# Distribution of Rare Earth Elements (REEs) in soil from Gua Musang, Kelantan.

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# DECLARATION

I declare that this thesis entitled “Distribution of Rare Earth Elements (REEs) in soil from Gua Musang, Kelantan” is the results of my own research except as cited in the references.

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# Distribution of Rare Earth Elements (REEs) in soil from Gua Musang, Kelantan

## ABSTRACT

Rare Earth Elements (REEs) distribution within the soils of Gua Musang, Kelantan, Malaysia.There is lack of previous REE studies comparing the rare earth element (REE) concentrations and patterns across various soil profiles and their associated intermediate-acidic complexes (IACs). This research is to characterize of grain size distributions across various soil profile layers at selected locations. Secondly, our research is to explore the distribution patterns of REEs within the soil profiles of the selected sites. Samples were collected from Paloh, Felda Aring, and Laluan Persekutuan Chiku, with each sample obtained from 16 distinct pin locations. A 4mm to 32 µm sieve was used to separate the grain sizes of the samples. The total digestion method, involving the use of $HNO_3$, HCl, $H_2O_2$, HF, and Boric acid, was employed to digest the samples. Subsequently, Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) was utilized to detect REEs elements in the liquid samples. Among the sites studied, LP-A exhibited the highest concentration of REEs within the total REEs content in the soil of Gua Musang, Kelantan, followed by PA-B> PA-E> PA-A> PA-O> PA-AB> LP-O> LP-C> FA-Core 1> FA-C> FA-O> FA-Core 2> FA-B> LP-B> FA-A> FA-E. Notably, the highest concentration observed was 266.954 ppm, while the lowest concentration was recorded in the FA-E sample, at 38.977 ppm.

Keywords: REEs, ICP-OES, Total Digestion Method, Sieve

# Taburan Unsur Nadir Bumi (REE) dalam tanah dari Gua musang, Kelantan

## ABSTRAK

Taburan Unsur Nadir Bumi (REE) dalam tanah Gua Musang, Kelantan, Malaysia. Terdapat kekurangan kajian REE terdahulu yang membandingkan kepekatan dan corak unsur nadir bumi (REE) merentas pelbagai profil tanah dan kompleks berasid perantaraan (IAC) yang berkaitan. Penyelidikan ini adalah untuk mencirikan taburan saiz bijian merentasi pelbagai lapisan profil tanah di lokasi terpilih. Kedua, penyelidikan kami adalah untuk meneroka corak taburan REE dalam profil tanah di kawasan yang telah di pilih. Sampel dikumpul dari Paloh, Felda Aring, dan Laluan Persekutuan Chiku, dengan setiap sampel diperoleh dari 16 lokasi pin yang berbeza. Pengayak 4mm hingga 32 µm digunakan untuk mengasingkan saiz butiran sampel. Kaedah penghadaman keseluruhan, yang melibatkan penggunaan HNO3, HCl, H2O2, HF, dan asid Borik, digunakan untuk mencerna sampel. Selepas itu, Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) telah digunakan untuk mengesan unsur REE dalam sampel cecair. Antara tapak yang dikaji, LP-A mempamerkan kepekatan tertinggi REE dalam jumlah kandungan REE di tanah Gua Musang, Kelantan, diikuti oleh PA-B> PA-E> PA-A> PA-O> PA-AB> LP-O> LP-C> FA-Core 1> FA-C> FA-O> FA-Core 2> FA-B> LP-B> FA-A> FA-E. Terutamanya, kepekatan tertinggi yang diperhatikan ialah 266.954 ppm, manakala kepekatan terendah dicatatkan dalam sampel FA-E, pada 38.977 ppm.

Kata kunci: REEs, ICP-OES, Kaedah Pencernaan Jumlah, Pengayak

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| PA | Paloh |
| FA | Felda Aring |
| LP | Laluan Persekutuan Chiku |
| REEs | Rare Earth Elements |
| LREE | Light Rare Earth Elements |
| HREE | Heavy Rare Earth Elements |
| UMK | Universiti Malaysia Kelantan |
| GREAT | Gold, Rare Eartg and Advance Technology |
| ICP-OES | Inductively Couple Plasma-Optical Emission Spectrometry |
| ICP-MS | Inductively Couple Plasma-Mass Spectrometry |
| IUPAC | International Union of Pure and Applied Chemistry |
| IACs | Iintermediate-Acidic Complexes |
| BDL | Below Detection Limit |

# LIST OF SYMBOLS

| | |
|---|---|
| % | Percentage |
| µm | Micrometer |
| Mm | Millimeter |
| $^2$ | Square |
| °C | Degree Celsius |
| ° | Degree |
| > | Larger than |
| < | Smaller than |
| = | is equal to |
| g | Gram |
| O | Oxygen |
| La | Lanthanum |
| Ce | Cerium |
| Pr | Praseodymium |
| Nd | Neodymium |
| Pm | Promethium |
| Sm | Samarium |
| Eu | Europium |
| Gd | Gadolinium |
| Tb | Terbium |
| Dy | Dysprosium |
| Ho | Holmium |

| | |
|---|---|
| Er | Erbium |
| Tm | Thulium |
| Yb | Ytterbium |
| Lu | Lutetium |
| Y | Yttrium |
| HF | Hydrofluoric Acid |
| $H_2O_2$ | Hydrogen Peroxide |
| $HNO_3$ | Nitric Acid |
| $H_3BO_3$ | Boric Acid |
| Zn | Zinc |
| Hg | Mercury |
| Cd | Cadmium |
| Pb | Lead |
| Cu | Copper |
| Ni | Nickel |
| As | Arsenic |
| Cr | Chromium |
| Al | Aluminum |
| Ba | Barium |
| Co | Cobalt |
| Mn | Manganese |
| Se | Selenium |
| Ag | Silver |
| Ppm | Parts Per Million |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Rare earth elements (REEs) is a group of 17 metallic elements. These comprise the 15 lanthanides listed on the periodic table, in addition to scandium and yttrium. More than 200 products require rare-earth elements (REEs), particularly high-tech consumer goods like cell phones, computer hard drives, electric and hybrid vehicles, flat-screen monitors, and televisions. REEs are also essential components of over 200 products across a wide range of uses. Electronic displays, guiding systems, lasers, radar, and sonar systems are examples of important defence uses. Despite the fact that the amount of REE used in a product may not constitute a sizable portion of it in terms of weight, value, or volume, the REE may be required for the device to operate. For instance, the spindle motors and voice coils of PCs and laptops would not be conceivable without magnets constructed of REEs, even though they frequently make up a small portion of the overall weight. (American Geosciences Institute, 2018).

The International Union of Pure and Applied Chemistry (IUPAC) defines rare earth elements (REEs) as a collection of 17 elements with comparable physicochemical properties. Of these elements, 15 belong to the group of lanthanides with atomic numbers between $Z = 57$ and $Z = 71$, as follows: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). They are joined by two further elements: scandium (Sc, $Z = 21$) and yttrium (Y, $Z = 39$). REEs are generally classified into two groups: light (LREE) and heavy (HREE). La, Ce, Pr, Nd, Pm, and Sm are the LREE. They are more abundant in the environment, have smaller atomic masses, and have higher solubility and alkalinity. The HREE group includes the following elements: Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, and Y. These elements have greater atomic masses, lower solubility, and are more alkaline. However, there is no total definition in the scientific community to classify any element inside the LREE or HREE groups (Ramos et al., 2016).

Alluvial, or red, soil makes up the majority of Gua Musang's soil and is found on the surface in most places (Yusof, 2018). The bedrock of Gua Musang, Kelantan, including slate, shale, andesite, mudstone, phyllite, and sandstone of various geological ages, is a source of soil (Zin, 2021). Gua Musang's soil is vital to the plantation sector, particularly for rubber and oil palm plantations. Nevertheless, heavy elements like iron, manganese, copper, zinc, lead, chromium, and cadmium that might have an impact on the ecosystem and soil quality may also be present in the soil (Ismail et al., 2023).

## 1.2 Problem Statement

There is lack of previous REE studies comparing the rare earth element (REE) concentrations and patterns across various soil profiles and their associated intermediate-acidic complexes (IACs). Rather than presenting detailed data on individual REE abundances and variations, the previous research only provided average values of total REE along with the percentage breakdown of light REE (LREE) and heavy REE (HREE) for each sampling location. (Citation!) Geochemical investigations concentrating on REEs from soils in each stratum of the O, A, E, B, C, and R Horizons are required to decipher a broad view of soil origin.

## 1.3 Objectives

The research objective are:

1) To determine the grain size distributions across the soil profile layers of the selected locations in Gua Musang, Kelantan.
2) To study the distribution of Rare Earth Elements (REEs) across the soil profiles of the selected locations in Gua Musang, Kelantan.

## 1.4 Scope of Study

The scope of the study on distribution of REEs in soil is to investigate the concentrations of REEs that contents in soil from 3 point of location at Gua Musang, Kelantan by extraction of REEs using total digestion method and the analysis measurement using ICP-OES.

## 1.5 Significances of Study

A study on the distribution of Rare Earth Elements (REEs) in the soil at Gua Musang, Kelantan, holds significant implications for various fields. First and foremost, understanding the spatial distribution of REEs in this region is critical for environmental assessment and management. Given the growing demand for REEs in various high-tech applications, including electronics and clean energy technologies, potential mining activities in the area could have significant environmental impacts. By delineating the REE distribution, the study provides valuable insights into the potential environmental risks and allows for informed decision-making regarding mining practices and environmental protection measures.

Additionally, the knowledge gained from such a study can be instrumental for the agricultural sector. Soil quality and nutrient content are vital for crop productivity, and some REEs can influence plant growth.Rare earth elements (REEs) have the capacity to regulate various physiological processes in plants through their modulation of cellular calcium ion ($Ca^{2+}$) levels, chlorophyll activity, and photosynthetic rates (Tyler, 2004). Furthermore, REEs can stimulate the synthesis of natural compounds and facilitate the absorption of additional nutrients within plants (Tao et al., 2022). By mapping the distribution of REEs in the soil, farmers and land managers in Gua Musang can make informed decisions about soil management and crop selection, ultimately enhancing agricultural productivity.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Rare earth elements (REEs)

The lanthanide elements, together with scandium and yttrium, which share similar physical characteristics and are frequently found in the same ores and deposits, make up the rare earth elements (REEs). REEs are specifically defined as the heavy REEs (HREEs) gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, scandium, and yttrium and the light REEs (LREEs) lanthanum, cerium, praseodymium, neodymium, samarium, and europium. Although the majority of these elements are often present in adequate quantities in the earth’s crust, they are not particularly unusual when it comes to being located in one place where mining them would be profitable. Although there is no comparable equivalent for the several significant uses of REEs in modern technologies, the growing demand for these elements has set pressure on supply (Rare Earth Elements.., 2012).

### 2.1.1 REEs characteristics

The 15 lanthanide elements on the periodic table, that include lanthanum (La) to lutetium (Lu), as well as the transition metals scandium (Sc) and yttrium (Y), are collectively referred to as rare earth elements (REEs). The REE are categorised as metals and have a relatively malleable, ductile, and soft texture. The majority are silver-gray in colour and quickly oxidise in air to create oxide compositions $(REEs)_2O_3$. Similar geochemical features and shared associations in nature result from the lanthanides (La to Lu) and Y's gradual decline in ionic radius and usual trivalent ionic state. Even while Sc and the other REEs share the same trivalent ionic structure, its significantly smaller ionic size causes it to behave differently geochemically and is more frequently linked to metallic elements like nickel (Ni), cobalt (Co), and chromium (Cr). The lone radioactive element in the series, promethium (Pm), is a lanthanide that is mostly created artificially as a byproduct of uranium fission and is incredibly rare in nature (Grover.., 2024).

The REEs are typically split into two groups: light REE (LREE) (La, Ce, Pr, Nd, Pm, Sm, Eu, and Gd) and heavy REE (Tb, Dy, Ho, Er, Tm, Yb, Lu, and Y). Although it is a somewhat arbitrary categorization, the LREE have a relatively large ionic radius similar to calcium ($Ca^{2+}$=1.12Å) and thorium ($Th^{4+}$=1.05 Å), whereas the HREE have a smaller ionic radius similar to uranium ($U^{4+}$=1.00 Å) and manganese ($Mn^{2+}$=0.96 Å). As a result of the variety of ionic sizes, substitution into more than 200 rock-forming minerals, particularly phosphates and carbonates, is possible. REE-bearing minerals frequently exhibit selective enrichment in LREE or HREE depending on the mineral compound's original composition and crystal structure, the geological conditions under which the mineral developed, and a number of complex ion exchange mechanisms (Gergorić et al., 2017).

Rare earth elements (REEs) consist of 17 metals distinguished by their distinct properties and widespread application in various technologies. While REEs aren't genuinely scarce, their extraction and refinement pose challenges due to their frequent intermixing with other minerals and their low abundance in the Earth's crust (King.., 2017).

## 2.2 Soil profile

The uppermost layer of the earth's crust, known as the soil, is mostly made up of organic materials and small pieces of rock that are important to life. A soil profile, consisting of layers parallel to the surface, is a vertical cross-section of the soil. Soil horizons are the names for these layers. In the process of forming, the soil is layered or horizontal. Soil profile refers to these horizons or layers. A soil pit exposes this vertical portion of the earth. The colour and particle size of the soil make it easy to distinguish between the soil layers. Topsoil, subsoil, and parent rock are the three separate soil layers; each layer has unique properties of its own. Determining the function of the soil is also aided by its profile. Using characteristics of the soil sample, such as colour, texture, structure, thickness, and chemical makeup, it aids in distinguishing it from other samples (Nations.., 2006).

The soil profile is made up of a series of horizons or layers of soil that are layered on top of one other. The letters O, A, E, C, B, and R symbolise these horizons. The O horizon is the topsoil's upper layer, and it is mostly made up of organic elements including dried leaves, grasses, dead leaves, small boulders, twigs, surface creatures, fallen trees, and other degraded organic matter. This horizon of soil is frequently black brown or dark brown in hue, owing to the presence of organic matter. Next is for A horizon. This layer, known as the humus layer, is rich in organic material. This layer is made up of both biological substances and degraded elements. The topsoil is soft and porous, allowing adequate air and water to pass through. This layer is responsible for seed germination and the formation of new roots, which eventually grow into a new plant. This layer is made up of microorganisms such as earthworms, fungi, bacteria, and so on. The E horizon is made up of nutrients that have been leached from the O and A horizons. The level is more abundant in forested areas and contains less clay. The B horizon, also known as subsoil, is the subsurface horizon that exists immediately beneath the topsoil and above the bedrock. It is much tougher and more compact than topsoil. It has a lower concentration of humus, soluble minerals, and organic materials. It is a place of mineral and metal salt deposition, such as iron oxide. Because of the presence of clay soil, this layer stores more water than the topsoil and is lighter brown. While ploughing the fields, the soil from horizons A and B is frequently combined. This type of layer is made mainly of shattered bedrock and is devoid of organic materials. This layer is also referred to as saprolite. This zone's geological substance has solidified. This is the C horizon, often known as the saprolite. The layer that known as the R horizon is compacted and cemented. This area is home to a variety of rocks, including limestone, granite, and basalt (Batjes et al., 2020).

### 2.2.1 Soil composition

Inorganic mineral matter accounts for around 40 to 45 percent of the soil volume, organic matter accounts for approximately 5 percent of the soil volume, and water and air account for approximately 50 percent of the soil volume. The amount of each of the four basic soil components varies according on the amount of vegetation, soil compaction, and water in the soil. A healthy soil contains enough air, water, nutrients, and organic matter to encourage and sustain plant growth (Libretexts.., 2022).

Everything that is visible and tactile, including as texture, colour, depth, structure, porosity (the gap between particles), and stone content, are examples of a soil's physical features. The health of the soil and plants is influenced by good soil structure, which permits air and water to pass through the soil profile (Department of Jobs, Precincts and Regions.., 2023). The distribution of grain sizes can have a big influence on how soils behave in certain applications. Grain mineral make up soils, and how these grain are arranged and sized greatly affects the soil's characteristics. Within a single soil sample, grain can vary in size from exceedingly coarse (>100mm) to very fine(<2micron) (Lees.., 2022).

## 2.3 Total digestion method

The technique of digestion in a sealed container in a microwave-heated reactor significantly reduces the danger of errors inherent in analysis when substances are dissolved using the usual dry process. One of the factors that contribute significantly to this reduction is the sample handling that takes place in a closed container, so the risk of contamination can be significantly reduced which can make reagents with high purity used and the reactor material handled free from impurities and also the time the sample is in contact with the reactor is shorter than traditional methods and can reduce risk (AZoM..,2023).

## 2.4 Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES)

ICP-OES, or inductively coupled plasma optical emission spectroscopy, is an analytical method that counts the concentration of certain elements in a sample. The ICP-OES principle transfers electrons from the ground state to an excited state by taking use of the fact that atoms and ions may absorb energy. The excited atoms' release of light at particular wavelengths upon transitioning to a lower energy level is the basis for the ICP-OES principle. The analytical method known as inductively coupled plasma-optical emission spectroscopy (ICP-OES) is used to determine the atomic composition of a given material. The method effectively determines the kind and relative quantity of each ingredient within the complexity of a compound by utilising the distinct photophysical signals of each element. ICP-OES is very useful for complicated sample analysis; it has been applied to the research on trace elements in the human brain, the chemical makeup of e-cigarettes, pesticide screening, and evaluating the quality of medicinal compounds (Khan et al., 2021). The method has also proven to be routinely useful in the analysis of wine, drinking water, and petrochemicals, where it plays a part in the extraction, purification, and discovery stages of the process (Levine.., 2023).

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 Materials

The chemicals and reagents that were used in the experiment are listed in Table 3.1.

**Table 3.1:** List of Chemical and Reagents

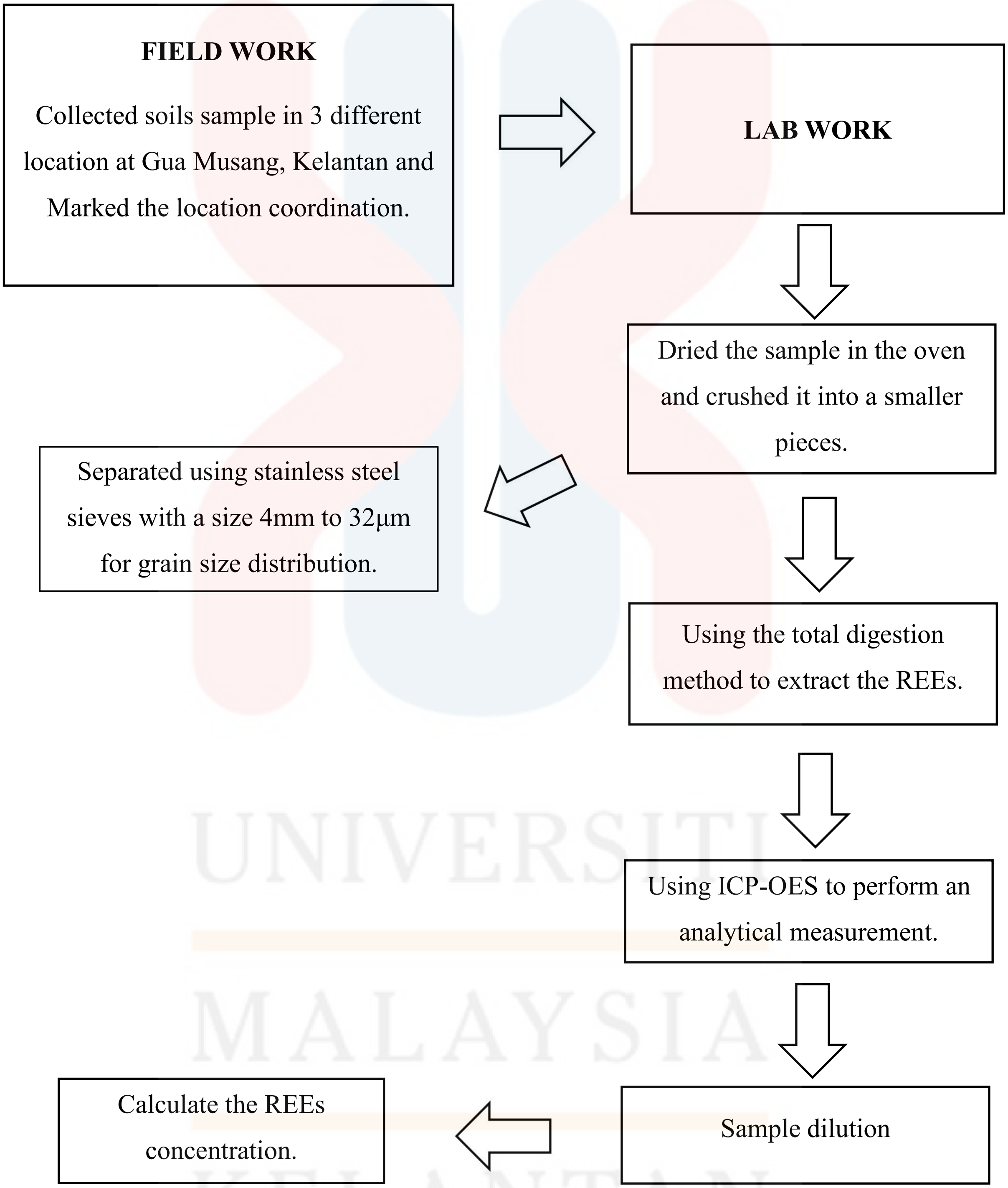
| No | Chemicals and Reagents |
|---|---|
| 1 | Hydrofluoric Acid (HF) from Merck |
| 2 | Hydrogen Peroxide ($H_2O_2$) from Merck |
| 3 | Nitric Acid ($HNO_3$) from Merck |
| 4 | Boric Acid ($H_3BO_3$) from Merck |
| 5 | De-ionised water |

The apparatus that were used are listed in Table 3.2.

**Table 3.2:** List of apparatus

| No | Apparatus |
|---|---|
| 1 | Measuring cylinder |
| 2 | Micropipette |
| 3 | Teflon beaker |
| 4 | Beaker |
| 5 | Crucible |
| 6 | Falcon tube |
| 7 | Sieve 32 μm |
| 8 | Sieve Set |
| 9 | Soil sample |
| 10 | Hotplate |
| 11 | Mortar and pestle |

## 3.2 Methods



**FIELD WORK**

Collected soils sample in 3 different location at Gua Musang, Kelantan and Marked the location coordination.

**LAB WORK**

Dried the sample in the oven and crushed it into a smaller pieces.

Separated using stainless steel sieves with a size 4mm to 32µm for grain size distribution.

Using the total digestion method to extract the REEs.

Using ICP-OES to perform an analytical measurement.

Sample dilution

Calculate the REEs concentration.

**Figure 3.1** : Flow chart of methodology

### 3.2.1 Collection of soil sample

The soil samples was collected at 3 point of location from Gua Musang, Kelantan that is at Felda Aring, Chiku and Paloh. The samples were taken by 15-16 October 2023. The samples was taken by the different horizons that is O, A, E, B, and C and place separately and sealed into different sample bag.

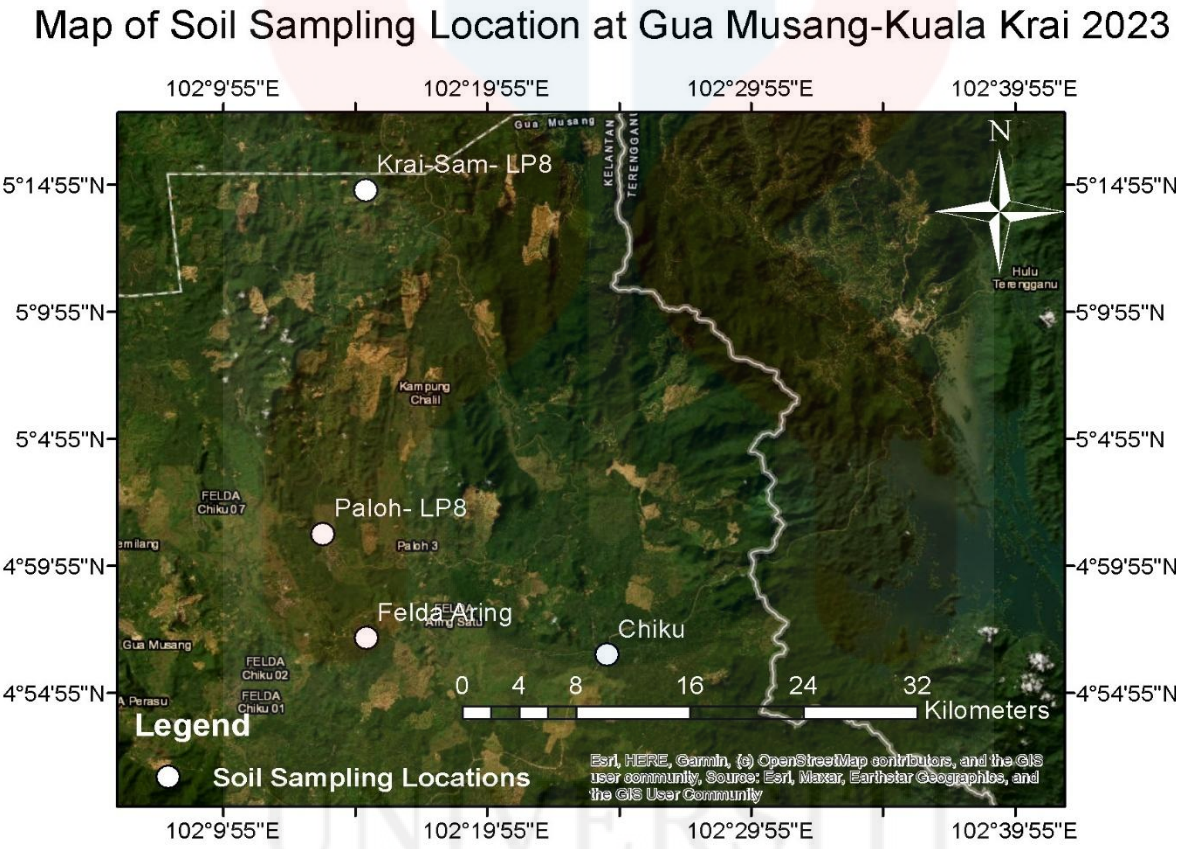


**Figure 3.2**: Soil Sampling Location

### 3.2.2 Preparation of sample

Once the samples attained a weight after drying, they were all weighed and oven-dried at 105°C. After that, the materials were crushed into little pieces using a hammer, and the soil grain sizes are separated using stainless steel sieves with a 4mm, 2mm, 1mm, 710µm, 500µm, 355µm, 250µm, 125µm, 63µm, and 32µm for the grain size distribution and 32 µm mesh size before being subjected to the full digesting process.

### 3.2.3 Extraction of REEs

The total digestion method is a common approach for extracting rare earth elements (REEs) from the soil samples. It involves digesting the entire sample to dissolve all the components, followed by various separation and analytical techniques. Crush the sample and sieve the sample using 32 μm into a fine powder to increase surface area. After that, treat the sample with strong acids by typically a mixture of nitric acid, hydrochloric acid, hydrogen peroxide and hydrofluoric acid to dissolve all components, including Rees. Techniques such as solvent extraction, ion exchange or precipitation are used to separate rare earth elements from dissolved solutions. Lastly, measure the concentrations of individual REEs using analytical methods like inductively coupled plasma optical emission spectrometry (ICP-OES). The total digestion method ensures that all elements in the sample are dissolved, allowing for a comprehensive analysis of REEs. It's crucial to follow strict quality control measures during each step of the process to obtain accurate results.

### 3.2.4 Inductively coupled plasma optical emission spectrometry (ICP-OES)

ICP-OES is the analytical technique that have been used to analysing the elements that contain in the sample. Each element emits characteristic wavelengths of light when in the plasma state. By measuring the intensity of these emitted wavelengths, the concentration of elements in the sample can be determined. ICP-OES typically has the higher detection limits compared to the other analytical technique, on the move from parts per million (ppm) to parts per billion (ppb) making it less sensitive for trace elemental analysis (Drawell.., 2023).

### 3.2.5 Calculation of REEs concentration

$$C = \left(\frac{a}{m}\right) x\, V \qquad \textbf{Equation 3.1}$$

C = concentration of metal test sample (mg/L)

a = sample concentration in the test solution (mg/L)

V = volume of the test solution (m/L)

m = weight of the test sample (g)

# CHAPTER 4

# RESULTS AND DISCUSSION

This chapter is presented the results and discussion for determine the grain size distribution across the soil profile layers, REEs analysis, and soil porosity in soil sample of Gua Musang, Kelantan. ICP-OES was used in analysis of REEs concentration and the result was compared with standard sample. The porosity percentage of the soil sample can be ascertained by applying the total water content method or the moisture content of the sample..

## 4.1 Soil Physical Characteristics (Grain Size)

The purpose of the grain size analysis test is to find out what proportion of each grain size is present in a sample of soil. The test findings can be utilized to create the grain size distribution curve. The information gathered from grain size distribution curves is used to design earth dam filters and assess if a particular soil is suitable for building roads, and air fields. Although permeability tests are more commonly employed, information from grain size analysis can be used to forecast soil water movement (Anon, 2024). These data are utilized to categorize the soil and forecast its behavior. The two most common techniques for determining the grain size distribution are hydra meter analysis for particles smaller than 0.075 mm in diameter and sieve analysis for particles bigger than 0.075 mm in diameter (Hossain..,2021).

In this research was use sieve analysis as small as <32 µm. This research was measured the granularity of the sample to calculate the percentages of gravel ( <4 mm ), sand ( 2 mm – 63 µm), silt ( 63 – 32 µm) and clay ( <32 µm). The table below shows the grain size distribution of the soil sample in Paloh (PA), Felda Aring (FA), and Laluan Persekutuan Chiku (LP).

| Soil type | | Particle Size (mm) |
|---|---|---|
| Gravel | | 4.75-75 |
| Sand | Coarse | 2.0-4.75 |
| | Medium | 0.42-2.0 |
| | Fine | 0.075-0.42 |
| Silt | | 0.002-0.075 |
| Clay | | <0.002 |

(Geoengineer..,2024)

**Table 4.1**: Grain Size Distribution in soil Sample

| Sample | Gravel(%) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|
| | | Paloh | | |
| PA-O | 0.01 | 95.22 | 3.96 | 0.83 |
| PA-A | 0.02 | 96.87 | 2.76 | 0.35 |
| PA-AB | 0.02 | 97.01 | 1.99 | 0.98 |
| PA-B | 0.03 | 96.53 | 2.41 | 1.03 |
| PA-E | 1.16 | 87.49 | 9.72 | 1.62 |
| | | Felda Aring | | |
| FA-O | 0 | 96.12 | 2.52 | 1.36 |
| FA-A | 0.01 | 98.41 | 1.36 | 0.22 |
| FA-B | 0.01 | 97.83 | 1.43 | 0.73 |
| FA-C | 35.26 | 59.69 | 3.92 | 1.13 |
| FA-CORE 1 | 0 | 96.73 | 2.65 | 0.62 |
| FA-CORE 2 | 0 | 97.42 | 2.08 | 0.50 |
| FA-E | 1.36 | 83.90 | 12.85 | 1.89 |
| | | Laluan Persekutuan | | |
| LP-O | 0 | 96.65 | 2.31 | 1.04 |
| LP-A | 0 | 97.74 | 1.86 | 0.40 |
| LP-B | 0.01 | 97.45 | 1.63 | 0.91 |
| LP-C | 34.13 | 59.65 | 4.97 | 1.25 |

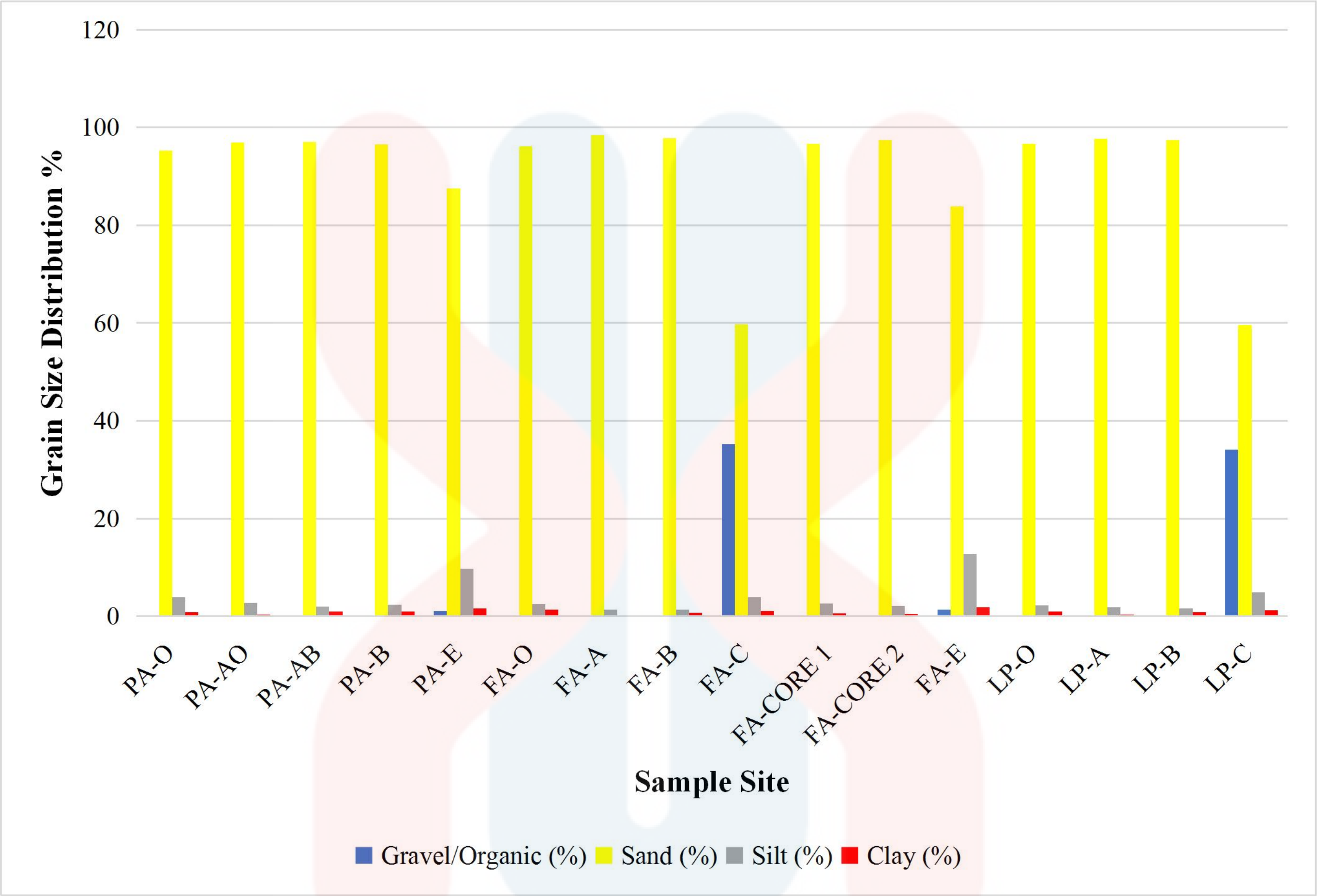


**Figure 4.1**: Grain Size Distribution in Soil Sample

Table 4.1 and Figure 4.1 illustrate the percentage distribution of grain size in soil samples collected from three different locations in Gua Musang, Kelantan. Soil analysis in the Gua Musang area revealed varying fractions, including gravel, sand, silt, and clay, ranging from 0% to 35.26% for gravel, 59.65% to 98.41% for sand, 1.36% to 12.85% for silt, and 0.22% to 1.89% for clay. On average, the soil composition in Gua Musang is 17.63% gravel, 79.03% sand, 7.105% silt, and 1.055% clay. Therefore, it is evident that the main component in the soil of this region is sand.

The highest percentage for sand is observed at sample site FA-A with 98.41%, while the lowest is recorded at LP-C with 59.65%. As for gravel, the lowest percentages are found at 5 sample sites: FA-O, FA-CORE 1, FA-CORE 2, LP-O, and LP-A, all registering 0%. Sample site

FA-E records the highest percentages for silt and clay. For silt, the recorded percentage is 12.85%, and for clay, it is 1.89%.

The soil sample under investigation exhibits the discernible attributes of a sandy soil, predominantly comprised of weathered primary rock minerals. Characterized by large and irregular sand particles, this soil type possesses a loose structure that impedes tight packing. Consequently, substantial interparticle pore spaces are formed, facilitating efficient air permeation within the soil matrix. Additionally, the porous nature of the soil promotes rapid water drainage, as water swiftly traverses through the interconnected pore network. Such structural attributes are conducive to optimal aeration, fostering favorable conditions for plant root proliferation and soil microbial activity. Nonetheless, the inherent looseness of sandy soils presents challenges, notably reduced water and nutrient retention capacities, necessitating frequent irrigation and fertilization regimes. A comprehensive grasp of these soil characteristics is imperative for informed agricultural or horticultural practices, guiding prudent plant selection and soil management strategies.

In contrast, silt, characterized by particles smaller than sand yet larger than clay, exerts pronounced influences on soil properties. With smaller pore spaces relative to sand, silt impedes efficient water drainage, potentially leading to adverse effects such as waterlogging. Unlike clay particles, which tend to flocculate, silt particles lack this propensity, thereby contributing to a less stable soil structure. Ranging in size from 0.002 to 0.05 mm, silt particles' diminutive pore spaces restrict water movement through the soil profile. These collective attributes underscore the complexities associated with managing silty soils, accentuating the imperative of comprehending soil composition for diverse applications, including agriculture and construction, wherein factors such as water retention and nutrient availability hold paramount significance.

Clay, distinguished by its minuscule particle size, assumes a pivotal role in soil composition and behavior. Resulting from chemical weathering processes, original mineral constituents degrade into elemental components, such as silicon, aluminum, iron, magnesium, potassium, and calcium, which subsequently undergo re-crystallization, giving rise to secondary minerals. Notably, clay particles exhibit a disproportionately large surface area relative to their minute pore spaces, endowing them with exceptional water retention capabilities. Further, their inherent negative charge renders them adept at attracting positively charged cations, including calcium, magnesium, hydrogen, aluminum, and potassium. This affinity for water and distinctive swelling and shrinking attributes, manifest upon wetting and drying cycles, contribute to clay's unique characteristics. Evident to denizens of clay-rich terrains, the soil's water retention capacity becomes conspicuous during drought periods, often resulting in the formation of deep, conspicuous cracks. Those navigating clay-laden landscapes may encounter the unmistakable residue adhering to footwear during such conditions, epitomizing the distinctive features of clay soils.

## 4.2 Moisture Content of Soil Sample

Soil moisture, though constituting a relatively small component within the broader hydrological cycle, holds paramount significance across a spectrum of hydrological, biological, and biogeochemical processes. Governmental bodies and commercial enterprises engaged in meteorology, hydrology, soil conservation, and related domains heavily rely upon soil moisture data for various purposes, including weather and climate analysis, runoff assessment, flood mitigation, erosion control, reservoir management, geotechnical engineering endeavors, and water quality monitoring.

The intricate interplay between the Earth's surface and the atmosphere, primarily facilitated through processes such as evaporation and plant transpiration, is profoundly contingent upon the moisture content present within the soil matrix. Consequently, the spatial and temporal distribution of soil moisture critically shapes weather patterns and influences the generation of precipitation events.

Furthermore, soil moisture plays an indispensable role in agricultural management, aiding in monitoring crop health, facilitating drought and flood prediction, informing forest fire risk assessments, and underpinning water resource management strategies. Importantly, soil moisture observations serve as early warning indicators for impending drought or flood conditions, often preceding conventional markers of such phenomena. Soil moisture serves as a linchpin for numerous natural and human systems, exerting profound influence on diverse processes spanning from meteorological phenomena to ecosystem dynamics, thereby warranting meticulous attention and scientific scrutiny (*Drought.gov..*, 2021).

The table presented below delineates the weights of soil samples before and after drying, along with the corresponding percentages of moisture content for the sampling site in Paloh (PA), Felda Aring (FA), and Laluan Persekutuan Chiku (LP).

**Table 4.2**: Moisture of Soil Sample

| Sample site | Sample Weight (g) | Dry sample weight (g) | Moisture (%) |
|---|---|---|---|
| | Paloh | | |
| PA-O | 1052.73 | 782.28 | 25.69 |
| PA-AO | 1042.05 | 572.85 | 45.03 |
| PA-AB | 1035.75 | 821.31 | 20.70 |
| PA-B | 1427.76 | 782.33 | 45.21 |
| PA-E | 1183.91 | 747.07 | 36.90 |
| | Felda Aring | | |
| FA-O | 1454.60 | 1292.47 | 11.15 |
| FA-B | 1347.86 | 1187.20 | 18.71 |
| FA-C | 1534.22 | 1431.70 | 17.80 |
| FA-CORE 1 | 1320.50 | 1073.46 | 11.92 |
| FA-CORE 2 | 1226.80 | 1008.37 | 6.68 |
| FA-A | 1368.61 | 1131.48 | 6.68 |
| FA-E | 760.17 | 593.43 | 18.71 |
| | Laluan Persekutuan Chiku | | |
| LP-O | 1452.54 | 1047.15 | 27.91 |
| LP-A | 1194.42 | 888.72 | 25.59 |
| LP-B | 1443.38 | 1051.25 | 27.17 |
| LP-C | 1243.19 | 1031.74 | 17.01 |

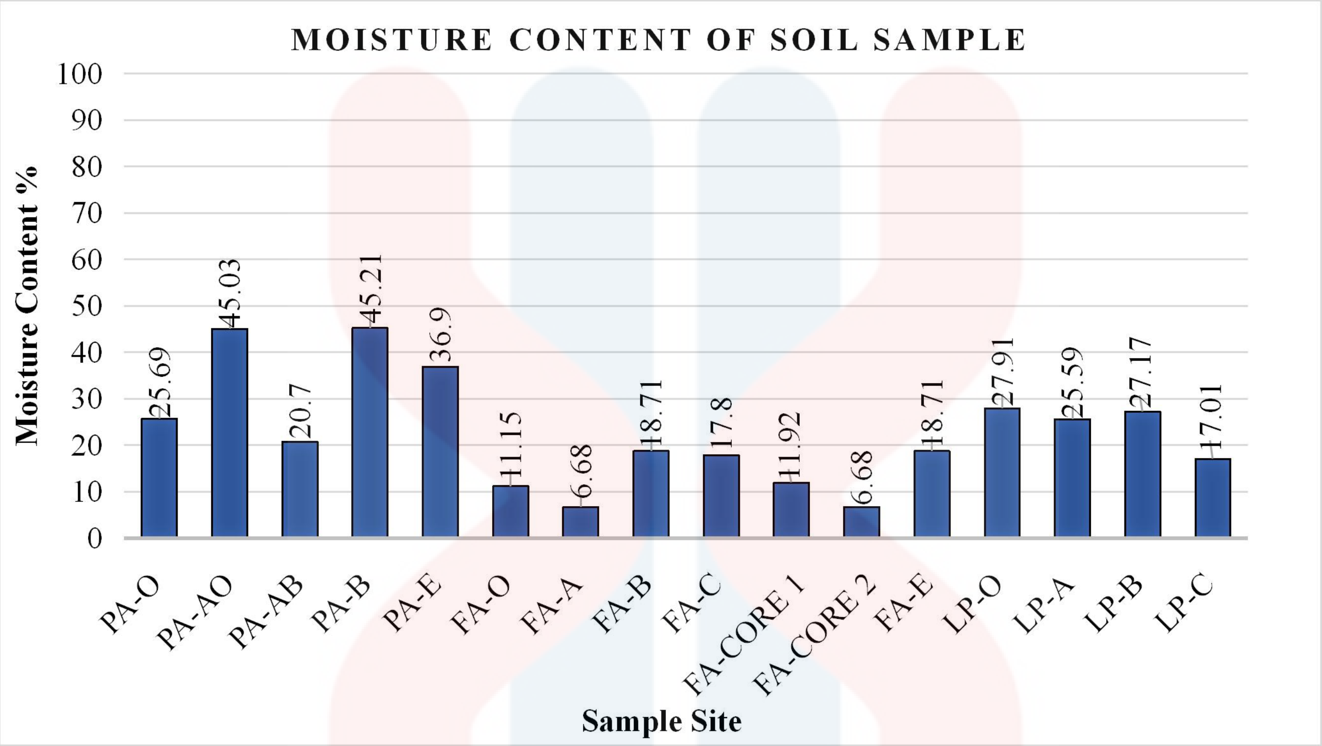


**Figure 4.2**: Moisture Content of Soil Sample

Soil samples collected in Paloh (PA) exhibited higher moisture content than the locations depicted in Figure 4.2, with two sample sites in Paloh recording an increase to 45 percent compared to other samples. In the sample Felda Aring (FA) recorded the lowest moisture content compared to the other samples. The highest percentage was observed at the FA-B soil sample site which was recorded at 18.71%, while the lowest percentage was recorded at the FA-CORE 2 soil sample site with 6.68%. In the soil sampling of the Laluan Persekutuan (LP) area, this location holds the second highest position among the three sampling sites in terms of moisture percentage. The highest recorded percentage at this location is 27.91%, observed at sample site LP-O, while the lowest percentage is at sample site LP-C, recorded at 17.01%. The sampling sites in LP demonstrate a relatively stable moisture content, with only sample site LP-C showing a moisture percentage below 25%.

## 4.3 Distribution of REEs in Soil

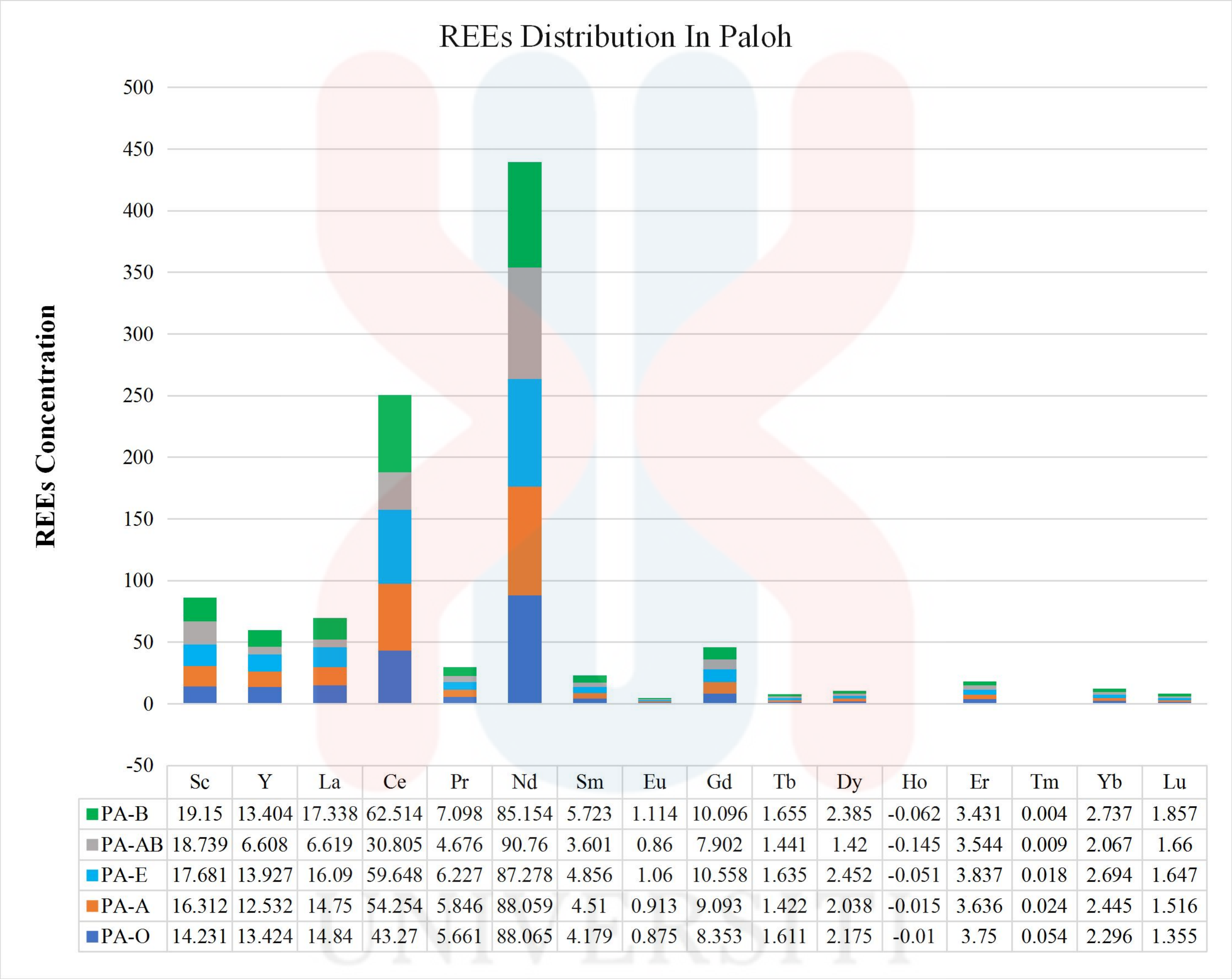
Table 4.3, 4.4, and 4.5 show the distribution of REEs in the soil sample at sample site Paloh, Felda Aring, and Laluan Persekutuan Chiku. The concentration is analysed using ICP-OES because has a better sample throughput than other methods because of its faster analysis time. It can evaluate several samples per hour.

### 4.3.1 REEs Distribution In Paloh (PA)

**Table 4.3**: REEs Distribution in Paloh (PA)

| **Sample Site** | **Concentration(ppm)** | | | | |
|---|---|---|---|---|---|
| | **PA-O** | **PA-A** | **PA-E** | **PA-AB** | **PA-B** |
| Sc | 14.231 | 16.312 | 17.681 | 18.739 | 19.150 |
| Y | 13.424 | 12.532 | 13.927 | 6.608 | 13.404 |
| La | 14.840 | 14.750 | 16.090 | 6.619 | 17.338 |
| Ce | 43.270 | 54.254 | 59.648 | 30.805 | 62.514 |
| Pr | 5.661 | 5.846 | 6.227 | 4.676 | 7.098 |
| Nd | 88.065 | 88.059 | 87.278 | 90.760 | 85.154 |
| Sm | 4.179 | 4.510 | 4.856 | 3.601 | 5.723 |
| Eu | 0.875 | 0.913 | 1.060 | 0.860 | 1.114 |
| Gd | 8.353 | 9.093 | 10.558 | 7.902 | 10.096 |
| Tb | 1.611 | 1.422 | 1.635 | 1.441 | 1.655 |
| Dy | 2.175 | 2.038 | 2.452 | 1.420 | 2.385 |
| Ho | | | BDL | | |
| Er | 3.750 | 3.636 | 3.837 | 3.544 | 3.431 |
| Tm | 0.054 | 0.024 | 0.018 | 0.009 | 0.004 |
| Yb | 2.296 | 2.445 | 2.694 | 2.067 | 2.737 |
| Lu | 1.355 | 1.516 | 1.647 | 1.660 | 1.857 |
| **Total** | **204.139** | **217.350** | **229.608** | **180.711** | **233.660** |

BDL: Below Detection Limit



| | Sc | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PA-B | 19.15 | 13.404 | 17.338 | 62.514 | 7.098 | 85.154 | 5.723 | 1.114 | 10.096 | 1.655 | 2.385 | -0.062 | 3.431 | 0.004 | 2.737 | 1.857 |
| PA-AB | 18.739 | 6.608 | 6.619 | 30.805 | 4.676 | 90.76 | 3.601 | 0.86 | 7.902 | 1.441 | 1.42 | -0.145 | 3.544 | 0.009 | 2.067 | 1.66 |
| PA-E | 17.681 | 13.927 | 16.09 | 59.648 | 6.227 | 87.278 | 4.856 | 1.06 | 10.558 | 1.635 | 2.452 | -0.051 | 3.837 | 0.018 | 2.694 | 1.647 |
| PA-A | 16.312 | 12.532 | 14.75 | 54.254 | 5.846 | 88.059 | 4.51 | 0.913 | 9.093 | 1.422 | 2.038 | -0.015 | 3.636 | 0.024 | 2.445 | 1.516 |
| PA-O | 14.231 | 13.424 | 14.84 | 43.27 | 5.661 | 88.065 | 4.179 | 0.875 | 8.353 | 1.611 | 2.175 | -0.01 | 3.75 | 0.054 | 2.296 | 1.355 |

**Figure 4.3**: Distribution of REEs in Paloh

Examining Figure 4.3.1 above, it is evident that Neodymium (Nd) is the predominant element found at sample site PA. Among the five sample sites in the PA area, PA-AB exhibits the highest recorded result, reaching 90.760 for Nd element. Conversely, the least abundant element at PA-AB is Holmium (Ho) with a BDL that's mean Below Detectiob Limit, marking the lowest for the five sample sites. Other elements recorded in the PA-AB results include Scandium (Sc) at 18.739, Yttrium (Y) at 6.608, Lanthanum (La) at 6.619, Cerium (Ce), Praseodymium (Pr) at

4.676, Samarium (Sm) at 3.601, Europium (Eu) at 0.860, Gadolinium (Gd) at 7.902, Terbium (Tb) at 1.441, Dysprosium (Dy) at 1.420, Erbium (Er) at 3.544, Thulium (Tm) at 0.009, Ytterbium at 2.067, and finally, Lutetium (Lu) with a result of 1.660.

For the five sampled sites, the highest concentration of REEs is attributed to the element Nd, with concentrations for PA-O at 88.065, PA-A at 88.059, PA-E at 87.278, PA-AB at 90.760, making it the highest. Meanwhile, PA-B records the lowest concentration of Nd at 85.154.

The variability in neodymium concentrations within soil samples can be attributed to diverse factors such as geographical locale, geological composition, and environmental dynamics. Numerous research investigations have underscored the frequent prominence of neodymium content relative to other rare earth elements in soil specimens sourced from diverse geographical regions, including but not limited to China, Brazil, and Iran. Plausible elucidations for this observation may encompass the abundance of neodymium-bearing minerals, the geochemical behavior of neodymium within soil matrices, and anthropogenic influences on its distribution and concentration (Pourjavid et al., 2012).

**Table 4.4**: Total REEs Concentration in Paloh

| **Sample Site** | **Concentration(ppm)** | | | | |
|---|---|---|---|---|---|
| | **PA-O** | **PA-A** | **PA-E** | **PA-AB** | **PA-B** |
| **Total** | 204.139 | 217.350 | 229.608 | 180.711 | 233.660 |

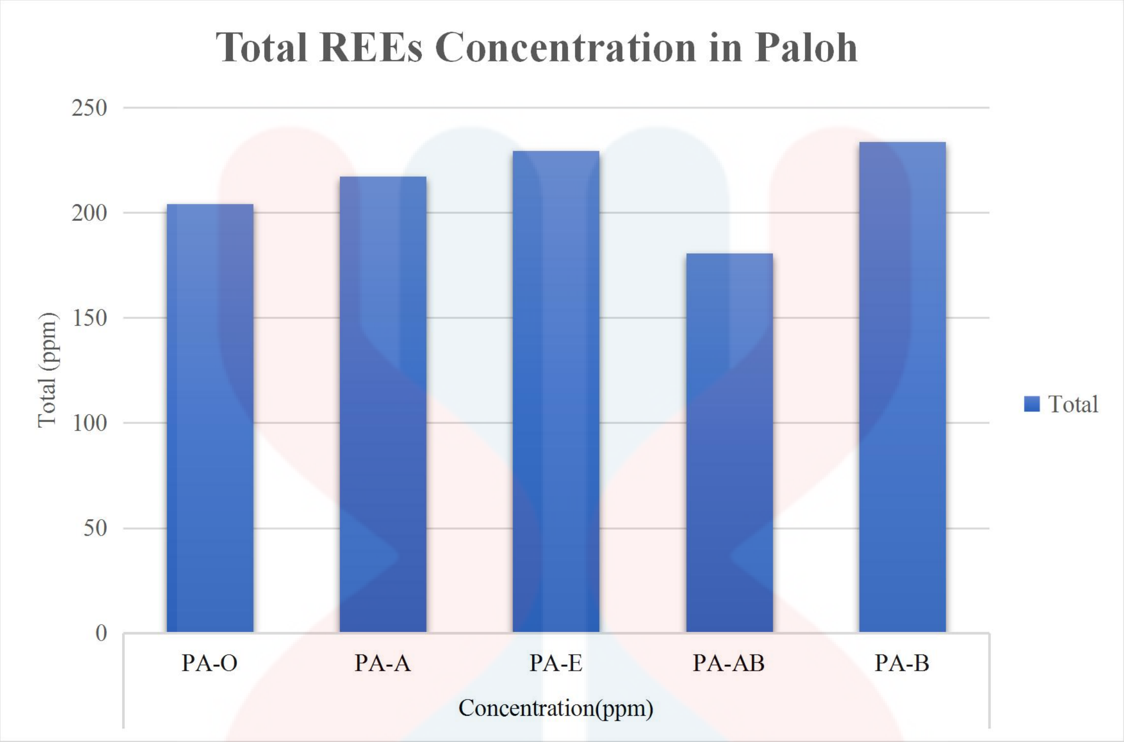


**Figure 4.4**: Total REEs concentration in Paloh

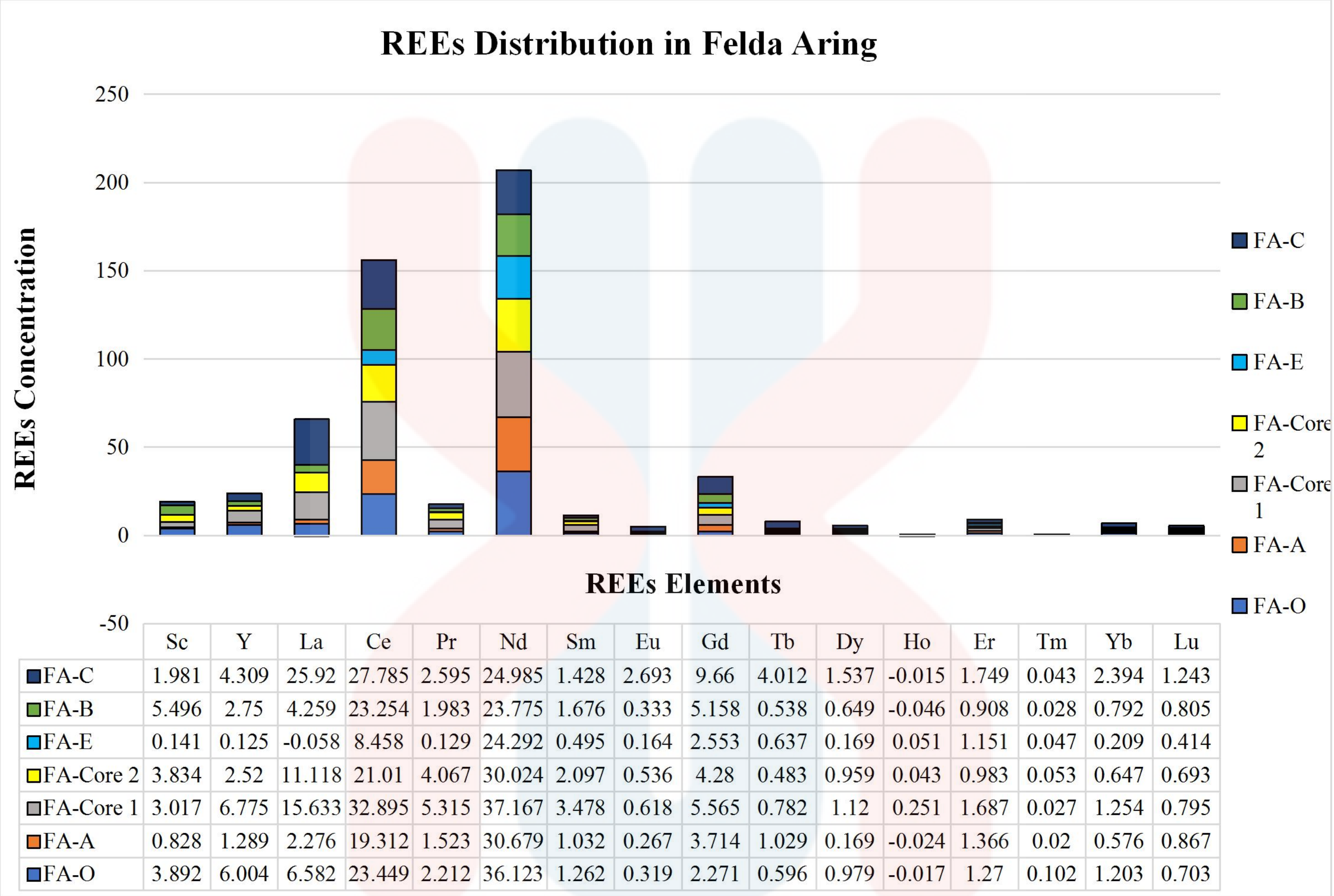
From table 4.4 and figure 4.4, we can discern the presence of all Rare Earth Elements (REEs) in the soil samples collected at the Paloh site. This enables us to identify the highest and lowest concentrations of each element, facilitating an assessment of the land usability in this area for various purposes. The total concentration of rare earth elements (REEs) was analyzed across various sample sites denoted as PA-O, PA-A, PA-E, PA-AB, and PA-B. The concentrations, expressed in parts per million (ppm), revealed varying levels among the sites, with exhibiting the highest concentration at PA-B at 233.660 ppm, followed by PA-E at 229.608 ppm. Next, PA-A at 217.350 ppm, PA-O at 204.139 ppm, and PA-AB recording the lowest concentration at 180.711 ppm. These findings suggest spatial discrepancies in REE distribution, highlighting the need for further investigation into the underlying geological and environmental factors influencing their accumulation.

### 4.3.2 REEs Distribution In Felda Aring (FA)

**Table 4.5**: REEs Distribution Felda Aring (FA)

| Sample Site | Concentration (ppm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **FA-O** | **FA-A** | **FA-Core 1** | **FA-Core 2** | **FA-E** | **FA-B** | **FA-C** |
| Sc | 3.892 | 0.828 | 3.017 | 3.834 | 0.141 | 5.496 | 1.981 |
| Y | 6.004 | 1.289 | 6.775 | 2.520 | 0.125 | 2.750 | 4.309 |
| La | 6.582 | 2.276 | 15.633 | 11.118 | -0.058 | 4.259 | 25.920 |
| Ce | 23.449 | 19.312 | 32.895 | 21.010 | 8.458 | 23.254 | 27.785 |
| Pr | 2.212 | 1.523 | 5.315 | 4.067 | 0.129 | 1.983 | 2.595 |
| Nd | 36.123 | 30.679 | 37.167 | 30.024 | 24.292 | 23.775 | 24.985 |
| Sm | 1.262 | 1.032 | 3.478 | 2.097 | 0.495 | 1.676 | 1.428 |
| Eu | 0.319 | 0.267 | 0.618 | 0.536 | 0.164 | 0.333 | 2.693 |
| Gd | 2.271 | 3.714 | 5.565 | 4.280 | 2.553 | 5.158 | 9.660 |
| Tb | 0.596 | 1.029 | 0.782 | 0.483 | 0.637 | 0.538 | 4.012 |
| Dy | 0.979 | 0.169 | 1.120 | 0.959 | 0.169 | 0.649 | 1.537 |
| Ho | BDL | | 0.251 | 0.043 | 0.051 | BDL | |
| Er | 1.270 | 1.366 | 1.687 | 0.983 | 1.151 | 0.908 | 1.749 |
| Tm | 0.102 | 0.020 | 0.027 | 0.053 | 0.047 | 0.028 | 0.043 |
| Yb | 1.203 | 0.576 | 1.254 | 0.647 | 0.209 | 0.792 | 2.394 |
| Lu | 0.703 | 0.867 | 0.795 | 0.693 | 0.414 | 0.805 | 1.243 |
| **Total** | **86.967** | **64.947** | **116.379** | **83.347** | **38.977** | **72.404** | **112.334** |

BDL: Below Detaction Limit



| | Sc | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ■FA-C | 1.981 | 4.309 | 25.92 | 27.785 | 2.595 | 24.985 | 1.428 | 2.693 | 9.66 | 4.012 | 1.537 | -0.015 | 1.749 | 0.043 | 2.394 | 1.243 |
| ■FA-B | 5.496 | 2.75 | 4.259 | 23.254 | 1.983 | 23.775 | 1.676 | 0.333 | 5.158 | 0.538 | 0.649 | -0.046 | 0.908 | 0.028 | 0.792 | 0.805 |
| ■FA-E | 0.141 | 0.125 | -0.058 | 8.458 | 0.129 | 24.292 | 0.495 | 0.164 | 2.553 | 0.637 | 0.169 | 0.051 | 1.151 | 0.047 | 0.209 | 0.414 |
| ■FA-Core 2 | 3.834 | 2.52 | 11.118 | 21.01 | 4.067 | 30.024 | 2.097 | 0.536 | 4.28 | 0.483 | 0.959 | 0.043 | 0.983 | 0.053 | 0.647 | 0.693 |
| ■FA-Core 1 | 3.017 | 6.775 | 15.633 | 32.895 | 5.315 | 37.167 | 3.478 | 0.618 | 5.565 | 0.782 | 1.12 | 0.251 | 1.687 | 0.027 | 1.254 | 0.795 |
| ■FA-A | 0.828 | 1.289 | 2.276 | 19.312 | 1.523 | 30.679 | 1.032 | 0.267 | 3.714 | 1.029 | 0.169 | -0.024 | 1.366 | 0.02 | 0.576 | 0.867 |
| ■FA-O | 3.892 | 6.004 | 6.582 | 23.449 | 2.212 | 36.123 | 1.262 | 0.319 | 2.271 | 0.596 | 0.979 | -0.017 | 1.27 | 0.102 | 1.203 | 0.703 |

**Figure 4.5**: REEs Distribution in Felda Aring

Table 4.4 and Figure 4.5 provide the data set of soil sample concentrations. We have measurements for various elements at different sampling sites, including FA-O, FA-A, FA-Core 1, FA-Core 2, FA-E, FA-B, and FA-C. These values represent distinct properties or characteristics of these elements, allowing us to analyze the data to identify the highest and lowest values for each element. Among the sampled elements, specific sampling sites exhibit the highest values. For example, Cerium (Ce) reaches its maximum concentration of 23.449 at FA-O, while Neodymium (Nd) attains its peak concentration of 30.679 at FA-A. Similarly, Gadolinium (Gd) displays its highest concentration of 9.660 at FA-C. Conversely, certain elements exhibit lower values at particular sampling sites. Holmium (Ho) records its lowest value with BDL at 4 sample site, and Thulium (Tm) registers its lowest value of 0.020 at FA-A. Europium (Eu) demonstrates its lowest concentration of 0.164 at FA-Core 1. In summary, the data set reveals varying concentrations of elements across different sampling sites, with specific elements displaying higher or lower values depending on the measurement location. This information is crucial for comprehending the distribution of these elements and their potential implications for the investigated site or area.

Nd, Ce, and La are constituents of the rare earth elements (REE) group, typically encountered across diverse geological settings such as alkaline and hyperalkaline magmatic environments, carbonatite formations, cationic clay deposits, and sedimentary strata (Kotelnikova et al., 2022). Their occurrence and dispersion within soil matrices are subject to multifaceted influences including parent rock characteristics, weathering processes, erosional dynamics, leaching phenomena, and anthropogenic interventions (Edahbi et al., 2018). Elevated concentrations of Nd, Ce, and La in soil profiles may stem from their origination in REE-enriched mineralogical substrates exposed at the earth's surface or transported via hydrological or aeolian mechanisms. Alternatively, human activities such as mining operations, industrial practices, agricultural activities, or waste management practices may contribute significantly to the augmented presence and mobilization of these elements within soil systems, potentially engendering environmental and health hazards (Edahbi et al., 2018).

**Table 4.6:** Total REEs Concentration in Felda Aring

| **Sample Site** | **Concentration (ppm)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **FA-O** | **FA-A** | **FA-Core 1** | **FA-Core 2** | **FA-E** | **FA-B** | **FA-C** |
| **Total** | 86.967 | 64.947 | 116.379 | 83.347 | 38.977 | 72.404 | 112.334 |

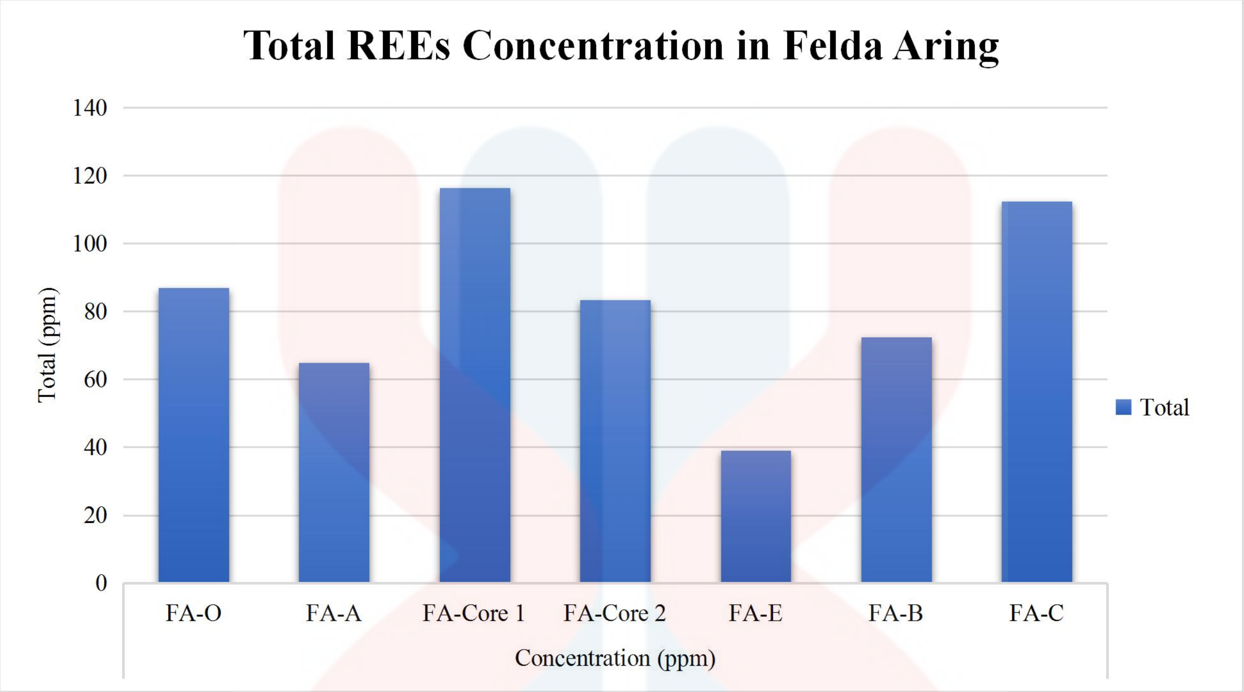


**Figure 4.6:** Total REEs Concentration in Felda Aring

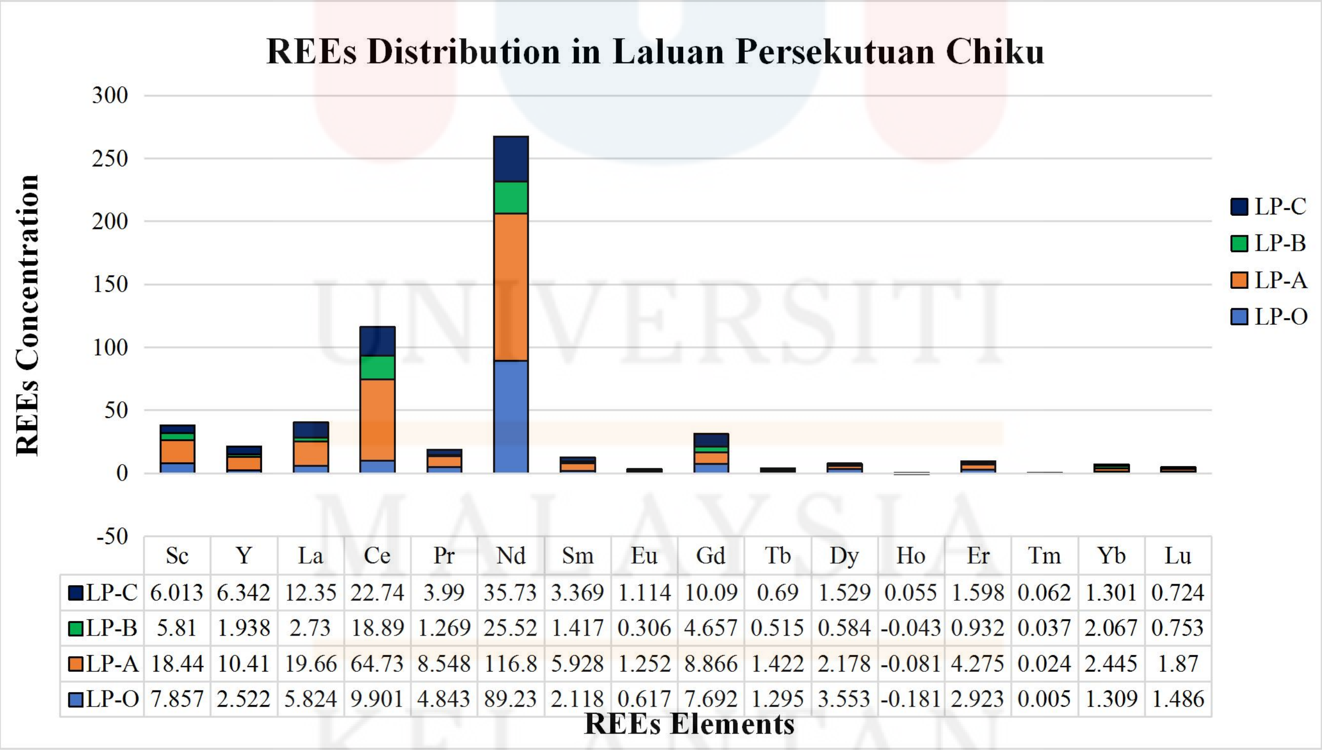
Table 4.6 and figure 4.6 shows the total concentration of rare earth elements (REEs) was analyzed across multiple sampling sites, revealing significant variations. The highest concentration was observed in FA-Core 1 with 116.379 ppm, followed by FA-C with 112.334 ppm, indicating enrichment in these areas. FA-A exhibited a moderate REE concentration of 64.947 ppm, while FA-Core 2 and FA-B displayed concentrations at 83.347 ppm and 72.404 ppm, respectively, FA-O recorded the total value of REEs at 86.967ppm. Notably, FA-E showed the lowest concentrations among the sites, with values of 38.977 ppm, respectively.

### 4.3.3 REEs Distribution In Laluan Persekutuan Chiku (LP)

**Table 4.6**: REEs Distribution Laluan Persekutuan Chiku (LP)

| **Sample Site** | **Concentration (ppm)** | | | |
|---|---|---|---|---|
| | **LP-O** | **LP-A** | **LP-B** | **LP-C** |
| Sc | 7.857 | 18.444 | 5.810 | 6.013 |
| Y | 2.522 | 10.418 | 1.938 | 6.342 |
| La | 5.824 | 19.660 | 2.730 | 12.350 |

| | | | | |
|---|---|---|---|---|
| Ce | 9.901 | 64.736 | 18.899 | 22.746 |
| Pr | 4.843 | 8.548 | 1.269 | 3.990 |
| Nd | 89.230 | 116.888 | 25.526 | 35.735 |
| Sm | 2.118 | 5.928 | 1.417 | 3.369 |
| Eu | 0.617 | 1.252 | 0.306 | 1.114 |
| Gd | 7.692 | 8.866 | 4.657 | 10.096 |
| Tb | 1.295 | 1.422 | 0.515 | 0.690 |
| Dy | 3.553 | 2.178 | 0.584 | 1.529 |
| Ho | BDL | | | |
| Er | 2.923 | 4.275 | 0.932 | 1.598 |
| Tm | 0.005 | 0.024 | 0.037 | 0.062 |
| Yb | 1.309 | 2.445 | 2.067 | 1.301 |
| Lu | 1.486 | 1.870 | 0.753 | 0.724 |
| **Total** | **141.175** | **266.954** | **67.440** | **107.659** |



| | Sc | Y | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LP-C | 6.013 | 6.342 | 12.35 | 22.74 | 3.99 | 35.73 | 3.369 | 1.114 | 10.09 | 0.69 | 1.529 | 0.055 | 1.598 | 0.062 | 1.301 | 0.724 |
| LP-B | 5.81 | 1.938 | 2.73 | 18.89 | 1.269 | 25.52 | 1.417 | 0.306 | 4.657 | 0.515 | 0.584 | -0.043 | 0.932 | 0.037 | 2.067 | 0.753 |
| LP-A | 18.44 | 10.41 | 19.66 | 64.73 | 8.548 | 116.8 | 5.928 | 1.252 | 8.866 | 1.422 | 2.178 | -0.081 | 4.275 | 0.024 | 2.445 | 1.87 |
| LP-O | 7.857 | 2.522 | 5.824 | 9.901 | 4.843 | 89.23 | 2.118 | 0.617 | 7.692 | 1.295 | 3.553 | -0.181 | 2.923 | 0.005 | 1.309 | 1.486 |

BDL: Below Detection Limit

**Figure 4.7**: REEs Distribution in Laluan Persekutuan Chiku

Table 4.5 and figure 4.7 is show the data provided contains measurements for different elements (Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) across four different sample sites (LP-O, LP-A, LP-B, and LP-C). Each element's concentration is recorded in concentration unit. Upon analyzing the data, several observations can be made. First, there is significant variation in element concentrations across the sample sites. For example, for the element Sc, the concentration ranges from 5.810 at LP-B to 18.444 at LP-A. Similarly, for Nd, the concentration ranges from 25.526 at LP-B to 116.888 at LP-A. This variation suggests that the composition of these elements varies significantly across the different locations. Furthermore, certain elements, namely Ho and Tm, exhibit negative concentrations at sample sites LP-B (BDL), LP-A (BDL), and LP-O (BDL). On the other hand, the element Tm records values below 1 at all four sample sites, with LP-O having the lowest value of 0.005. The highest concentration of the Tm element is observed at sample site LP-C, with a value of 0.062, while LP-B and LP-A both register Tm concentrations of 0.037 and 0.024, respectively. These findings suggest that these elements are either present in extremely low quantities or potentially absent altogether at those locations. The data analysis reveals substantial differences in element concentrations across the sample sites, which may be of significance in various scientific or industrial applications.

Table 4.5 reveal soil sample a rich tapestry of REEs elemental concentrations, with LP-A emerging as the epicenter of high values in Sc (18.444), Y (10.418), La (19.660), Ce (64.736), Pr (8.548), Nd (116.888), Sm (5.928), Eu (1.252), Gd (10.096), Tb (1.422), Dy (3.553), Er (4.275), Yb (2.445), and Lu (1.870). In contrast, LP-B stands in stark contrast, displaying the lowest concentrations in many of these elements, with Sc (5.810), Y (1.938), Ce (18.899), Pr (1.269), Nd (25.526), Sm (1.417), Eu (0.306), Gd (4.657), Tb (0.515), Dy (0.584), Er (0.932), Yb (1.301), and Lu (0.724). Meanwhile, LP-O also exhibits some noteworthy values, with the highest concentration of Dy (3.553), while LP-C showcases its Ho concentration BDL, albeit LP-O has also record Ho concentration BDL.

The findings recorded in table 4.6 reveal the lowest concentrations of Ho and Tm elements within the Laluan Persekutuan Chiku sample site. Within surface soils of humid climates, Thulium concentrations typically exhibit diminishment relative to the parent material, primarily attributable to heightened rates of weathering and leaching in comparison to average soil constituents. Fractionation phenomena may occur due to the formation of secondary minerals with specific affinities for certain elements. Thulium's distribution is further modulated by soil acidity and solubility (Tyler et al.., 2004). Thulium exhibits auspicious potential across diverse domains, encompassing personal radiation dosimeters, nuclear reactors, lasers, and magnets. Nevertheless, its scarcity and elevated cost render it among the scarcest and most financially prohibitive rare earth elements (REEs), thus constraining its practical utilization (Davison & Van Rythoven.., 2023).

**Table 4.7:** Total REEs Concentration in Laluan Persekutuan Chiku

| Sample Site | Concentration (ppm) | | | |
|---|---|---|---|---|
| | **LP-O** | **LP-A** | **LP-B** | **LP-C** |
| **Total** | 141.175 | 266.954 | 67.440 | 107.659 |

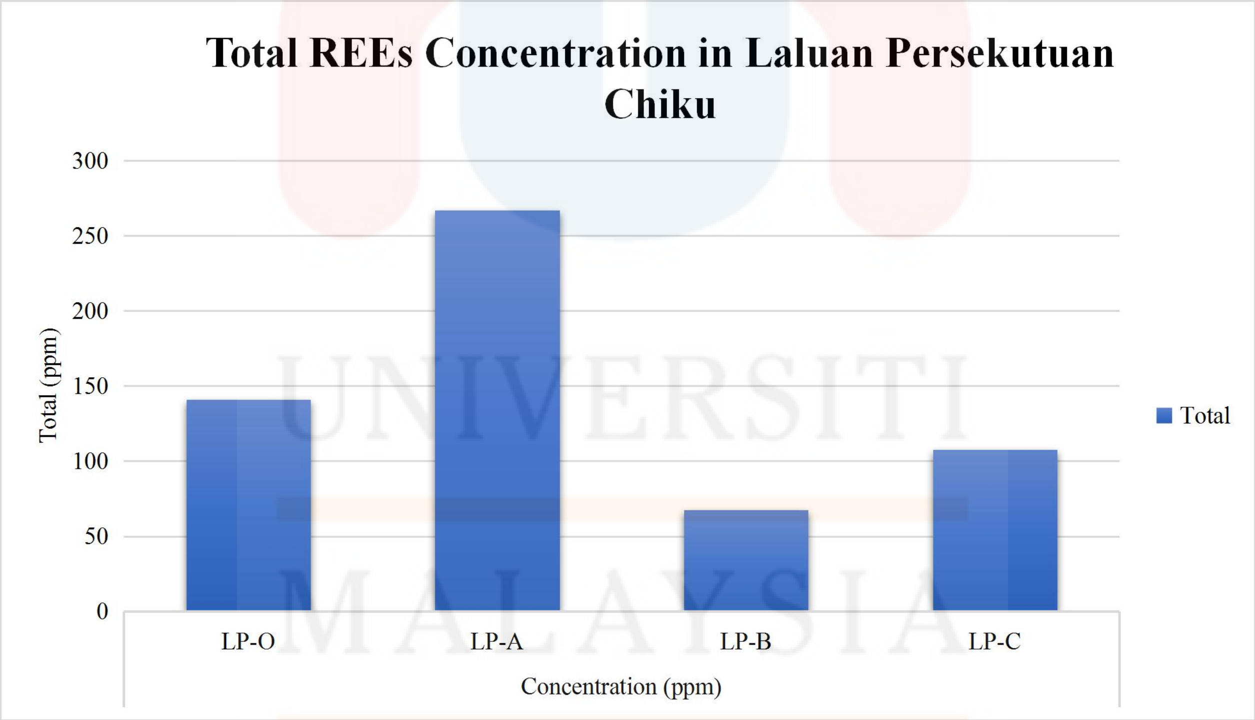


**Figure 4.8**: Total REEs Concentration in Laluan Persekutuan Chiku

Table 4.7 and figure4.8 is show the analysis of total rare earth elements (REEs) concentration across four sample sites, namely LP-O, LP-A, LP-B, and LP-C, revealed varying levels of concentration. Among the sites, LP-A exhibited the highest total REEs concentration at 266.954 parts per million (ppm), while LP-B showed the lowest concentration at 67.440 ppm. LP-O and LP-C had concentrations of 141.175 ppm and 107.659 ppm, respectively. This data illustrates a significant range in REEs concentration across the sampled sites, indicating spatial variability in environmental conditions or geological processes influencing REEs distribution. These findings may have various applications, including environmental studies, mineral exploration, or industrial processes, where the presence and concentration of these elements play a crucial role.

## 4.4 Heavy Metals in Soil

Soil contamination by heavy metals can result from both natural processes and human activities. Heavy metals found in polluted areas often originate from the parent soil, which is also known as a lithogenic source. Many heavy metals do not exist in isolation; instead, they form synthetic compounds that can be easily absorbed by living organisms. Common heavy metals detected in soil include Zn, Hg, Cd, Pb, Cu, Ni, As, and Cr. Additionally, other heavy metals like aluminum (Al), barium (Ba), cobalt (Co), manganese (Mn), selenium (Se), and silver (Ag) can be present in soil at elevated concentrations, posing environmental and health hazards. Natural events, such as volcanic emissions, sea salt sprays, wind-blown soil particles, forest fires, and the natural weathering of rocks, can contribute to the presence of heavy metals in soil. Furthermore, biogenic sources, such as the decomposition of organic matter, can release heavy metals into the soil (Priya et al., 2023).

Table 4.6 and Figure 4.9 display the concentration values of heavy metal elements Zn, Cd, b, Cu, Ni, and Cr that found in soil samples from Paloh, Felda Aring, and Laluan Persekutuan Chiku.

**Table 4.8**: Heavy Meals in soil sample site Paloh, Felda Aring, and Laluan Persekutuan CHiku

| **Sample Site** | **Concentration (ppm)** | | | | | |
|---|---|---|---|---|---|---|
| | **Zn** | **Cd** | **Pb** | **Cu** | **Ni** | **Cr** |
| Paloh | | | | | | |
| PA-O | 170.170 | 0.491 | 22.506 | 25.848 | 10.938 | 48.727 |
| PA-A | 180.689 | 0.321 | 21.167 | 25.069 | 17.290 | 56.319 |
| PA-AB | 52.921 | 1.181 | 29.566 | 39.502 | 21.857 | 70.556 |
| PA-B | 187.135 | 1.095 | 24.692 | 26.399 | 15.187 | 62.854 |
| PA-E | 152.539 | 1.268 | 18.971 | 24.411 | 14.832 | 59.508 |
| Felda Aring | | | | | | |
| FA-O | 131.615 | 0.486 | 4.814 | 21.185 | 6.234 | 19.770 |
| FA-A | 42.316 | 0.387 | 14.317 | -2.594 | 1.573 | 4.751 |
| FA-B | 36.870 | 0.323 | 23.087 | 7.586 | 2.470 | 8.904 |
| FA-C | 60.512 | 0.919 | 26.158 | 59.877 | 85.550 | 138.197 |
| FA-CORE 1 | 42.371 | 0.356 | 10.741 | 2.008 | 4.062 | 7.401 |
| FA-CORE 2 | 50.409 | 0.419 | 17.522 | 5.720 | 8.097 | 13.218 |
| FA-E | 40.105 | 0.344 | 5.502 | 2.249 | 2.778 | 3.338 |
| Laluan Persekutuan Chiku | | | | | | |
| LP-O | 157.815 | 0.709 | 17.460 | 56.377 | 25.886 | 63.231 |
| LP-A | 53.174 | 1.152 | 25.363 | 39.025 | 20.510 | 73.424 |
| LP-B | 32.360 | 0.407 | 10.522 | 2.569 | 2.083 | 5.494 |
| LP-C | 50.169 | 0.371 | 13.733 | 4.116 | 4.606 | 7.362 |

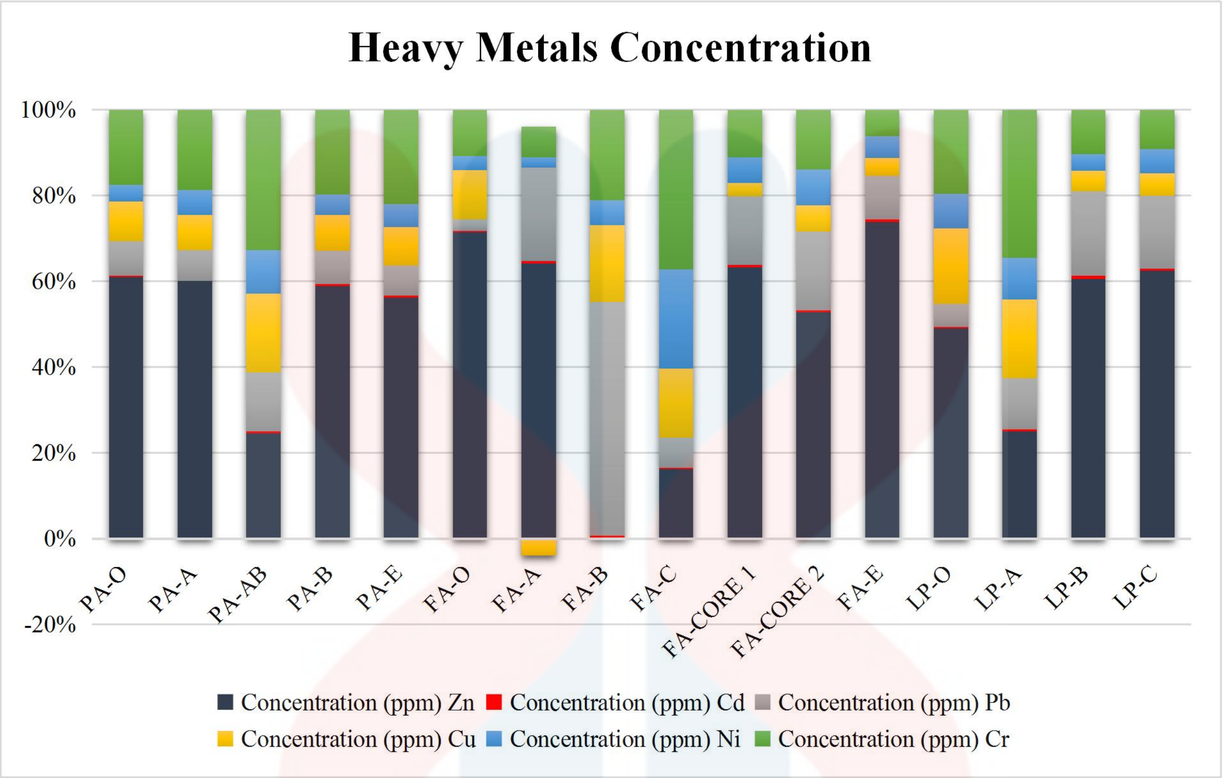


**Figure 4.9**: Heavy Metals Elements in Soil samples

From Figure 4.9, we can observe that the element Cd consistently records low values at every sample site, where all sample sites register values below 1. In Figure 4.9, it is also evident that the line for element Cd is horizontal.

The data presented in Table 4.6 and figure 4.9, which depicts the concentrations of heavy metals (Zn, Cd, Pb, Cu, Ni, Cr) in soil samples collected from various locations (Paloh, Felda Aring, and Laluan Persekutuan CHiku), significant variations in the levels of these elements across different sample sites become evident. Commencing with the most abundant element in the soil samples, Zinc (Zn) exhibits relatively high concentrations at most sites, with the highest recorded value at PA-B (187.135) and the lowest at LP-B (32.360). Cadmium (Cd) displays lower overall concentrations when compared to Zinc. The highest Cd concentration is observed at PA-E (1.268), while the lowest is found at PA-A (0.321). Lead (Pb) also demonstrates significant variability across sites, with the highest concentration noted at PA-AB (29.566) and the lowest at FA-O (4.814). Copper (Cu) shows varying levels, with the highest concentration recorded at FA-C (59.877) and the lowest at FA-A (-2.594). Nickel (Ni) exhibits variations across sites, with the highest value at FA-C (85.550) and the lowest at FA-A (1.573), which appears to be an outlier. Lastly, Chromium (Cr) displays considerable fluctuations, with the highest concentration observed at FA-C (138.197) and the lowest at FA-E (3.338). In summary, the data indicates that soil samples from different sites exhibit notable disparities in heavy metal concentrations. Locations such as FA-CORE 2 and FA-E generally display lower levels of heavy metals, while sites like FA-C and LP-A demonstrate higher concentrations, particularly for certain elements. The presence of negative values and the wide range of concentrations underscore the necessity for further investigation and monitoring to gain a more comprehensive understanding of the environmental implications associated with these levels of heavy metals.

The soil samples designated as FA-A exhibit a pronouncedly diminished concentration of Copper (Cu), measuring at -2.594. Multiple factors may contribute to this observation, encompassing a reduced abundance of copper in the original soil matrix, lowered soil pH levels, scant organic matter content, increased precipitation levels, and an elevated cation exchange capacity. For instance, heavy metal solubility in soil typically experiences restriction under acidic conditions but tends to escalate as soil pH transitions towards alkalinity. Furthermore, the incorporation of organic matter into the soil matrix can effectively attenuate the bioavailability of heavy metals through their complexation with organic ligands (Pan et al., 2020). There exists potential for variability in Cu concentration among soil samples owing to inherent soil properties such as texture, mineral composition, and drainage characteristics. These parameters possess the capacity to influence the mobility and accessibility of heavy metals within the soil matrix, consequently impacting their concentration (Pan et al., 2020).

**Table 5.0**: Total Heavy Metals Elements in 16 Sample site

| **Sample Site** | **Paloh** | **Felda Aring** | **Laluan Persekutuan Chiku** |
|---|---|---|---|
| **Total** | 1384.009 | 911.947 | 667.918 |

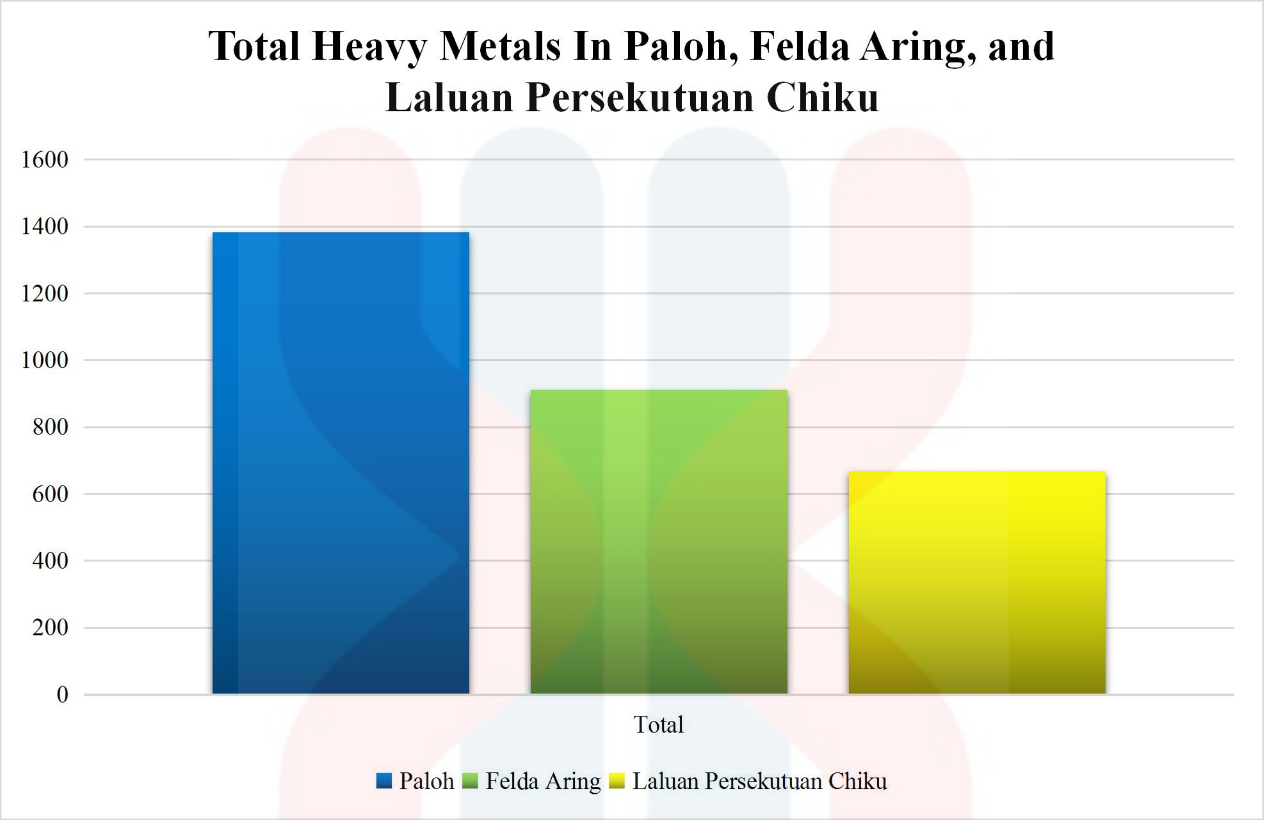


**Figure 4.9.1**: Total Heavy Metals Elements in 16 Sample Site

Table 4.7 and figure 4.9.1 shows the total heavy metals concentration data collected from three different sample sites, namely Paloh, Felda Aring, and the Federal Route Chiku, reveal varying levels of contamination. At Paloh, the total concentration of heavy metals measured is 1384.009 parts per million (ppm). Felda Aring exhibits a slightly lower concentration at 911.947 ppm, while the Laluan Persekutuan Chiku shows the lowest concentration among the three sites, with a total of 667.918 ppm. These concentrations indicate the presence of heavy metals in soil sample at sample site Paloh, Felda Aring, and Laluan Persekutuan Chiku in Gua Musang, Kelantan. These values highlight the disparities in heavy metal contamination across the sampled sites, with Zinc being the most prevalent and Cadmium the least.

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

To summarize, the soil in Gua Musang, Kelantan consists of sand, silt, and clay. The three primary rare earth elements (REEs) found in the soil in Gua Musang, Kelantan are Neodymium (Nd), Cerium (Ce), and Lanthanum (La). After analysis, it is evident that the distribution of REEs indicates that Gua Musang, Kelantan is enriched with Nd element but has a low concentration of Ho element. The high concentration of Nd can be attributed to its greater abundance in the Earth's crust compared to holmium. Additionally, soil samples in the Gua Musang, Kelantan area also contain heavy metals, including Zinc (Zn), Cadmium (Cd), Lead (Pb), Copper (Cu), Nickel (Ni), and Chromium (Cr), with the highest concentration being Zn. This may be due to various factors such as soil pH, organic matter content, and the presence of other heavy metals. Yg paling tinggi adalah paloh.

## 5.2 Recommendations

For further research, as an alternative to using inductively coupled plasma- mass spectrometry (ICP-MS) for sample analysis, I recommend employing inductively coupled plasma-optical emission spectroscopy (ICP-OES). ICP-OES offers several advantages over ICP-MS. Firstly, it provides faster results, capable of analyzing up to 74 different elements in a sample in less than a minute. Additionally, ICP-OES proves highly effective in analyzing samples with exceptionally high levels of total dissolved solids (TDS) or suspended solids. Furthermore, ICP-OES boasts a significantly higher tolerance for TDS, allowing for concentrations of up to 30%. In contrast, ICP-MS has a much lower tolerance for TDS, typically limited to around 0.2%, although there are methods to enhance this tolerance. ICP-OES also excels in providing robust, rapid, multi-element analysis of solutions, including those derived from digested solid samples. It achieves this by detecting element "lines" or peaks at characteristic wavelengths resulting from electron transitions between excited and lower energy states in the outer electron shells.

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# APPENDIX A

# APPENDIX B

# APPENDIX C