatan logam berat dalam air dan sampel sedimen yang dikumpul di sepanjang saluran pengairan Sungai Air Itam yang sebahagiannya dibina semula di Kampung Sungai Chenaam. 11 titik persampelan dikenal pasti dari hulu ke atas hingga hilir berhampiran muara Sungai Air Itam. Titik persampelan terakhir terletak di pintu air Jeti Sungai Air Itam. Bagi setiap sampel, jumlah kepekatan 21 logam berat ditentukan melalui kaedah Inductively Coupled Plasm Optical-Emission Spectroscopy (ICP-OES). Daripada pengukuran tersebut, keputusan yang ketara diperolehi terhadap 8 jenis logam berat iaitu kromium (Cr), besi (Fe), plumbum (Pb), kadmium (Cd), kuprum (Cu), mangan (Mn), nikel (Ni). dan zink (Zn). Cr tidak dikesan dalam mana-mana sampel air yang dikumpul di seluruh Sungai Air Itam. Oleh itu, kepekatan keseluruhan Fe, Pb, Cd, Cu, Mn, Ni dan Zn dalam sampel air adalah antara 0.51-2.49, 0.00-0.12, 0.0089-0.028, 0.057-0.063, 0.066-0.57, 0.066-0.57, 0.0.6-0.8, 0.00-0.0. mg/L masing-masing. Sebaliknya, kepekatan keseluruhan Cr, Fe, Pb, Cd, Cu, Mn, Ni dan Zn dalam sampel sedimen adalah antara 0.063-0.38, 28.53-191.04, 0.00-0.24, 0.032-0.12, 0.11-0.36, 0.11-0.36, 2.79, 0.00-0.24 dan 0.30-2.94 mg/L masing-masing. Trend penurunan logam berat diperhatikan dalam air permukaan sebagai Fe>Mn>Ni>Cu>Pb>Zn>Cd>Cr dan dalam sedimen sebagai Fe>Mn>Zn>Cu>Cr>Pb>Ni>Cd.

# ABSTRACT

Water pollution negatively impacts both human and aquatic organisms; hence, the evaluation and critical observation of water contamination and its effects have become crucial. Sungai Air Itam receives wastes from various sources such as agricultural activity, boating activity, aquaculture and municipal solid wastes. As a result, Sungai Air Itam's water and sediment became polluted with heavy metals. A preliminary assessment was conducted on the concentration of heavy metals in water and sediment samples collected along the partially reconstructed irrigation channel of Sungai Air Itam in Kampung Sungai Chenaam. 11 sampling points were identified from the upstream up till the downstream near the river mouth of Sungai Air Itam. The final sampling point is located at the water gate of Sungai Air Itam Jetty. For each sample, the total concentration of 21 heavy metals was determined via the Inductively Coupled Plasm Optical-Emission Spectroscopy (ICP-OES) method. From the measurements, significant results were obtained on 8 types of heavy metals, namely chromium (Cr), iron (Fe), lead (Pb), cadmium (Cd), copper (Cu), manganese (Mn), nickel (Ni) and zinc (Zn). Cr was not detected in any of the water samples collected throughout Sungai Air Itam. Therefore, overall concentrations of Fe, Pb, Cd, Cu, Mn, Ni and Zn in water samples ranged from 0.51-2.49, 0.00-0.12, 0.0089-0.028, 0.057-0.063, 0.066-0.57, 0.00-0.11 and 0.046-0.068 mg/L respectively. On the other hand, overall concentrations of Cr, Fe, Pb, Cd, Cu, Mn, Ni and Zn in sediment samples ranged from 0.063-0.38, 28.53-191.04, 0.00-0.24, 0.032-0.12, 0.11-0.76, 0.32-2.79, 0.00-0.24 and 0.30-2.94 mg/L respectively. The decreasing trend of heavy metals were observed in surface water as Fe>Mn>Ni>Cu>Pb>Zn>Cd>Cr and in sediment as Fe>Mn>Zn>Cu>Cr>Pb>Ni>Cd.

# TABLE OF CONTENT

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER 1

## INTRODUCTION

### 1.1 Background Study

Since the dawn of civilization, rivers have contributed a significant role in shaping and affecting the growth of the country. Almost every major town in Malaysia is situated along a river. Manufacturing and construction are currently the primary sources of the country's economic growth. The industrial sector contributes over 46% of Gross domestic product (GDP), whereas the contribution of the agricultural sector has decreased to about 13%. Rapid growth through urbanization, industrialization and land development has always had a negative impact on the environment. Such development-related impacts have not been spared rivers (Haji, 2017).

Both point and non-point source pollutions causes river water quality to deteriorate, which is associated to urbanization. The general trend, according to the data provided by the Department of Environment, indicates a gradual but persistent worsening in the water quality of rivers across the nation. In terms of heavy metal contamination, out of 116 rivers monitored, fifty-five rivers have been discovered to surpass the maximum limit of 0.001 mg/L for cadmium, forty-four rivers surpassed the maximum limit of 1.00 mg/L for iron, thirty-six rivers surpassed the maximum limit of 0.01 mg/l for lead and twenty rivers surpassed the maximum limit of 0.0001 mg/L for mercury. Industrial and Domestic sewage, discharges from palm oil factories, rubber manufacturing, and livestock farming are the main causes of organic pollution of water. Excessive concentrations of suspended sediment in downstream stretches of rivers are produced by mining activities, building and road construction, logging and deforestation. Organic pollution of water has produced environmental problems and negatively impacted aquatic organisms in some industrial and urban areas. each day, an estimated 50-60 tons of garbage enter the river system in the Klang Valley alone (Haji, 2017).

Heavy metals pollution in the natural environment is regarded as a major crisis globally, with a large share in third world countries, such as Malaysia. Contamination of heavy metals in river is a global issue since contaminants aren't cleared from water by self-purification, but instead collect in reservoirs due to biological and geological factors, where they might enter the biological chain (Sany et al., 2011). Lithogenic and anthropogenic are the two major sources of heavy metals in the environment. Lithogenic refers to a natural process, such as rock weathering or volcanic activity, that contributes to heavy metal enrichment in reservoir water. Anthropogenic sources are due to the human activities such as industry, agriculture, mining, and urban development construction can transport pollutants to marine waters via rivers and outlets. Heavy metals have been accumulating in the marine environment due to urban and industrial activity in recent decades, and when they reach standard concentrations, they have toxic effects on living creatures, as well as reducing survival, growth, and species variety (Islam et al., 2015).

Heavy metal poisoning can have a range of adverse health impacts on human. It can result in a range of medical issues, including psychological disorders, harm blood components, damage to the kidneys, liver, lungs, and other vital organs. Long-term exposure to heavy metal may also impede the development of physical, muscular, and neurologic degenerative processes that resemble illness like Parkinson's and Alzheimer's disease. Exposure over an extended period of time to some heavy metals or their compounds can harm nucleic acids, cause mutations, mimic hormones, disturb the endocrine and reproductive systems, and finally cause cancer (Engwa et al., 2019). The development of aquatic creatures such as phytoplankton, zooplankton, and fish are also inhibited by heavy metal overload. Metallic substances have the potential to disrupt oxygen levels, mollusk development, byssus production, and reproductive functions (Gheorghe et al., 2017).

## 1.2 Problem Statement

Penang State, which is situated on Peninsular Malaysia's northwest coast, (5°8'–5°35'N latitude and 100°8'–100°32' E longitude), is separated into 2 parts, which are Seberang Perai and Penang Island. One of Malaysia's most urbanized, developed, populated, and economically important state is Penang. (Alsaffar et al., 2016). Even tough, Penang is a prosperous and advanced state, but it lacks one important resource which is clean water, both on the island and mainland. Heavy metal concentrations were found to be higher on northwest coast of Peninsular Malaysia than in other places, due to extensive land usage and industrialization (Talib et al., 2003). This state has had a problem with unclean water for at least ten years, with some locals stating it has been going on for over 40 years. According to Numbeo, the water pollution in Penang on December 2018 is considered high with a pollution index of 61.11 (Kata Malaysia, 2019).

According to a news article by The Straits Times (2018), an environmental consultant for over 20 years, pointed out that Seberang Perai is the most polluted area of Penang. Nibong Tebal is a major and most populated town in the Seberang Perai district. For instance, Sungai Tengah from Nibong Tebal believed to have been polluted by effluent discharged from adjacent factories and farms has impacted the livelihood of fishermen. Unfortunately, octopuses and prawns, as well as fish, are now barely surviving in the contaminated water. Only a few dead fish were discovered floating in the river when the pollution first began. However, the situation has worsened, with thousands of fishes have been discovered dead. As a result, fishermen were unable to capture enough fish to sell, and their revenue was severely disrupted (Kata Malaysia, 2019).

Over the year, there have been numerous studies on heavy metal content in rivers in Seberang Perai including Sg. Juru (Idriss, 2012), Sg. Kerian (Alsaffar et al., 2016) and Sg. Perai (Yii and Hashim, 2020). However, until now there is inadequate information on heavy metal content in Sungai Air Itam, Nibong Tebal which receives numerous pollutants from upstream to downstream of the river. Thus, this study has been conducted to analyze the metal concentrations in Sungai Air Itam from eleven different locations along the river.

## 1.3 Objectives

This research aims to evaluate the heavy metal pollution at Sungai Air Itam. The objectives in this study are:

i. To determine the heavy metal concentrations in surface water and sediment.
ii. To evaluate the heavy metal concentration distribution within the lower basin of Sungai Air Itam using GIS mapping.

## 1.4 Scope of Study

The site chosen for this study is Sungai Air Itam. This river is heavily used by the locals for a variety of purposes, including drinking water, agriculture and plantation irrigation, aquaculture, and fishing. Some of these activities mentioned above give significant impact to this river. The discharge of waste into Sungai Air Itam, whether directly or indirectly, contaminates the river. When a river is constantly exposed to the pollutants, its quality deteriorates.

In a previous study, total concentrations of chromium (Cr), iron (Fe), lead (Pb), cadmium (Cd), copper (Cu), manganese (Mn), nickel (Ni), and zinc (Zn) in surface water samples were analyzed to evaluate the quality of the surface water in the major rivers at Penang, Malaysia, which are Sungai Muda, Sungai Jarak, Sungai Kerian, and Sungai Kongsi (Alsaffar et al., 2016). Hence, the concentration of these similar heavy metals will be determined by this investigation in Sungai Air Itam. The heavy metals present in Sungai Air Itam and its tributaries were determined using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES).

Furthermore, preliminary observation was carried out to identify and associate pollution levels to human activities. The maps provided on Google (Google Maps, iPlan Malaysia, and Google Earth) were used to compare. Aside from that, the findings will aid in a better understanding of the types of human activities that lead to pollution in Sungai Air Itam at the conclusion of the study. The findings of the tests will then be mapped out using GIS.

## 1.5 Significance of Study

In 2018, within Penang river's basins, 10 (25.6%) were found to be polluted and 21 (53.8%) slightly polluted. Exposure to pollution would threaten marine resources, endanger the stability and diversity of the marine ecosystem and species, and have negative impact on coastal communities. As a result, ensuring access to a clean and healthy water supply has become a major concern for the government (Penang Institute, 2020). Hence, evaluating the concentration of heavy metals in Sungai Air Itam will ensure whether the water from this river is not harmful to humans and other living organisms.

## 1.6 Dissertation Outline

The thesis is organized into five chapters to ease the viewing and understanding. The general description of each of the chapters is explained below.

**Chapter 1: Introduction**

This chapter contains information about the background of the study, the problem statement of the research, the research objectives, and the scope of research which briefly gives an overall understanding of this thesis as well as explains the purpose of why this research is carried out and gives an idea about the outcome of this research.

**Chapter 2: Literature Review**

This chapter provides a fundamental understanding of the research topic based on research papers and articles by scientists and experts. The paper referred was done by previous researchers.

**Chapter 3: Methodology**

This chapter discusses the methods used to obtain data related to this research. Elements such as workflow and conducting experiments are described in this chapter. It provides detailed explanation, starting from the collection of samples until the analysis part.

**Chapter 4: Results and Discussion**

This chapter evaluates the results obtained from the previous chapter. The objectives of this thesis will be identified in this chapter. The data analysis obtained were discussed in detail includes data from laboratory works and GIS mapping.

**Chapter 5: Conclusion and Recommendations**

This chapter finalizes and summarizes the research including recommendations for future research and study in this field.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 River Pollution

The term "river pollution" refers to the contaminating of a river's water bodies, typically as a result of human activities. River pollution results when pollutants are discharged into the natural ecosystem (Hakimi, 2020). River water quality and environmental integrity are typically not protected by laws in many parts of the world, and even where laws do exist, they are often not applied consistently or effectively (Hydro International, 2018). Hence, river pollution is a serious issue in the global environment (Haseena et al., 2017).

Sediment is one of the three primary causes of water contamination in streams and rivers, according to the Environmental Protection Agency (Beaudry, 2019). In many aquatic systems, deposition of contaminants, including heavy metals, can increase sediment concentrations to levels that could be harmful to aquatic life. The adsorption of dissolved heavy metals is significantly aided by sediments and suspended particulate matter (SPM). They can also serve as a metal reservoir, by releasing them to the water column under changing physical and chemical conditions. The behavior of metals, including sedimentation and resuspension, has drawn the interest of many researchers because it is well known that sediments play a crucial role in regulating the metal concentrations in many of these aquatic ecosystems (Karbassi et al., 2008).

Malaysia is blessed with an abundance of water resources and heavy rainfall. An estimated 900 billion $m^3$ of water flow into the river systems annually with an average annual rainfall of 3,000 mm (World Wide Fund for Nature, n.d.). However, drastic increase in urbanization in all of the major cities and towns has degraded the quality of Malaysian rivers. The development of agriculture and industrialization have had a very harmful impact on rivers. Hence, there is water shortage in many areas of the nation (Chan, 2012). There are now 25 river basins that have been designated as having water stress (Chan et al., 2003).

The expense of treating contaminated waters is too costly, and in certain cases, they cannot be treated for consumption, which significantly limits the total amount of water that is available. Unfortunately, due to river pollution, the abundance of water resources in the basin does not ensure an adequate supply for Malaysian citizens. (Afroz et al., 2014). Moreover, river pollution has a dangerous effect on aquatic flora and fauna (Agrawal et al., 2010).

## 2.2 Causes of River Pollution

River pollutants come from either point sources or non-point sources (Jerry, 2022). A point source is a single, identifiable source of pollution, such as a discharge pipe from a factory or sewage treatment facility. Commercial and industrial businesses use hazardous materials in manufacturing or maintenance, and then release various wastes as a result of their operations. Pollutants like solvents, petroleum products (like oil and gasoline), or heavy metals may be present in the raw materials and waste. Animal feeding operations, animal waste lagoons, or storage, handling, mixing, and cleaning areas for pesticides, fertilizers, and petroleum can all be point sources of pollution from agricultural activity. Wastewater treatment facilities, landfills, utility stations, motor pools, and fleet maintenance facilities are examples of municipal point sources (Julie, 2022).

In contrast to point-source pollution, non-point source pollution may derive from many different sources (Edwin et al., 2009). Nonpoint source pollution happens when contaminants are carried into waterways such as rivers, streams, lakes, wetlands, and even groundwater by runoff from rain and snowmelt. Illegal discharges, illegal dumping of solid or liquid waste, hazardous waste spills, chemical spills, agricultural operations, fertilizer application, soil sediment from construction projects, construction debris, improper grading, improper quarrying, pesticide application, improper storage of solid waste, discharge of chemical substances, motor oil, antifreeze, paint, and other similar practices are some of these sources (County of Santa Clara, 2022).Because nonpoint source water contamination results from everyday activities, it is difficult to control (Wu, 2017).

### 2.2.1 Agricultural Activity

In most of the developing countries in the world, surface water is at a serious risk of pollution due to chemicals utilized in agricultural activities (Keskin, 2010).The use of various types of fertilizers, insecticides and pesticides in agriculture cause river pollution (Begum et al., 2008). These chemical-based products are used to safeguard crops against pests, weeds, and infections. The runoff from the agricultural farms is one of the major reasons why rivers are being contaminated. Rainwater makes it possible for farm sediment to disperse into surrounding water bodies like lakes and rivers (Ghosh, 2020). Even though fertilizers are crucial for supplying enough nutrients and assuring effective harvests, repeated long-term applications of fertilizers, insecticides and fungicides that include metals can eventually build up to potentially dangerous levels. The stream water will become unsuitable for in-stream use or abstraction due to the presence of organics, heavy metals, and bacterial contamination. (Agrawal, 1999). Other environmental effects are linked to toxicological and ecotoxicological dangers, such as exposure to non-target organisms, unfavorable aftereffect on particular species, communities, or ecosystems as a whole (Muhammetoglu et al., 2010).

### 2.2.2 Boating Activity

Fishing activities significantly increases the usage of motor boats in water bodies. Every boat releases a specific amount of oil into the water. Even the smallest outboard motor boat may leave in its wake a film of that is spilling from bearings or in the exhaust (Scorer et al., 1963). In aquatic habitats, boat engine fuel can potentially cause lead pollution (Murphy and Eaton, 1983). One of the most prominent possible signs of outboard motor environmental pollution is rising lead (Pb) levels in lakes, rivers, and estuaries, especially where lead is added as a fuel additive (Whitfield and Becker, 2014). When oil spills over water, it starts to spread right away. Both the liquid and gaseous parts evaporate. Some drop to the bottom due to gravity pulls, while others dissolve in water, even oxidize, or go through bacterial transformations. The resultant contamination of the soil has a severe effect on terrestrial life. As the dissolving of the less volatile components with the ensuing emulsified water impacts aquatic organisms, so does the evaporation of the volatile lower molecular weight components affect aerial life (Greenland and Molen, 2006). The main reasons why oil leaks occur in coastal locations are boat accidents, crashes or sinking (Singkran, 2013). Other than that, the major source of heavy metals are antifouling paints from boats. Anti-fouling paints work by gradually releasing a toxin into the boat's surrounding. Marine creatures are poisoned by the soluble toxin. In locations with high boating activities, some antifouling substances, including copper, can bioaccumulate and have indirect effects on marine organisms further up the food chain. Antifoulants used in boating have been shown to harm non-target species when used in high amounts (Nitonye et al., 2015).

### 2.2.3 Aquaculture

Aquaculture, or simply "fish farming," is the practice of raising fish for human consumption (Cassidy, 2019). The aquaculture industry, which first appeared in the 1920s, is expanding quickly and is now a key pillar of Malaysia's national food security. Aquaculture is also currently growing into a significant economic sector in Malaysia. According to estimates, the yearly demand for fish would rise to 1.7 million tons in 2011 and then to 1.93 million tons by 2020 as a result of an expanding population and a growing preference for fish as a lean source of animal protein. To fulfill the anticipated demand by 2020, aquaculture production will need to increase from the current annual output of approximately 525,000 tons to 790,000 tons (Yusof et al., 2022). Despite its many advantages, aquaculture in Malaysia is still closely associated with environmental issues (Kurniawan et al., 2021). Aquaculture projects are normally situated on or near estuaries and coastal areas because these waterways frequently offer perfect conditions for salt water aquaculture (Mokhtar et al., 2009). Many aquaculture farms that are land-based and use filtration and recirculation systems, thus removing the pollution risk of effluent being dumped into natural water bodies (Healey et al., 2016).The aquaculture industries are subjected to a variety of chemical, biological and other pollutants. The use of antibiotics, agrochemicals formulated feed resulted in presence of several chemical and biological contaminants beside the anthropogenic inputs like heavy metals (Retnam and Zakaria, 2009). Scientifically, farmers are not allowed to use illegal pharmaceuticals in aquaculture. Even though, some illicit substances, such furazolidone and chloramphenicol, were frequently used in aquaculture industry to treat and prevent disease, which helped to increase bacteria's resistance. It is difficult to evaluate how using a lot of chlorides, heavy metals, and pharmaceutical residues during pond disinfection may affect the ecological environment (Healey et al., 2016).

### 2.2.4 Municipal Solid Waste Disposal

Municipal solid wastes (MSW) are very nonhomogeneous combination of trashes from commercial, residential, and industrial sectors. Boxes, papers, office disposable tables, cans, yard wastes, disposables tableware and clothing are typical components of residential and commercial MSW, while office papers, corrugated boxes, plastics, wooden pallets and classroom and restaurant wastes are typical components of institutional and industrial MSW. Despite the possibility of a wide range in the composition of MSW, it is normally acknowledged that organic materials make up the majority of MSW (Adhikari et al., 2018). Municipal solid waste management in Malaysia has become a more difficult issue for authorities as a result of the exponential rise in solid waste generation as a result of rapid urbanization and population growth (Kamaruddin et al., 2017). The generation of Malaysian MSW has increased by more than 91% in the last 10 years (Samsudin and Don, 2013). In developing nations, a typical solid waste management system exhibits a number of issues, such as inadequate collection coverage and inconsistent collection services (Manaf et al., 2009). Particularly, most rural areas have insufficient service coverage and no collection. Residents of rural areas lack access to waste collection services. Hence, they throw trash into the river (Sekito et al., 2013). Approximately 20% of the solid wastes are discharged into rivers due to Malaysian's irresponsible behavior. The drawback is that by discharging pollutants into the rivers, it results in the depletion of natural resources and the destruction of the ecosystem (Jalil, 2010). A serious problem of MSW is it might potentially cause the local environment to become contaminated with heavy metals (Sharifi et al., 2016).

## 2.3 Heavy Metals

Although frequently not precisely defined, the term "heavy metal" is generally used to refer to metals with specific weights greater than $5 g/cm^3$. Approximately 40 elements fall under this group (Sharma and Agrawal, 2003). Despite the fact that several metals are required for living organisms at minimal concentrations like as micronutrients (Copper, Cu; Zinc, Zn; Iron, Fe; Manganese, Mn; Cobalt, Co; Molybdenum, Mo; Chromium, Cr; and Selenium, Se) and macronutrients (Calcium, Ca; Magnesium, Mg; and Sodium, Na), at higher concentrations, they could cause hazardous effects impairing organisms' growth, metabolism, or reproduction with impact on the entire trophic chain, including humans. Additionally, even at very low concentrations, non-essential metals including Lead (Pb), Cadmium (Cd), Nickel (Ni), Arsenic (As), and Mercury (Hg) increase the overall harmful effect on organisms (Gheorghe et al., 2017b). The dose, method of exposure, chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals, all affect how hazardous they are (Tchounwou et al., 2012). Due to its negative effects on human health, heavy metal environmental contamination has recently gained international attention (Timothy and Williams, 2019).

Even though heavy metals are naturally existing compounds which are present throughout the earth's mantle, most of the environmental pollution and human exposure are caused by anthropogenic activities like metal mining and smelting, industrial manufacturing and use, agricultural and domestic use of metals metal-containing compounds (Tchounwou et al., 2012). Industrial effluents, mining, fuel production, military operations, smelting procedures, use of agricultural chemicals, brick kilns, small-scale industries, and coal burning are examples of anthropogenic sources of heavy metal contamination (Bharwana et al., 2013).

Heavy metal concentrations in aquatic ecosystems are often measured by comparing their levels in the water and sediments, where they typically reside at low levels in the water and reach significant concentrations in sediments. The majority of heavy metals have a tendency to collect in sediments, while some heavy metal inputs may be in dissolved or particulate form. Usually, recent inputs are the cause of their presence in water (Hejabi et al., 2011). Based on the chemical and geological conditions, it has been discovered that metal ions partition into several chemical forms connected with a range of organic and inorganic phases in the sediment storage. Knowledge of metal speciation in the sedimentary environment may be more crucial for risk assessment studies than total quantities of traces because the partitioning pattern of traces is crucial to the potential toxicity and mobility of contaminating metals (Farkas et al., 2007).

### 2.3.1 Chromium, Cr

Chromium (Cr) is the 17th most abundant element in the Earth's crust. Pressure-treated lumber, refractory bricks, ceramic glazes, pigments, textile dyes and mordants, tanning animal hides, alloying and plating are just a few of the industrial uses for Cr. This extensive anthropogenic usage of Cr led to significant environmental contamination, which has grown in importance over the past few years. Chromium exists in a variety of oxidation states, although the trivalent Cr (III) and hexavalent Cr (VI) species are the most stable and predominant forms (Oliveira, 2012). Cr (III) is said to be a necessary element in mammals as it plays a significant role in the metabolism of glucose, lipids, and proteins. Trivalent chromium has relatively low toxicity since it has weak membrane permeability, is noncorrosive, and has very little ability to bio magnify in the food chain. Hexavalent chromium is regarded as more hazardous than trivalent form because it may easily pass-through cell membrane (Bakshi and Panigrahi, 2018). Even at low concentrations, prolonged exposure to chromium can harm the skin, eyes, blood, respiratory system, and immune system. Chromium's genotoxic action causes oxidative stress, DNA damage, and other damages on a cellular level that might result in the growth of tumors (Tumolo et al., 2020).

### 2.3.2 Iron, Fe

Iron is the 2$^{nd}$ most abundant metal and 4$^{th}$ most abundant element in the Earth's mantle (Xing and Liu, 2011). The majority of the iron in surface water is in its ferric form (Kamble et al., 2013). Water can get contaminated by iron either naturally or as a result of domestic and industrial waste and effluents. Iron is an important element for hemoglobin, myoglobin, and other enzymes, and a lack of it can cause anemia and other health problems. However, its overuse leads to serious health issues in humans, including infertility, heart disease, diabetes, liver cirrhosis, and cancer. Higher iron concentrations cause water to alter in color, taste, and smell, leave stains on clothing, and damage water pipe lines (Kumar et al., 2017). Moreover, by destroying benthic food supplies, Fe may have the potential to indirectly impact aquatic animals like fish. High concentrations of this metal in the water can also be harmful to aquatic life because it precipitates on their gills and lowers their ability to breathe (Sanders et al., 1998).

### 2.3.3 Lead, Pb

According to the new European REACH regulations, lead (Pb), the second-worst contaminant among heavy metals after arsenic, has lately been identified as the chemical of major concern. (Ashraf et al., 2017). The crust of the Earth contains the naturally occurring hazardous element lead. Due to its widespread use, there have been serious public health issues, environmental damage, and human exposure in many different parts of the world. Mining, smelting, manufacturing, recycling, and, in some nations, the constant utilization of leaded paint and aviation fuel are important sources of environmental pollution. The production of lead-acid batteries for automobiles results for more than three-quarters of all lead usage worldwide. Nevertheless, lead is also present in a wide range of other items, including pigments, paints, solder, stained glass, lead crystal glassware, ammunition, ceramic glazes, jewelry, toys, and several traditional medicines and cosmetics. Young children are more susceptible to the toxic effects of lead and can have severe, long-lasting health problems, especially on the brain and nervous system development. Adults who consume lead run the risk of developing chronic kidney disease and high blood pressure. High amounts of lead exposure during pregnancy can result in stillbirths, premature births, low birth weights, and miscarriages (World Health Organization, 2021).

### 2.3.4 Cadmium, Cd

Cadmium (Cd) is a heavy metal that is widely known to be an environmental contaminant and a possible poison that could be harmful to human health. The earliest cases of cadmium toxicity in people working in zinc smelters were first noted in the nineteenth century. Chronic Cd toxicity typically affects industrial workers exposed to Cd or people living in highly polluted areas. Cd is a contaminant of zinc and lead containing ores. Cd is still utilized in Li-Cd battery production, pigment production (particularly for plastics), and electroplating. Today, workers who handle, assemble, and disassemble batteries, computer circuit boards, and other types of "electronic waste" are most at danger; however, symptoms of chronic poisoning take years of exposure to become evident. Furthermore, based on the route of consumption, chemical form, amount, tissue affinity, age, sex, and whether exposure is acute or chronic, heavy metal poisoning can exhibit itself in various ways. The primary organ harmed by persistent Cd exposure and toxicity is the kidney (Johri et al., 2010).

### 2.3.5 Copper, Cu

The engineering industry frequently chooses copper for its vast range of industrial uses. It is regarded as one of the first hazardous metals ever discovered. It supplies the copper forming sector with raw materials. Because of emissions from different sectors, as well as from natural and other man-made sources, the amount of copper in the environment is higher than it should be. Environmentalists are paying close attention to the rising copper levels in the environment since they pose a major hazard to people as well as to flora and fauna. Due to its inability to degrade through biological processes, biological magnification, and extended environmental persistence, copper pollution is harmful to human health. Its excessive consumption can cause a variety of acute and chronic diseases, as well as health risks for flora, fauna, and humans. Its overconsumption poses a risk to the health of people, animals, and plants in a variety of acute and chronic illnesses. Wilson's disease is reportedly brought on by routine and continuous copper consumption in amounts above those recommended for human consumption (Shrivastava, n.d.).

### 2.3.6 Manganese, Mn

The earth's crust contains manganese (Mn), a heavy metal that occurs naturally. The most common forms of this necessary metal, which is the 12th most abundant element, are oxides, carbonates, and silicates. Mn is widely distributed in streams as a result of earth erosion. Furthermore, Mn's natural properties have led to widespread employment of the element in numerous industrial applications. Batteries, ceramics, steel, cosmetics, leather, fireworks, glass, and other fabrics are all made with manganese. Additionally, methylcyclopentadienyl Mn tricarbonyl, an antiknock gasoline additive, contains Mn. Mn is also a component of fungicides and insecticides, smoke inhibitors, and contrast agents used in MRI scans for medical purposes. Despite the availability of Mn in the environment, food sources account for the majority of the typical human's Mn intake (Chen et al., 2015).

### 2.3.7 Nickel, Ni

Nickel is the 24th most abundant element in the earth's crust and has been found in various media throughout the whole biosphere. Thus, although in varying degrees, humans are always exposed to this element. Prior to present levels, the average natural nickel exposure from food was probably a little, but not substantially, lower. Nickel is a valuable metal, especially when used in different alloys, batteries, and nickel plating. In particular, nickel compounds are utilized as pigments and catalysts. The amount of nickel in the environment is mostly determined by natural sources, pollution from companies that produce nickel, and airborne particles from the burning of fossil fuels. Little care should be given to nickel absorption from air pollution. The oral intake of nickel may be dramatically influenced by leaching or corrosion processes. Therefore, human nickel exposure is highly varied and comes from a range of sources. Major relevance is attached to occupational nickel exposure, and nickel leaching may increase dietary intakes and cutaneous exposures (Grandjean, 1984).

### 2.3.8 Zinc, Zn

Zinc is crucial for life and is involved in many biological processes, including protein synthesis, cell division, immune system and growth in organisms (including people, animals, and plants). Because zinc has beneficial properties such anti-corrosion, strong durability, and wear resistance capabilities, the industrial sector actively uses it to create items from galvanized brass, metal, and in die casting. Zinc is the fourth most often used metal. However, several research revealed that zinc in surface waters may be hazardous to aquatic organisms over the long term, pose a risk to aquatic species, and have environmental implications. Zinc has been assessed as posing unacceptable hazards in both local and regional scenarios based on the European Union risk assessment report. Additionally, because zinc exists naturally, its environmental effects cannot be evaluated in the similar manner as those of chemical compounds manufactured by humans because doing so would not be possible and might potentially have adverse impacts oecosystem as a whole (Andarani et al., 2020).

## 2.4 Impacts of Heavy Metal Presence in River

In most major cities, the issue of harmful metals polluting the water has started to raise concerns. Geoaccumulation, bioaccumulation, and biomagnifications may result from the hazardous heavy metals infiltrating the ecosystem. Heavy metals like Fe, Cu, Zn, Ni, and other trace elements are necessary for biological systems to function properly, and their excess or shortage can cause a variety of illnesses. Heavy metal's potential to accumulate in biosystems through contaminated water has made their poisoning of food chains a pressing issue in recent years (Prabu, 2009). Metals are poorly soluble in water; they are adsorbed and collect on the sediments at the bottom, acting as sinks. River sediments have a significant impact on the contamination of river water (Paramasivam et al., 2015). The capacity of soil to filter, absorb, and precipitate the compounds drops on its surface is one of its most essential qualities. The status and function of the soil microbial biocenosis, soil fertility, and human health are all affected by the existence of significant concentrations of various highly biologically active chemical substances such as petroleum products, dioxins polychlorinated biphenyls and furans, polycyclic carbohydrates, pesticides and heavy metals (Donkova and Kaloyanova, 2008). Heavy metal pollution is arguably the most dangerous issue because it is almost completely irreversible. Human health, flora, and fauna can be impacted by contamination through direct or indirect contact (Amanullah, 2018).

### 2.4.1 Impact of Heavy Metal Pollution Towards Human

Metals have been proven to poison people both acutely and chronically (Mahurpawar, 2015). Different human organs are impacted by a number of acute and chronic harmful effects of heavy metals. Examples of the consequences caused by the toxic effects of heavy metals include gastrointestinal and kidney failure, neurological system disorders, skin lesions, vascular damage, immune system malfunction, birth defects, and cancer. Exposure to 2 or more metals simultaneously may have cumulative impacts. Exposure to excessive doses of heavy metals, especially lead and mercury, can cause serious side effects such as bloody diarrhea, and abdominal cramping. Another crucial feature of chronic exposure is the discovery of many metals as human carcinogens. Arsenic, cadmium, and chromium are carcinogenic metals that can interfere with DNA synthesis and repair. Heavy metal toxicity and carcinogenicity are dose-dependent. In humans, high-dose exposure creates serious reactions that exacerbate DNA damage and neuropsychiatric problems. The toxic mechanism of heavy metals functions in similar pathways normally via reactive oxygen species (ROS) generation, enzyme inactivation, and suppression of the antioxidant defense (Mood et al., 2021).

### 2.4.2 Impact of Heavy Metal Pollution Towards Flora

The heavy metals that are soluble in soil solution or that have been solubilized by root exudates are those that plants can absorb. Certain heavy metals are necessary for plant growth and maintenance, but too much of these metals can be hazardous to plants. Plants' capacity to store essential metals also makes it possible for them to accumulate non-essential metals. Due to their inability to be broken down, metals have harmful direct and indirect effects on plants when concentrations within the plant exceed optimal levels. Some of the direct toxic effects of high metal concentrations include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress. The replacing of vital nutrients at cation exchange sites in plants has an indirect harmful effect. Heavy metals' harmful effects on the development and function of soil microorganisms also have an indirect impact on plant growth. Because of the high metal concentration, fewer beneficial soil microbes may be present, which may slow down the decomposition of organic matter and reduce soil fertility. Heavy metal interaction with soil microorganism activity impairs enzyme activities, which are very important for plant metabolism. These hazardous impacts (both direct and indirect) lead to decline in the development of plant, which ultimately causes plant death (Asati et al., 2016).

### 2.4.3 Impact of Heavy Metal Pollution Towards Fauna

Heavy metals are just one of the many pollutants that marine ecosystems are subjected to. Some of these may have an impact on organisms in the food chain since they can stay in the environment for a very long time. Heavy metals can frequently alter the environment to the point that it is impossible to restore it to its natural state. The impact of heavy metal on marine resources is growing. Among other things, it has an impact on many organisms' health, changing the structure of the food chain and influencing bioaccumulation in the tissues of marine animals. Heavy metals have an impact on living things even at low environmental concentrations. They are hazardous not only because of the magnitude of environmental contamination, but also because of the biochemical role they play in metabolic processes and the volume that marine species take up and excrete. The endocrine system, reproduction, and growth can become defective as a result of excessive amounts of particular hazardous metals. Additionally, metals that can build up in tissues and organs of living things may negatively impact cellular processes by interacting with systemic enzymes. Growth, reproduction, immune system, and metabolism issues may result from this (Jakimsa et al., 2011).

## 2.5 National Water Quality Standards, NWQS

In 1995, Malaysia's Department of Environment (DOE) launched a comprehensive program to develop water quality standards and criteria. This investigation was conducted in 5 phases (I - IV). It was decided that home water supply, fisheries and aquatic propagation, livestock drinking, recreational use, and agricultural use should be the main priorities of the beneficial uses. Phase I of the study includes the evaluation of more than 120 physicochemical and biological characteristics for the recommended beneficial uses from regional and global literature. The initial stage of the study recommended a set of Interim National Water Quality Standards (INQWS) that specified six classes (I, IIA, IIB, III, IV, and V) that would be used to classify rivers or river segments into quality classes in descending order (Zainudin, 2010). All the data in Table 4.1 were compared with National Water Quality Standards for Malaysia (NWQS). Figure A1 and Figure A2 in APPENDIX A shows the National Water Quality Standards for Malaysia and Water Classes and Uses respectively.

## 2.6 Soil Quality Index

All the data in Table 4.2 were compared with allowable limit from World Health Organization (WHO), European Regulatory Standards (EURS), United States Environmental Protection Agency (US-EPA), Australia, Canada, Poland and Japan as listed in the Figure A3 in APPENDIX A due to the lack of information on soil background values for heavy metal concentration in Malaysia (Norbaya et al., 2014).

## 2.7 Acid Digestion

In order to measure the total or pseudototal concentrations of metallic elements in soils, acid digestion methods are typically performed to transform solid samples into liquid extracts. In order to determine the metal by conventional methods like inductively coupled plasma optical emission spectrometry or atomic absorption spectroscopy, this principle entails releasing the metals that are exist in the solid matrix to the acidic solution during the extraction process. The digestion of samples is the key contributor to the inaccuracy of analytical results due to the wide variance in metal content acquired by various techniques. The National Environment Council of Brazil (CONAMA 2009) mandates that the USEPA techniques 3050 and 3051 or their updates should be implemented in the digestion of soil samples for the determination of heavy metals for regulatory reasons. The US-EPA methods 3050 and 3050B are regarded as conventional processes because they are carried out in an open system and the elements in the solid phase are extracted by a heat source while hydrochloric and nitric acids are present. The potential of atmospheric pollution and reduction of more volatile metals like mercury are drawbacks of this procedure (Silva et al., 2014). During the extraction process, various types of acid mixtures will be used such as $HNO_3$, $HNO_3$-HF and $HNO_3$-HCl as reactives. The nature of matrix to be decomposed determines which acid or mix of acids should be used (Güven and Akinci, 2011).

## 2.8 Inductively Coupled Plasma–Optical Emission Spectrometry (ICP-OES)

Inductively coupled plasma-optical emission spectrometry (ICP-OES) is a method that uses plasma and a spectrometer to analyse the elemental composition of samples, most of which have elements dissolved in water. A peristaltic pump pumps the solution to be tested through a nebulizer and into a spray chamber. An argon plasma is created from the aerosol that was formed. In addition to the solid, liquid, and gaseous states of matter, plasma is the $4^{th}$ state of matter. In the ICP-OES, a cooled induction coil that is powered by a high frequency alternating current produces plasma at the end of a quarts torch. Hence, a different magnetic field is produced, accelerating the electrons into a circular motion. Ionization, which results from the argon atom and electrons colliding, creates a stable plasma. At 6000–7000 K, the plasma is extremely hot. It can even reach 10,000 K in the induction zone. The samples are atomized and ionised during the torch desolvation process. The electrons attain a more "excited" state as a result of the thermic energy they have absorbed. As the electrons descend back to the ground, energy is released as light (photons). Every element has a distinctive emission spectrum of their own that may be evaluated using a spectrometer. A concentration is determined using the measured light intensity at the wavelength and the calibration (Krosse and Ven, 2011). Continuum background emission, greater detection