



**DISTRIBUTION OF METALS IN SEDIMENT
AND WATER AT SUNGAI GEMANG, JELI,
KELANTAN**

By

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DECLARATION

I declare that this thesis entitled Distribution of Metals in Sediment and Water at Sungai Gemang, Jeli, 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.

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ABSTRACT

Rapid industrialization over the past century has led to increased irresponsible resource extraction, exacerbating environmental contamination globally. Industrial activities contribute significantly to the accumulation of heavy metals in water and sediment, which is further intensified by accelerating industrialization. Concerns about the environmental and health impacts of heavy metals such as cadmium (Cd), lead (Pb), copper (Cu), nickel (Ni), and zinc (Zn) have grown, emphasising the need for comprehensive analyses. Sungai Gemang, situated near the community of Kampung Gemang, serves as a vital water and protein source for the nearby population. Due to the potential carcinogenic and toxic nature of some metal contaminants, their impact on both the environment and human health warrants investigation. This study aims to determine the concentrations of heavy metals (Pb, Cd, Cu, Zn, and Ni) in both sediment and water in Sungai Gemang, Jeli, and Kelantan. Additionally, it seeks to establish correlations between metal concentrations in sediment and water bodies. The methodology involves the collection of 3 samples of water and sediment samples at three sampling stations from Sungai Gemang, followed by an acid digestion method to digest the samples for analysis using atomic absorption spectroscopy (AAS). Risk characterization is performed through the application of Sediment Quality Guidelines (SQG), Geoaccumulation Index (Igeo), and Enrichment Factor (EF). The results indicate a low distribution of metal concentrations in Sungai Gemang, suggesting an uncontaminated status of the water sources. While water quality meets acceptable standards, the elevated metal concentrations in sediment compared to water highlight the dynamic interplay between water and sediment, emphasising the importance of sustainable management practices for this crucial aquatic ecosystem.

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Taburan Logam Dalam Sedimen Dan Air di Sungai Gemang, Jeli, Kelantan

ABSTRAK

Logam berat, yang didefinisikan sebagai logam semulajadi dengan ketumpatan unsur melebihi 5 g/cm³ dan nombor atom melebihi 20, mempunyai sifat unsur jejak penting dan potensi toksisiti apabila hadnya melebihi paras yang tinggi. Perkembangan industri yang pesat sepanjang kurun waktu seratus tahun yang lepas telah menyebabkan peningkatan dalam pengeluaran sumber secara tidak terkawal, yang memberi impak negatif kepada alam sekitar secara global. Aktiviti industri merupakan penyumbang terbesar terhadap peningkatan aktiviti logam berat dalam air dan sedimen. Selain itu, aktiviti pengangkutan, pertanian, dan perbandaran turut menyumbang kepada peningkatan logam berat secara meluas. Kebimbangan tentang kesan alam sekitar dan kesihatan yang disebabkan oleh logam berat seperti kadmium (Cd), plumbum (Pb), kuprum (Cu), nikel (Ni), dan zink (Zn) telah berkembang, menekankan keperluan untuk analisis yang komprehensif. Sungai Gemang, yang terletak berdekatan dengan komuniti Kampung Gemang, berperanan sebagai sumber air dan protein penting untuk penduduk setempat. Oleh kerana sifat logam tertentu yang bersifat karsinogenik dan toksik, impaknya terhadap alam sekitar dan kesihatan manusia memerlukan penyelidikan. Kajian ini bertujuan untuk menentukan kepekatan logam berat (Pb, Cd, Cu, Zn, dan Ni) dalam sedimen dan air di Sungai Gemang, Jeli, Kelantan. Selain itu, kajian ini juga bertujuan untuk mencari hubungkait antara kepekatan logam dalam sedimen dan air. Metodologi tersebut melibatkan pengumpulan sampel air dan sedimen dari Sungai Gemang, diikuti dengan kaedah penghadaman asid untuk mencerna sampel bagi analisa menggunakan spektroskopi serapan atom (AAS). Pencirian risiko dilakukan melalui aplikasi Garis Panduan Kualiti Sedimen (SQG), Indeks Geoakumulasi (Igeo), dan Faktor Pengkayaan (EF). Hasil kajian menunjukkan penyebaran kepekatan logam yang rendah di Sungai Gemang, menunjukkan status sumber airnya adalah tidak tercemar. Walaupun kualiti air memenuhi standard yang diterima, kepekatan logam yang lebih tinggi dalam sedimen berbanding air menyorot peranan dinamik antara air dan sedimen, menekankan kepentingan amalan pengurusan lestari bagi ekosistem akuatik yang penting ini.

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LIST OF ABBREVIATION

| | |
|-------|---|
| AAS | Atomic Absorption Spectrometry |
| DOE | Department of Environment |
| DO | Dissolved Oxygen |
| EF | Enrichment Factor |
| Igeo | Geoaccumulation Index |
| NWQS | National Water Quality Standard |
| PEC | Probable Effect Concentration |
| SQG | Sediment Quality Guidelines |
| TEC | Threshold Effect Concentration |
| TDS | Total Dissolved Solid |
| TSS | Total Solid Suspended |
| USEPA | United States Environment Protection Agency |
| WHO | World Health Organization |

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LIST OF SYMBOLS

| | |
|----|------------------|
| °C | Degree Celsius |
| n | Number of Sample |
| % | Percentage |



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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Heavy metals are characterized as "naturally occurring metals with an elemental density exceeding 5 g cm^{-3} and an atomic number surpassing 20" (Ali and Khan, 2018). While some heavy metals serve as essential trace elements, elevated concentrations of most can prove toxic to various life forms due to their ability to form complex compounds within cells. Additionally, heavy metals pose a threat as they resist natural decomposition mechanisms, unlike organic pollutants (Liu et al., 2021). Human-induced activities such as industrial discharges, mining, transportation, agriculture, and urban operations contribute to the accumulation of heavy metals in both sediments and water. Natural sources, including geological weathering, atmospheric precipitation, erosion caused by wind, waves, storms, and bioturbation, further contribute to the presence of heavy metals (Mezga et al., 2021).

Heavy metals in sediment can enter the food chain via a variety of mechanisms, including sediment-dwelling animals, benthic invertebrates, and bottom-feeding fish. As species at lower trophic levels collect heavy metals from sediment, their predators are exposed to larger quantities of these toxins. This biomagnification process can result in substantial heavy metal concentrations in upper trophic level species, including fish ingested by human (Sarah & Raj, 2023).

Heavy metals can also pollute water sources, with serious ecological and health consequences. These metals can alter the ecological equilibrium in aquatic environments, influencing aquatic creature survival and reproduction (Khalid et al., 2021). Mercury (Hg) is a well-known heavy metal that may be transformed by certain bacteria into poisonous methylmercury. Methylmercury bioaccumulates in the food chain, with predatory fish at the top, threatening both animals and people (Singh et al., 2023). Consumption of methylmercury-contaminated seafood has been linked to neurological problems, especially in developing fetuses and young children (USEPA, 2015). Heavy metals in water can also have a negative impact on the physicochemical features of aquatic ecosystems. Copper (Cu) pollution, for example, can disturb aquatic creatures' normal physiological processes, weakening their respiratory systems and producing metabolic imbalances. This might result in decreased species diversity and possibly ecological collapse (Chen et al., 2022).

1.2 Problem Statement

Over the last century, industrialization has experienced a rapid surge, leading to an increased demand for irresponsible extraction of Earth's natural resources. This has significantly worsened the global predicament of environmental contamination. Industrialization stands as a primary contributor to the accumulation of heavy metals in water and sediment, and the intensification of industrial activities exacerbates metal pollution in river ecosystems (Jahan & Singh, 2023). Other factors contributing to the proliferation of heavy metals in the environment encompass transportation, agriculture, and urban practices (Liao et al., 2021). Presently, researchers express heightened concerns regarding the environmental impact and health implications associated with heavy metals such as cadmium (Cd), lead (Pb), copper (Cu), nickel (Ni), and zinc (Zn) (Ali et al., 2019). While heavy metals are naturally occurring and essential for life, their accumulation within living organisms can pose hazards (Mitra et al., 2022). Among the most common heavy metals harmful to the environment are mercury, cadmium, arsenic, nickel, copper, lead, and chromium. Furthermore, heavy metals can adversely affect human health through the food web and bioaccumulation (Mitra et al., 2022).

Sungai Gemang is located close to the community of Kampung Gemang. Thus, it is vital to assess the metals distribution in Sungai Gemang since it plays an important role as water and protein source for the community that lives nearby. Since some metal contaminants are carcinogenic and toxic, they can lead to environmental and health concerns for humans and animals (Nazal & Zhao, 2021). Hence, it is vital to analyse the concentrations of heavy metals in the river body and sediments of Sungai Gemang.

1.3 Objectives Study

- a) To determine the metal (Pb, Cd, Cu, Zn and Ni) concentration in sediment and water in Sungai Gemang, Jeli, Kelantan.
- b) To determine the correlation of metals in sediment and water bodies in Sungai Gemang, Jeli, Kelantan.

1.4 Scope of Study

For this study, there were 3 sampling points that were chosen along the Sungai Gemang, which were near the residential area, domestic dumping area, and agricultural area. The in-situ assessments of water were conducted with five replications for each of the three sampling points. The sample collection of water and sediment and the in-situ analysis of water quality were conducted at Sungai Gemang, Jeli, Kelantan, whereas the sample analysis was conducted at the UMK Jeli campus. The in-situ analysis of water was run using the YSI multiparameter to determine pH, temperature, turbidity, dissolved oxygen (DO), and total solids suspended (TSS). The concentration of metal elements was determined by using atomic absorption spectrometry (AAS). The comparison of the metal contents in sediment samples was done in this study using the numerical Sediment Quality Guidelines (SQGs). The SQGs are environmental standards that are used to evaluate the possible impact of pollutants in sediments on aquatic ecosystems. Other methods to analyse the risk assessment of metal toxicity in water and sediments are the Geoaccumulation Index (Igeo). The Geoaccumulation Index (Igeo) is a quantitative metric that compares the level of pollution in sediments or soils to their natural background values (Barbieri, 2016).

1.5 Significance of the Study

Heavy metals can build in sediments over time because of anthropogenic activity like industrial discharges, mining, and urban runoff. Investigating the presence and concentrations of heavy metals in sediment and water gives important information regarding environmental quality and potential contamination issues. This assessment can assist in identifying areas of concern and guiding remediation actions.

Understanding the physical, chemical, and biological characteristics of the aquatic environment is very beneficial for using water. This investigation can provide information regarding the concentration of heavy metals in Sungai Gemang. In order to prevent metal pollution and potential health risks, it is crucial to monitor the overall amounts of metals in water and sediment.

CHAPTER 2

LITERATURE REVIEW

2.1 Types of Heavy Metals

Heavy metals are classified into two types which are an essential heavy metals and non-essential heavy metals. Non-essential heavy metals are those that are not necessary for biological processes and can be detrimental even at low concentrations, whereas essential heavy metals are those that are required in trace quantities for the regular functioning of organisms (Hamed et al., 2022).

2.1.1 Essential Heavy Metal

Essential heavy metals are key components of water and sediment, and they play critical roles in a variety of biological and chemical functions. Their excessive concentration, however, can cause environmental and health hazards, making their study and monitoring critical (Li et al., 2020).

Essential heavy metal is important for skeletal structure creation, acid-base equilibrium regulation, and colloidal system maintenance all depending on the

necessary elements (Akhtar et al., 2021). Apart from that, these metals are also crucial because they are components of vital enzymes, structural proteins, and hormones, such as the glutathione peroxidase enzyme, which requires selenium, iron, and zinc (Kaur et al., 2021). Although non-essential heavy metals play no significant roles in the body, they can nonetheless be harmful because they can change the body's levels of essential elements (Studies, 2023).

2.1.2 Non-Essential Heavy Metal

Non-essential heavy metals have no biological purpose and are hazardous to the body even in tiny concentrations. (Slobodian et al., 2021). The main group includes the trace elements, which include cobalt, copper, iron, manganese, molybdenum, selenium, and zinc. Through similar physicochemical properties with their essential equivalents, such as ionic charge, these very poisonous non-essential metals can penetrate living things (Jomova et al., 2022). Environmental exposure or unintentional occupational exposure in manufacturing, agricultural, or industrial environments are two ways they might enter the body. They may also absorb through the skin. The main source of exposure for adults is the manufacturing or industrial environment (Segal & Giudice, 2019).

2.2 Metal Distribution in the Environment

Metal distribution in the environment is influenced by various processes, including geochemistry, sediment deposition, and the availability of metal sources (Peng et al., 2020). Various physical and chemical characteristics, including pH, temperature, and dissolved organic matter concentration, might influence metal dispersion in aquatic settings (Dai et al., 2023). Furthermore, due to their strong

attraction to solid surfaces, certain metals such as copper, zinc, and lead tend to collect in sediment (Nour et al., 2022).

2.2.1 Heavy Metal in Water

The degradation of water quality caused by the presence of foreign contaminants is referred to as water pollution (Akhtar et al., 2021). Water pollution encompasses all forms of liquid pollution, including river and ocean pollution (Hassan Al-Taai, 2021). There are two types of water contamination which are point sources and non-point sources. Point source pollution is pollution that has a clear source, like a spill or discharge. Non-point source pollution occurs when there is no single identifiable source or when there are multiple sources involved (Tan et al., 2022).

Heavy metals may enter water systems through a variety of natural and artificial causes. Heavy metal contamination in water is mostly caused by industrial operations such as mining, metal processing, and manufacturing (Khalef et al., 2022). Furthermore, agricultural practices such as the use of metal-based insecticides and fertilizers can result in runoff that transports heavy metals into surrounding rivers (Kour et al., 2021). Heavy metals, once introduced into water systems, can undergo physical, chemical, and biological modifications that affect their distribution and mobility.

Heavy metal contamination is a major threat to aquatic environments. Heavy metal levels in water can have a direct impact on aquatic animals such as fish, invertebrates, and algae, causing physiological and reproductive problems (Radomirović et al., 2020). Heavy metals can accumulate in organism tissues via processes such as bioaccumulation and biomagnification, potentially causing long-term consequences on the food chain. Heavy metal toxicity can alter biological

processes, reduce biodiversity, and deteriorate overall water quality (Sonone et al., 2020).

Heavy metal exposure from polluted water sources can have adverse effects on health. Drinking water contaminated with heavy metals can cause a variety of health issues, including neurological abnormalities, kidney failure, and carcinogenic consequences (Zhou et al., 2020). Vulnerable groups, such as new-borns and pregnant women, are more easily exposed to the negative consequences of heavy metal intake. To preserve public health, heavy metal levels in drinking water sources must be monitored and regulated (Rani & Dhok, 2023).

2.2.2 Heavy Metal in Sediments

Heavy metals in sediments come from both natural and anthropogenic sources. Weathering of rocks, volcanic activity, and erosion processes are all natural sources that contribute to background levels of heavy metals in sediments. Agricultural practises, urban runoff, industrial discharges, and mining operations are anthropogenic sources of heavy metals in sediment. (Ji et al., 2019). Heavy metal distribution and accumulation in sediment are influenced by deposition mechanisms such as sedimentation, settling, and resuspension (Lv et al., 2021).

In soil and sediment, contaminants can be retained for a very long period (Noe et al., 2020). Less than 1% of these are dissolved in water at any point in the hydrological cycle, and more than 99.9% of them are stored in the sediments and soils. Sediments are mineral species combinations that act as the final sink for heavy metals established into the environment (Abbas et al, 2009). Metals that enter the environment are distributed between the aqueous phase and the suspended sediments. As a result,

water sediment is a potential metal reservoir and is crucial for the adsorption of dissolved heavy metals (Liu et al., 2023).

Heavy metal pollution in sediments can be harmful to aquatic environments. Benthic organisms live in sediments, and high heavy metal concentrations can affect their survival, growth, and reproductive success. Heavy metal bioaccumulation and biomagnification in sediment-associated species can have harmful consequences at higher trophic levels (Liu et al., 2022).

2.3 Effects of Heavy Metals on Human Health

Heavy metals such as nickel, copper, arsenic, cadmium, and lead are extensively dispersed in the environment and have well-documented detrimental effects on human health. Table 2.1 presents an overview of these metals' toxicity, concentrating on their health consequences and underlying toxicity processes.

Table 2.1: Effects of Heavy Metals (Ni, Cu, As, Cd & Pb) on Human Health

| | |
|--------|---|
| Nickel | Nickel is a recognized respiratory and skin sensitizer that can cause allergic responses in sensitive people. Nickel compounds, such as nickel oxide and nickel sulfate, can cause respiratory symptoms, asthma, and occupational lung disorders in the workplace (Begum et al., 2022). Long-term nickel exposure has also been linked to an elevated risk of lung and nasal cancer (IARC, 2012). |
| Copper | While copper is necessary in tiny amounts, excessive amounts can be hazardous to numerous organs. Wilson's disease, a hereditary illness characterized by poor copper metabolism, causes copper buildup in the liver and brain, resulting in liver dysfunction and neurodegeneration (Sánchez-Monteagudo et al., 2021). Acute high-dose copper salt exposure can result in gastrointestinal symptoms, liver damage, and hemolysis (Hajimohammadi et al., 2022). |

| | |
|---------|--|
| Zinc | <p>Zinc is an essential trace element that plays a crucial role in various physiological processes in the human body. It is important for immune function, wound healing, DNA synthesis, cell division, and the proper functioning of enzymes (Chasapis et al., 2020). While zinc is important for health, but excessive intake of zinc can have adverse effects. Too much zinc can lead to nausea, vomiting, loss of appetite, abdominal cramps, and headaches. Chronic excessive intake of zinc can also interfere with the absorption of other minerals, such as copper and iron Harvard School of Public Health (2019)</p> |
| Cadmium | <p>Cadmium is a toxicant that accumulates in the body, especially affecting the kidneys and bones. Long-term cadmium exposure, typically from contaminated food or cigarette smoke, causes renal dysfunction, including proximal tubular damage and renal tubular failure (Tsai et al., 2021). Cadmium is also a human carcinogen, with evidence connecting it to lung and prostate cancers (IARC, 2012).</p> |
| Lead | <p>Lead poisoning is still a major public health problem, particularly among youngsters. Lead has a wide range of effects on the central nervous system, kidneys, cardiovascular system, and hematological system. Lead exposure disrupts neurodevelopment in children, resulting in cognitive impairments, reduced IQ, and behavioral issues (Bellinger, 2016). Lead exposure in adults is linked to hypertension, renal impairment, and poor reproductive results (Jalili et al., 2021).</p> |

2.4 Risk Assessment

Sediment quality guidelines (SQG) have been recognized as ideal thresholds for revealing the negative impacts of metallic elements in sediments on human health (Gharibreza et al., 2013). SQGs are commonly used in environmental risk assessments to analyse the possible consequences of polluted sediments. The dangers to aquatic

ecosystems can be determined by comparing identified pollutant concentrations to guideline levels. SQGs consider both the level of chemical concentrations and the accompanying ecological consequences, allowing for a thorough assessment of possible implications (Zhang et al., 2021). In general, SQGs define two concentration thresholds: one for which a hazardous response is unlikely and one for which a harmful response is likely. Generally, there are two types of SQG that are often used today: empirical and theoretical SQG. Empirically based SQGs are based on field and laboratory evidence of benthic organism responses to metal-contaminated sediments. These correlations are determined by compiling data from numerous sites with varying types and quantities of pollutants. Theoretical SQGs use equilibrium partitioning (EqP) to characterize the bioavailability of pollutants from sediments to benthic organisms (Thompson & Wasserman, 2015).

The Geoaccumulation Index (Igeo) is a valuable tool for evaluating the degree of anthropogenic pollution in sediments, soils, and other environmental compartments. It assesses the enrichment of a particular element or pollutant relative to its background concentration. The index considers both natural and anthropogenic sources of contamination and provides a numerical classification of contamination levels ranging from unpolluted to extremely polluted (Mavakala et al., 2022). Igeo has been widely used in environmental studies to assess the extent of metal pollution in sediments and soils (Prasad Ahirvar et al., 2023).

CHAPTER 3

METHODOLOGY

3.1 Research Methodology Flowchart

In this chapter, the methodology used for this study is discussed. Figure 3.1 shows the summary of the methodology that has been used. Sungai Gemang was selected as the sampling sites for the collection of water and sediment samples. The analysis was carried out using atomic absorption spectroscopy (AAS). For the risk characterization, the Sediment Quality Guidelines (SQG), Geoaccumulation index (Igeo) and Enrichment Factor (EF).

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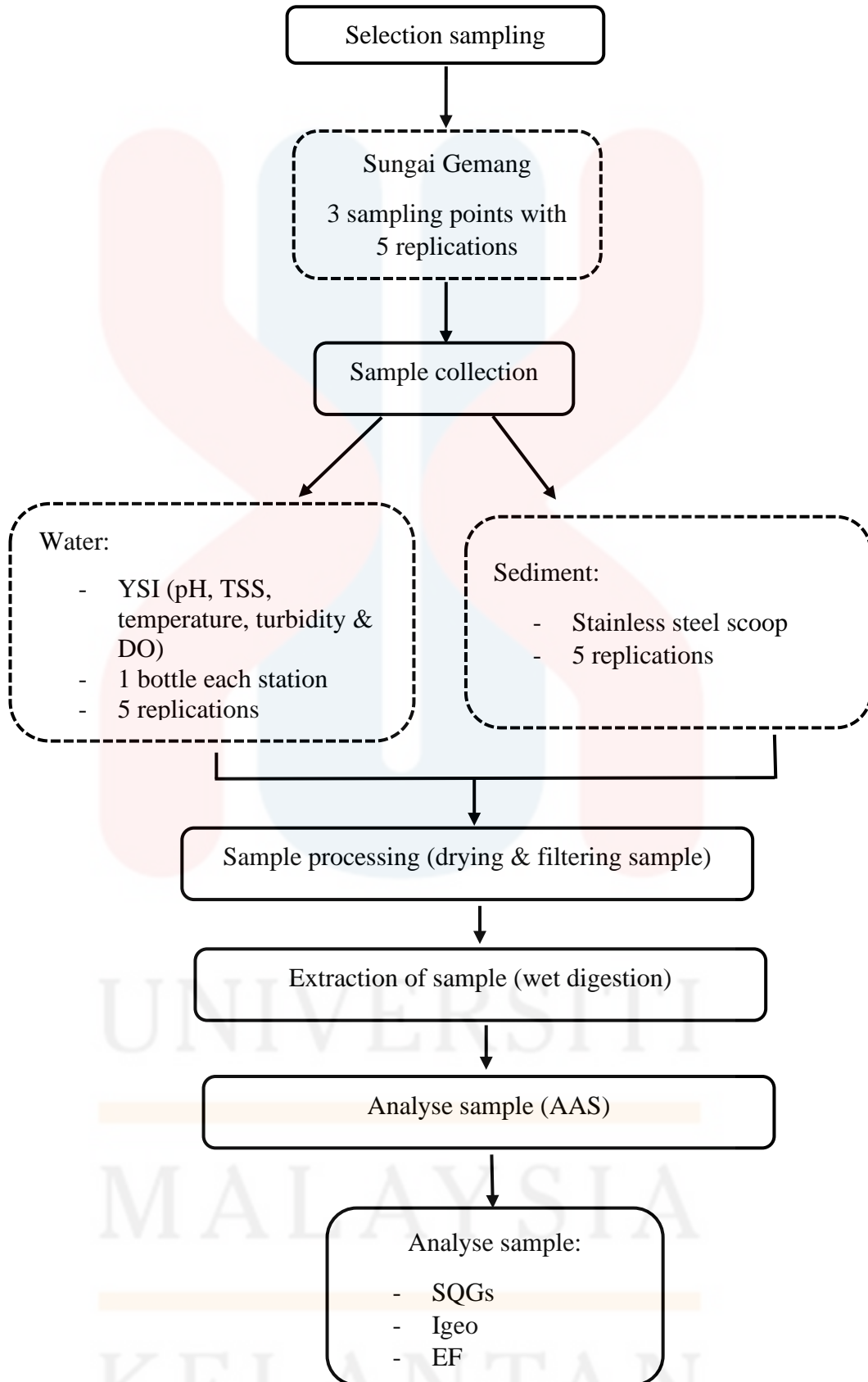
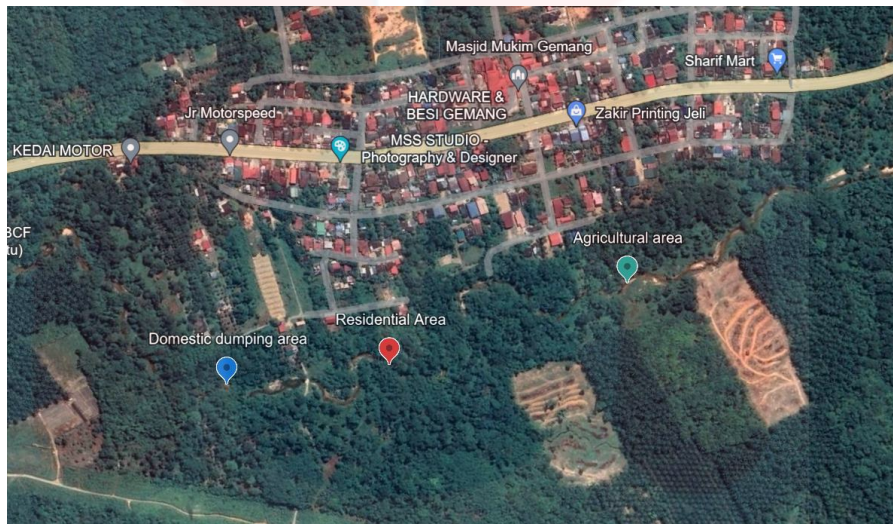


Figure 3.1: Research methodology flowchart

3.2 Study area

Sungai Gemang is a river in the Jeli district of Kelantan, Malaysia. The gemang river lies near the community of kampung gemang. The river is roughly 33.4 km long and flows through Jeli before entering the Lebir River. The Sungai Gemang watershed is a vital supply of water for the district's agricultural activities. The latitude of Sungai Gemang is 5.75° and the longitude is 101.86667° (Figure 3.1).

Figure 3.2: The map of Sungai Gemang, Jeli, Kelantan



This research encompassed three distinct sampling stations along Sungai Gemang (Figure 3.2). Samples were collected from various stations representing different areas, which are the residential area, the domestic dumping area, and the agricultural area. This approach aimed to identify the primary contributors to river water contamination. Water samples were systematically collected during the morning hours in an alternating fashion to mitigate the influence of natural variations that could impact the analytical outcomes.

Table 3.1: Sampling Station along with their Longitude and Latitude

| Sampling stations | Area | Latitude | Longitude |
|-------------------|--------------------------|--------------|---------------|
| Station 1 | Residential Area | 05°45.5148'N | 101°51.7362'E |
| Station 2 | Domestic Dumping Area | 05°45.8420'N | 101°51.7619'E |
| Station 3 | Agricultural area | 05°45.6450'N | 101°51.5809 |

3.3 Reagents and standard materials

Nitric acid (HNO₃) 65% and Hydrogen peroxide (H₂O₂) 30% solution of Suprapur® quality were used in the lab analysis.

3.4 Cleaning glassware

All equipment were cleansed and submerged overnight in diluted 10% HNO₃ to prevent cross-contamination and lessen any potential decontamination. They were dried and carefully washed with distilled water before being used. (Bhuyan et al., 2019).

3.5 Sample Collection and Preparation

3.5.1 Sampling of Water

In this study, there was 3 sampling point which indicated five replications of each. To prevent early contamination, glass vials used to store water samples were prewashed with acid overnight and dried. Before being collected from surface water for water sampling, the bottle sampling has been rinsed twice with the water sample. The uncovered glass bottle was entirely submerged under the surface of bodies of water until it is filled with water samples. The bottles then were capped below the

water's surface. The water samples were stored in less than 8 °C for further elemental analysis. (EPA, 2019).

3.5.2 Sampling of sediment

For sediment sampling, stainless steel scoop was used to collect the sediment samples from the bottom of the river. Bulk samples were collected, labelled, and packed in polyethylene sampling bags before being sent back to the lab and stored under -20 °C.

3.5.3 In-Situ Water Analysis

Parameters of physical analysis that have been analysed in this study are temperature and turbidity, whereas parameters for chemical analysis are pH, total solids suspended (TSS), and dissolved oxygen (DO). These in-situ analyses were conducted using the YSI multiparameter.

3.6 Sample processing

Before being dried in an oven at a temperature of 60 °C or below, all foreign material (detritus, stones) were removed from the sediment sample (Wang et al., 2018). The dried materials were then ground and put through a sieve with a mesh size of 354 micron. For further examination, the homogenized samples will be stored in amber jars in a desiccator (EPA, 1996).

3.7 Extraction of sediment samples

Wet digestion was utilized to remove sediment samples according to analytical techniques for atomic absorption spectrometers. About 1-2 g of the dried samples were added to 15 ml of HNO₃ in a 250 ml beaker. The beaker then was put

on a hot plate and heated for one hour at 100 °C. After cooling to room temperature, 5 ml of H₂O₂ were added and gently warmed at 100 °C until the sample retains 10 ml. Following digestion, the samples were filtered into a volumetric flask measuring 100 ml, and the volume were topped up until the marked line of the volumetric flask with deionized water.

3.8 Heavy Metal Analysis

Atomic Absorption Spectrometry (AAS) is a technique that employs specific wavelengths of electromagnetic radiation emitted by a light source to identify elements present in liquid or solid samples. The absorption of different wavelengths by various elements is quantified by comparing them to established standards. Essentially, AAS utilizes the unique radiation wavelengths absorbed by each atom. In the AAS process, analytes are initially atomized to liberate and record their distinctive wavelengths. Subsequently, during excitation, as the respective atoms absorb specific energy, the electrons within those atoms transition to a higher energy level. This energy possesses a distinct wavelength exclusive to the element. The identification and quantification of certain components depend on the wavelength and intensity of the light (SciMed, 2022).

3.9 Risk Characterisation

The Sediment Quality Guidelines (SQG), Geoaccumulation Index (Igeo), and Enrichment Factor (EF) are three separate indices that were used in this study to analyse and evaluate the sediment contamination of the study region.

3.9.1 Sediment Quality Guideline (SQGs)

The Sediment Quality Guidelines were created to evaluate the potential impacts of sediment contamination on aquatic species and benthic populations. They act as benchmarks or thresholds for specific contaminants or characteristics, assisting in determining the level of pollution that may pose environmental problems. Environmental regulators, academics, and risk assessors employ SQGs to evaluate the health and ecological integrity of aquatic ecosystems (Table 3.1) (Asare et al., 2022).

Table 3.2: Heavy metals guidelines for sediment in mg/kg (US EPA, 2015b).

| Heavy metals | Not polluted | Moderately polluted | Heavily polluted |
|--------------|--------------|---------------------|------------------|
| Ni | <20 | 20-50 | >50 |
| Cu | <25 | 25-50 | >50 |
| Cd | - | <6 | >6 |
| Zn | <90 | 90-200 | >200 |
| Pb | <40 | 40-60 | >60 |

Source: (US EPA, 2015b).

3.9.2 Geoaccumulation Index (Igeo)

The geoaccumulation index (Igeo) was created by Muller (1969) to evaluate the level of heavy metals and metalloid elements in the sediment by contrasting the current concentration with the pre-industrial level (Che Abdullah et al., 2020). The index is calculated based on equation:

$$I_{geo} = \log_2 \left[\frac{C_n}{1.5B_n} \right] \quad (3.1)$$

Where 1.5 is the background matrix correction factor due to lithogenic effects, C_n is provided metal levels, and B_n is the background value of a specific metal element (Che Abdullah et al., 2020). The background value were Zn: 70, Cd: 0.2, Cu: 55, Ni:75, Pb:13 mg/kg (Kabata-Pendias & Mukherjee, 2007). Table 3.2 shows the classification of geoaccumulation index (Igeo).

Table 3.3: Geoaccumulation Index Classification

| Index Class | Igeo Value | Level of Contamination Classification |
|-------------|-------------------|--|
| 0 | $I_{geo} < 0$ | Uncontaminated |
| 1 | $0 < I_{geo} < 1$ | Uncontaminated to moderately contaminated |
| 2 | $1 < I_{geo} < 2$ | Moderately contaminated |
| 3 | $2 < I_{geo} < 3$ | Moderately to heavily contaminated |
| 4 | $3 < I_{geo} < 4$ | Heavily (strongly) contaminated |
| 5 | $4 < I_{geo} < 5$ | Heavily (strongly) to extremely contaminated |
| 6 | $I_{geo} \geq 5$ | Extremely contaminated |

Source: Muller (1969)

CHAPTER 4

RESULT AND DISCUSSION

4.1 Water Quality (In-Situ Parameter)

The physicochemical quality of Sungai Gemang is shown in Table 4.1. All parameters are measured in situ with the YSI multiparameter and turbidity meter. Table 4.1 below shows physico-chemical quality of Sungai Gemang. The results presented in Table 4.1 demonstrate that all recorded values fall within the permissible limits outlined by the National Water Quality Standard (NWQS). This comprehensive assessment ensures that Sungai Gemang adheres to the prescribed regulatory standards, confirming its overall compliance with the established water quality criteria.

The temperature recorded in Table 4.4 ranges between 24.8 °C and 27.2°C. The highest temperature was in the residential area, which was 27.2°C, and the lowest was in the agricultural area, which was 24.8°C.

Table 4.1: The physico-chemical quality of Sungai Gemang

| | Stations | | | Legal limits (NWQS) | | | | |
|-----------------|----------|-------|-------|---------------------|---------------|-------------|----------|---------|
| | S1 | S2 | S3 | Class I | Class IIA/IIB | Class III | Class IV | Class V |
| Temp (°C) | 27.2 | 25.4 | 24.8 | - | Normal +2°C | Normal +2°C | - | - |
| Turbidity (NTU) | 6.95 | 7.04 | 6.70 | 5 | 50 | - | - | - |
| TDS (mg/L) | 51.35 | 49.40 | 18.85 | 500 | 1000 | - | 4000 | - |
| pH | 6.98 | 7.21 | 6.94 | 6.5-8.5 | 6-9 | 5-9 | 5-9 | - |
| DO (mg/L) | 7.68 | 6.85 | 10.64 | 7 | 5-7 | 3-5 | <3 | <1 |
| Salinity (ppt) | 0.04 | 0.03 | 0.01 | 0.5 | 1 | - | 4000 | - |

The value is still within the legal limits of NWQS. In general, a variety of factors, including the sample site, time, and weather, influence temperature changes, which in turn have an impact on biological activity, dissolved oxygen percentage, and other measurements (Al-Badaai et al., 2013).

Furthermore, the area with the highest turbidity recorded is the domestic dumping area, which recorded a value of 7.04 NTU. The value is slightly higher than the first-class limits of NWQS. In contrast, the lowest turbidity is 6.95 NTU, which indicates a residential area. The value is within the II class of NWQS. The turbidity value of all three sampling points is within class II of NWQS. Turbidity in water can come from a variety of causes. Turbidity in water can be caused by a variety of factors, such as debris or runoff, wastewater containing leftover particles, or the decomposition

of plant and animal matter (Morsy et al., 2020). Furthermore, impermeable surfaces such as pavement and roadways are common in housing areas. Rainwater runoff could carry contaminants and sediments into rivers by removing them from these surfaces (Zhou, 2019). All other key parameters, including pH, total dissolved solids (TDS), dissolved oxygen (DO), and salinity, consistently fall within the established legal limits of the National Water Quality Standard (NWQS). This collective adherence underscores the overall health and compliance of Sungai Gemang's water quality with regulatory standards. The balanced pH levels signify a neutral and stable aquatic environment (Jiao & Lu, 2020). Additionally, optimal levels of TDS and salinity contribute to the suitability of the water for designated uses (Shil et al., 2019). The presence of Dissolved Oxygen within acceptable ranges further indicates the capacity of Sungai Gemang to support aquatic life (Fitri et al., 2021). This comprehensive alignment with national standards emphasizes the effectiveness of environmental management practices and underscores the importance of ongoing monitoring to ensure the continued well-being of this crucial water resource.

4.2 Metal Concentrations on the surface water

The concentration of 5 metals in water samples is summarised in Table 4.2. ~~below.~~ The mean metal concentrations in water show variations that can be related to the human activities surrounding them.

Table 4.2: Mean metal concentration of water in Sungai Gemang

| Conc. Of metal (mg/L) | Sampling Location | | | NWQS (DOE 2007) | Drinking Water Quality Standard | |
|-----------------------|---|--|--|-----------------|---------------------------------|------------|
| | S1 | S2 | S3 | Class IIA/IIB | WHO 2006 | USEPA 2009 |
| Zn | 6.6×10^{-3} $\pm 5.7 \times 10^{-3}$ | 2.2×10^{-3} $\pm 2.4 \times 10^{-3}$ | 3.3×10^{-3} $\pm 3.3 \times 10^{-3}$ | 5.0 | 3.0 | 5.0 |
| Cd | ND | ND | ND | 0.01 | 0.003 | 0.005 |
| Pb | 3.05×10^{-2} $\pm 2.3 \times 10^{-2}$ | ND | ND | - | 0.01 | 0.015 |
| Ni | 2.1×10^{-2} $\pm 2.1 \times 10^{-3}$ | 1.1×10^{-2} $\pm 4.7 \times 10^{-3}$ | ND | 0.05 | 0.07 | - |
| Cu | $3 \times 10^{-3} \pm 0$ | ND | ND | 0.02 | 2.0 | 1.3 |

Mean \pm standard deviation (n=5) Note:
ND = Not Detected

The results presented in Table 4.2 above indicate that the mean concentrations of metal elements in the study area were all below the benchmark levels classified under category IIA/IIB of the National Water Quality Standard (NWQS) in Malaysia. These results suggest that all values are within the legal limits set by the NWQS, WHO, and USEPA. Figure 4.1 illustrates the trend in metal distribution in the water body of Sungai Gemang.

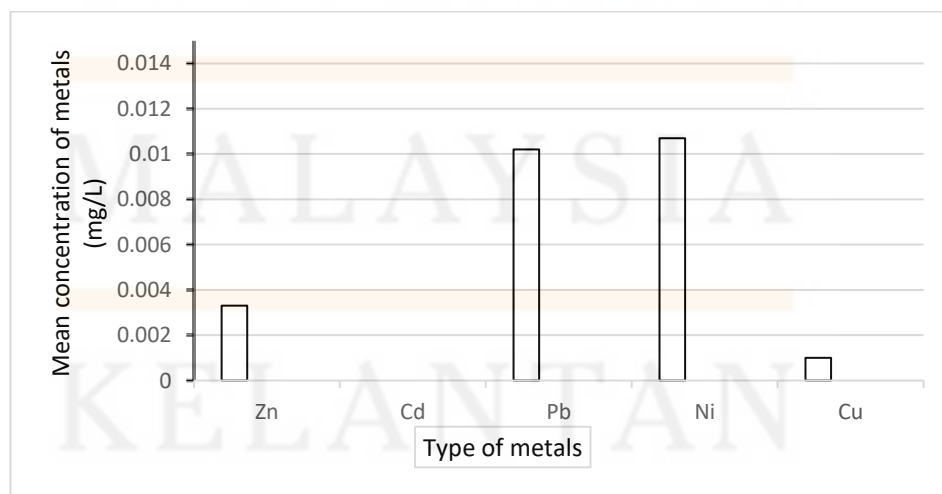


Figure 4.1: Distribution of heavy metal in surface water sample of Sungai Gemang

Figure 4.1 indicate that the highest amount of metal found in the water body of Sungai Gemang is nickel, followed by lead, zinc, and copper.

Natural processes and human activities are potential contributors to elevated metal concentrations in rivers. Pollution sources include farm runoff carrying metals from fertilisers and urban runoff transporting pollutants from roadways (Briffa et al., 2020). Improper disposal of home wastewater and the inappropriate dumping of electrical waste into the river can further exacerbate metal contamination (Rajesh et al., 2022). Agriculture and dumping activities near water bodies can have adverse effects on the environment, flora and fauna ecosystems, and human health (Lin et al., 2022). However, some metals in a few areas did not detect the presence of metals; this is possibly due to the water's properties, which may not retain metals for an extended period. Instead, metals might either settle into sediment or be carried downstream by the river flow (Algül & Beyhan, 2020).

4.3 Metal concentration in the sediment

Metal concentration in sediment refers to the quantity of different metals present in the bed of a water body. Sediments function as a metal sink, collecting particles that settle from the water column (Algül & Beyhan, 2020). Metal concentration in sediment is affected by both natural geological processes and human activity, including urban runoff and agricultural and industrial discharges (Gunes, 2021). Table 4.3 summarizes the mean metal concentration in sediment samples of Sungai Gemang.

Table 4.3: Metal concentration in sediment sample

| Conc. Of metal (mg/kg) | Sampling Location | | | | Sediment Quality Guidelines | |
|------------------------------|-------------------|------------|------------|-------|-----------------------------------|------|
| | S1 | S2 | S3 | Mean | TEC | PEC |
| Zn | 15.42±1.57 | 11.63±2.69 | 9.36±0.94 | 12.14 | 121 | 459 |
| Cd | 0.24±0.04 | 0.17±0.01 | 0.225±0.04 | 0.64 | 0.99 | 4.98 |
| Pb | 8.27±4.15 | 6.84±0.47 | 5.51±0.61 | 6.87 | 35.8 | 128 |
| Ni | 3.12±4.83 | ND | 0.12±0.05 | 1.08 | 22.7 | 48.6 |
| Cu | 3.75±1 | 12.64±7.51 | 9.94±4.25 | 8.77 | 31.6 | 149 |

Mean ± standard deviation (n=5)

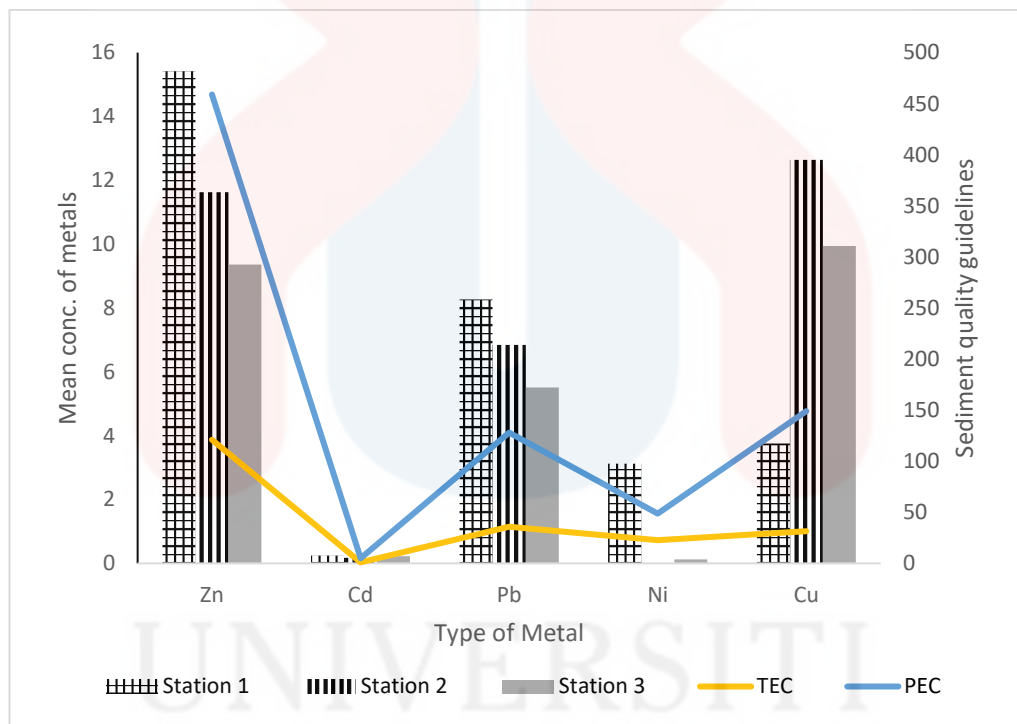
Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) are terms commonly used in environmental risk assessment to evaluate the potential impact of contaminants on aquatic ecosystems (Xu et al., 2019). TEC represents the concentration of a contaminant below which no adverse effects are expected to occur on a specific organism or ecological endpoint. It is a threshold level, and exposure to concentrations below TEC is considered safe for the environment. PEC is the concentration of a contaminant above which adverse effects are likely to occur. It is a level at which there is a probability of harmful impacts on organisms or ecosystems (Islam et al., 2018).

Referring to Table 4.4, it is evident that the metal concentrations in sediment across all areas are consistently below the Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) levels established by the Sediment Quality Guidelines (SQG). None of the recorded metal concentration levels surpass the specified limits outlined in the sediment quality standards (Table 4.4). Notably, even

though station 1 exhibit the highest recorded metal concentrations in comparison to station 2 and station 3, these concentrations remain within acceptable limits according to the guidelines. The prevalence of trace-level metals in these sediments suggests a predominantly natural origin, with only minimal contributions from anthropogenic activities (Harmesa et al., 2022).

Figure 4.2 illustrate the metal concentration distribution in sediment samples of Sungai Gemang.

Figure 4.2: Distribution of metal concentration in sediment samples of Sungai Gemang



As illustrated in Figure 4.2, the sediment analysis reveals distinctive metal distribution patterns across different areas. Notably, in the station 1, zinc (Zn) dominates as the most prevalent metal, followed by lead (Pb), copper (Cu), nickel (Ni), and cadmium (Cd) in sequential order. Conversely, within the station 2, copper (Cu) emerges as the predominant metal, followed by zinc (Zn), lead (Pb), and cadmium (Cd), with nickel (Ni) notably absent in this location. In the station 3, copper (Cu) again exhibits the highest metal concentration, followed by zinc (Zn), lead (Pb),

cadmium (Cd), and nickel (Ni) in progression. The differences observed emphasize the diverse spatial distribution of metals in sediments, highlighting the varied environmental influences present in residential, domestic dumping, and agricultural areas.

Elevated levels of zinc (Zn), lead (Pb), copper (Cu), nickel (Ni), and cadmium (Cd) around station 1 may be linked to anthropogenic activities such as construction, and household practices, leading to the release of metals (Sojka & Jaskuła, 2022). Furthermore, higher copper (Cu) concentrations in station 2 might result from discarded electronic waste or other items containing copper (Kumar & Fulekar, 2019). Elevated copper (Cu) levels in station 3 could be associated with the use of copper-based fungicides or pesticides in farming practices as it located around the agriculture area (Kaiser, 2018).

Nevertheless, in comparison to the Sediment Quality Guidelines (SQGs) in Table 4.4, the concentrations of the metals investigated in Sungai Gemang did not exceed the Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) levels. This observation suggests that the water in Sungai Gemang is within acceptable limits, indicating a lack of significant pollution. The fact that none of the studied metals surpassed these levels provides reassurance regarding the safety of the water for both aquatic ecosystems and human consumption. It is important to note that compliance with SQGs is a positive indicator, implying that the metal concentrations do not pose adverse effects on the environment or human health according to the established guidelines. This finding underscores the importance of ongoing monitoring efforts to ensure the continued health and sustainability of Sungai Gemang's water resources.

4.4 Assessment of Metal Contamination in Sediment using Igeo

In environmental research, the Geoaccumulation Index (Igeo) is a metric used to evaluate the level of contamination or accumulation of pollutants or trace elements in sediments (Shirani et al., 2020). It gives a numerical representation of how much of a certain element has accumulated relative to its natural background levels in a specific place (Che Abdullah et al., 2020). The Geoaccumulation Index is often categorised into seven classes to interpret the degree of contamination, as shown in Table 4.4.

Table 4.4: Igeo classification

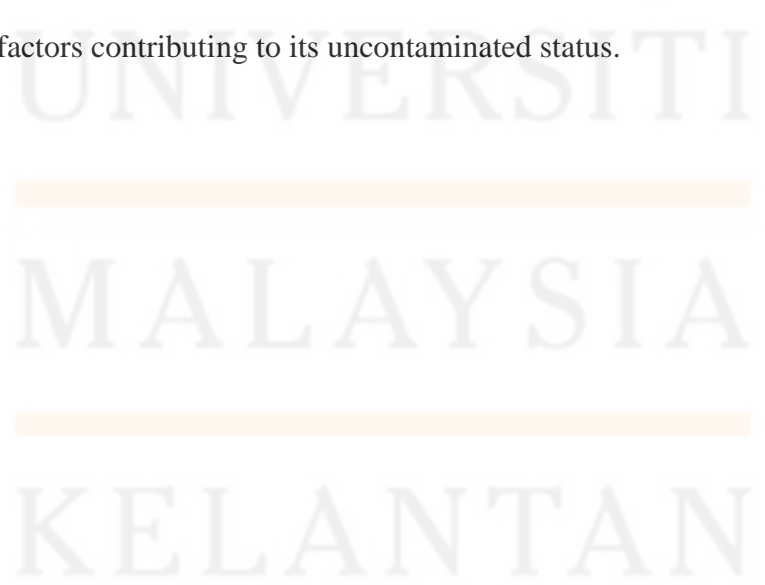
| Index Class | Igeo Value | Level of Contamination Classification |
|-------------|-------------------|--|
| 0 | $I_{geo} < 0$ | Uncontaminated |
| 1 | $0 < I_{geo} < 1$ | Uncontaminated to moderately contaminated |
| 2 | $1 < I_{geo} < 2$ | Moderately contaminated |
| 3 | $2 < I_{geo} < 3$ | Moderately to heavily contaminated |
| 4 | $3 < I_{geo} < 4$ | Heavily (strongly) contaminated |
| 5 | $4 < I_{geo} < 5$ | Heavily (strongly) to extremely contaminated |
| 6 | $I_{geo} \geq 5$ | Extremely contaminated |

On the other hand, Table 4.5 shows the results of the Igeo values of heavy metals in sediment samples of Sungai Gemang. The findings presented in Table 4.5 reveal the calculated Igeo values for sediment samples collected from Sungai Gemang. These findings clearly show that the river has a high degree of uncontamination. The Igeo values for all metals analyzed consistently register below 0, signifying a low level of contamination when compared to the Igeo classification provided in Table 4.4.

Table 4.5: Geoaccumulation Index (Igeo) of heavy metals in sediment samples

| Metal elements | Sampling location | | | | | |
|----------------|-------------------|-------|-----------------------|-------|------------------|-------|
| | Residential area | | Domestic dumping area | | Agriculture area | |
| | Igeo | Class | Igeo | Class | Igeo | Class |
| Zn | -2.77 | 0 | -3.17 | 0 | -3.49 | 0 |
| Cd | -0.32 | 0 | -0.82 | 0 | -0.38 | 0 |
| Pb | -1.23 | 0 | -1.51 | 0 | -1.82 | 0 |
| Ni | -5.17 | 0 | 0 | 0 | -10.57 | 0 |
| Cu | -4.46 | 0 | -2.71 | 0 | -3.05 | 0 |

The geoaccumulation index is a valuable tool for assessing the degree of metal pollution, with negative values indicating uncontaminated conditions (Shirani et al., 2020). In this context, the consistently negative Igeo values affirm the pristine nature of Sungai Gemang, reinforcing the notion that elevated metal concentrations do not significantly impact the river sediment. These results contribute valuable insights into the overall environmental health of the river and can inform further investigations into the factors contributing to its uncontaminated status.



CHAPTER 5

CONCLUSION

5.1 Conclusion

This study extensively examines the distribution of zinc (Zn), copper (Cu), lead (Pb), nickel (Ni), and cadmium (Cd) in both water and sediment within Sungai Gemang. Utilizing various analytical approaches, including assessments against Sediment Quality Guidelines (SQGs), Geoaccumulation Index (Igeo) calculations, and the determination of Enrichment Factors (EF), a comprehensive evaluation is conducted to discern the intricate trends of heavy metal accumulation and distribution across the study area. These multidimensional analyses offer insights into the potential environmental impact of metal concentrations in both the aqueous and sedimentary components of Sungai Gemang. By incorporating SQGs, Igeo, and EF, this study aims to provide a robust understanding of the complex interactions between water and sediment, shedding light on the prevailing patterns of heavy metal dynamics and their implications for environmental health in Sungai Gemang.

Based on the comprehensive analysis of the results, it is evident that the distribution of metal concentrations in Sungai Gemang is notably low, signifying an uncontaminated status. The water sources in Sungai Gemang, as indicated by the various physicochemical parameters examined, are deemed safe, posing no discernible harm to human health or the environment. Notably, a comparative examination of metal concentrations in both water and sediment reveals a slight elevation in metal levels within the sediment. This phenomenon can be attributed to the transient nature of metals in the water, which has a limited capacity to retain them over an extended period. In contrast, sediments function as a sink for metals, accumulating them over time. While water quality remains within acceptable standards, the higher metal concentrations in sediment suggest a natural process of metal deposition. It is crucial to recognize this dynamic interplay between water and sediment in Sungai Gemang to understand the environmental fate of metals better and to inform sustainable management practices for this vital aquatic ecosystem.

5.2 Recommendation

In the present study, the sampling locations for the collection of water and sediment in Sungai Gemang only involve three locations. In future research, the researchers can add more sampling locations so that the distribution of metals in Sungai Gemang can be analyzed more widely, and the results will be more accurate. Other than that, most of the results that AAS analyzed were not detected. It might be because of the small amount of metal present in the samples. For more accurate results, future researchers can use other methods as an alternative to AAS.

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