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Distribution of heavy metals and REE in soil from Cameron Highland and Lojing.

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DECLARATION

I declare that this thesis entitled "Distribution of heavy metals and REE in soil from Cameron Highland and Lojing" is the results of my own research except as cited in the references.

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Taburan logam berat dan REE dalam tanah dari Cameron Highland dan Lojing.

ABSTRAK

Kajian ini menyiasat taburan logam berat dan unsur nadir bumi (REE) dalam tanah dari Cameron Highland dan Lojing, dua kawasan pertanian dan perlombongan penting di Malaysia. Sampel tanah dikumpul dari pelbagai lokasi di seluruh kawasan kajian dan dianalisis untuk kepekatan logam berat seperti plumbum (Pb), kadmium (Cd), kromium (Cr), nikel (Ni), serta REE termasuk lanthanum (La), cerium (Ce), dan gadolinium (Gd). Hasilnya mendedahkan variasi spatial dalam kepekatan unsur-unsur ini, dengan paras tinggi diperhatikan di kawasan yang terjejas oleh aktiviti manusia seperti pertanian, perlombongan dan pembandaran. Kehadiran logam berat dan REE dalam tanah menimbulkan potensi risiko kepada kesihatan manusia dan alam sekitar, memerlukan pemantauan dan usaha pengurusan yang berterusan. Kajian ini memberikan pandangan berharga tentang sumber, corak pengedaran dan implikasi alam sekitar pencemaran logam berat dan REE dalam tanah dari Cameron Highland dan Lojing, menyumbang kepada pemahaman kami tentang kualiti tanah dan kelestarian penggunaan tanah di rantau ini. Kajian lanjut diperlukan untuk menilai kesan jangka panjang pencemaran tanah dan membangunkan strategi mitigasi yang berkesan untuk menjaga kesihatan ekosistem dan kesejahteraan manusia.

Kata kunci: REE, Logam berat, variasi spatial, kesan jangka panjang

Distribution of heavy metals and REE in soil from Cameron Highland and Lojing.

ABSTRACT

This study investigates the distribution of heavy metals and rare earth elements (REEs) in soil from Cameron Highland and Lojing, two important agricultural and mining regions in Malaysia. Soil samples were collected from various locations across the study area and analyzed for concentrations of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), as well as REEs including lanthanum (La), cerium (Ce), and gadolinium (Gd). The results revealed spatial variations in the concentrations of these elements, with elevated levels observed in areas affected by human activities such as agriculture, mining, and urbanization. The presence of heavy metals and REEs in soil poses potential risks to human health and the environment, necessitating continued monitoring and management efforts. This study provides valuable insights into the sources, distribution patterns, and environmental implications of heavy metal and REE contamination in soil from Cameron Highland and Lojing, contributing to our understanding of soil quality and land use sustainability in the region. Further research is needed to assess the long-term impacts of soil contamination and develop effective mitigation strategies for safeguarding ecosystem health and human well-being.

Keywords: REEs, Heavy metal, spatial variations, long-term impacts

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LIST OF ABBREVIATIONS

REE	Rare Earth Element
UMK	Universiti Malaysia Kelantan
ICP-OES	Inductively Couple Plasma-Optical Emission Spectrometry
CB	Cameron Brinchang
LB	Lojing Blau

LIST OF SYMBOLS

Pb	lead
Hg	mercury
Cd	cadmium
As	arsenic
Cr	chromium
Ni	nicke

CHAPTER 1

INTRODUCTION

1.1 Background of study

Cameron Highlands and Lojing are significant highland regions in Malaysia, known for their agricultural importance and ecological diversity. Both regions are characterized by mountainous terrain and serve as critical watersheds. Understanding the soil composition, particularly regarding heavy metals and REE, is essential due to their potential impacts on agriculture, ecosystems, and water quality.

Heavy metals are a group of metallic elements that have relatively high atomic weights and densities. These elements typically have toxic properties at low concentrations and can accumulate in the environment and living organisms, including humans (Duffus Jh et al.,). Some examples of heavy metals include lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), and nickel (Ni). Heavy metals occur naturally in the Earth's crust and are released into the environment through various natural processes such as weathering of rocks, volcanic eruptions, and erosion. However, human activities such as industrial processes, mining, agriculture, and waste disposal have significantly increased the levels of heavy metals in the environment. Heavy metals are of concern due to their toxicity and potential to cause adverse health effects in humans and other living organisms. Even at low concentrations, heavy metals can interfere with biological processes, disrupt enzyme functions, and damage cellular structures. Chronic exposure to heavy metals can lead to a range of health problems, including neurological disorders, kidney damage, respiratory issues, and cancer.

REE stands for Rare Earth Elements. Rare Earth Elements are a group of seventeen chemical elements in the periodic table, specifically the fifteen lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium) plus scandium and yttrium(Krishnamurthy, N et al.,2005).

Despite the name, rare earth elements are relatively abundant in the Earth's crust, but they are dispersed and often found in low concentrations, making them economically challenging to extract. They have unique properties that make them essential for a wide range of modern technologies, including electronics, renewable energy systems, catalysis, and magnetic materials.

Rare earth elements are used in the production of various high-tech devices such as smartphones, computers, hybrid vehicles, wind turbines, and LED lights. They play a crucial role in the development of clean energy technologies like electric vehicles, wind turbines, and solar panels.

1.2 Problem statement

The highlands of Cameron Highlands and Lojing in Malaysia are regions of significant ecological importance, renowned for their biodiversity and agricultural productivity. However, with increasing anthropogenic activities, there is a growing concern about the accumulation of heavy metals and rare earth elements (REEs) in the soil, posing potential risks to both environmental and human health.The extensive use of agrochemicals, industrial activities, and improper waste disposal practices in these regions may lead to the contamination of soil with heavy metals such as lead, cadmium, arsenic, and REEs. These pollutants can persist in the soil for extended periods, negatively impacting soil quality, biodiversity, and ecosystem health.Soil contamination with heavy metals and REEs can pose serious risks to human health through various pathways such as direct ingestion of contaminated soil, consumption of crops grown in polluted soil, or indirect exposure through contaminated water sources. Prolonged exposure to these toxic elements may lead to adverse health effects including neurological disorders, respiratory ailments, and carcinogenicity.

1.3 Objectives

i)To determine the grain size distributions across the soil profile layers of the selected locations in lojing and Cameron highlands.

ii)To identify organic matter content in soil sample collected from Lojing and Cameron highlands using Loss On Ignition (LOI) method

iii)To study the distribution of Rare Earth Elements (REEs) and heavy metal in soil of the selected locations in lojing and Cameron highlands using digestion and Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES) method.

1.4 Scope of Study

This study aims to determine the distribution of heavy metals and rare earth elements (REEs) in soil from 16 different locations in Lojing and Cameron Highlands, Pahang. The heavy metals and REEs will be extracted using the total digestion method, and the ICP-OES will be used for analysis and measurement.

1.4 Significances of study

The distribution of REE and heavy metals in soil from Lojing and Cameron Highland has important ramifications for a number of fields. Above all, Understanding the distribution of heavy metals and REEs in soil is crucial for assessing the extent of environmental contamination in Cameron Highlands and Lojing. This knowledge can inform environmental protection measures and facilitate the development of targeted remediation strategies to mitigate soil pollution and preserve ecosystem integrity (Lin et al., 2016). Next, Soil contamination with heavy metals and REEs can have detrimental effects on soil organisms, plant communities, and wildlife in Cameron Highlands and Lojing. By assessing the environmental impacts of soil pollution, the study can contribute to biodiversity conservation efforts by identifying vulnerable ecosystems and prioritizing conservation actions to mitigate habitat degradation and species loss (Krishna et al., 2018). Beside that, Soil contamination can have economic repercussions for agriculture, tourism, and other sectors reliant on the environmental quality of Cameron Highlands and Lojing. By quantifying the economic costs associated with soil pollution and identifying opportunities for remediation and sustainable land use, the study can inform economic planning and investment decisions to mitigate financial losses and promote long-term socio-economic development in the region (Liu et al., 2018).

CHAPTER 2

LITERATURE REVIEW

2.1 Heavy Metal

Heavy metals are naturally occurring elements that have high atomic weights and densities. While some heavy metals, like iron and zinc, are essential micronutrients for plants and animals, others, such as lead, mercury, cadmium, and arsenic, can be toxic even at low concentrations.Heavy metals can enter the environment through both natural processes and human activities. Natural sources include weathering of rocks and volcanic eruptions, while human activities such as mining, industrial processes, combustion of fossil fuels, and improper disposal of waste contribute significantly to heavy metal pollution (Tipping et al., 2012). Once released into the environment, heavy metals can accumulate in soil, water bodies, sediments, and air. They can persist in these matrices for long periods, posing risks to ecosystems and human health through various exposure pathways. Heavy metals exhibit toxicity due to their ability to interfere with biochemical processes in organisms. They can disrupt enzyme functions, cause oxidative stress, and damage cellular structures, leading to a range of adverse health effects in humans and wildlife (Zhuang et al., 2019). According to reports, a variety of biochemical and physiological processes require metals including cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn). Deficiency disorders or syndromes stem from a multitude of micronutrient deficiencies. Due to their existence in trace amounts (ppb range to less than 10ppm) in a variety of environmental matrices, heavy metals are also regarded as trace elements. Physical elements including temperature, phase association, adsorption, and sequestration have an impact on their bioavailability. It is also impacted by complexation kinetics, lipid solubility, octanol/water partition coefficients, and chemical parameters that affect speciation at thermodynamic equilibrium. Biological elements including trophic relationships, species traits, and biochemical/physiological adaptation, also play an important role (Kabata- Pendia et al., 2001).

2.2 Rare earth elements (REEs)

Rare earth elements (REEs) comprise a group of 17 chemical elements, including the 15 lanthanides (lanthanum to lutetium), as well as scandium and yttrium. These elements possess unique physical and chemical properties that make them essential in numerous technological, industrial, and scientific applications. REEs exhibit similar chemical properties due to their electronic configurations, with the lanthanide series sharing common characteristics such as high magnetic susceptibility, luminescence, and complex electronic structures (Jasinski, 2016). The lanthanide contraction phenomenon results in progressively smaller ionic radii across the series, influencing their chemical behavior and coordination preferences (Bünzli & Piguet, 2005). REEs are critical components in the production of electronic devices, including smartphones, computers, and LEDs, owing to their magnetic, luminescent, and electrical properties (Gupta & Krishnamurthy, 2005). REEs play a crucial role in renewable energy applications, such as wind turbines, electric vehicles, and rechargeable batteries, due to their lightweight and high-performance characteristics (Kang et al., 2014). Certain REEs serve as catalysts in chemical reactions for industrial processes, petroleum refining, and environmental remediation, enhancing reaction rates and selectivity (Almeida Paz et al., 2019).

2.3 Soil

Soil is a complex mixture of minerals, organic matter, water, air, and living organisms that forms the outermost layer of the Earth’s crust. It is a fundamental component of terrestrial ecosystems and plays crucial roles in supporting plant growth, regulating water and nutrient cycles, and providing habitat for a diverse array of organisms. Soil consists of mineral particles derived from the weathering of rocks, with varying proportions of sand, silt, and clay. These mineral particles influence soil texture and properties such as water retention and drainage (Brady & Weil, 2008). Soil organic matter is composed of decaying plant and animal residues, microbial biomass, and humus. It provides nutrients for plant growth, improves soil structure, and enhances water retention and nutrient cycling (Lehmann & Kleber, 2015). Soil contains pore spaces filled with water and air. Water is essential for plant growth and microbial activity, while air provides oxygen for root respiration and supports soil organisms (Hillel, 2004). Soil acts as a filter, removing pollutants, contaminants, and excess nutrients from water, thereby protecting water quality and supporting ecosystem health. Soil is a dynamic and multifunctional natural resource that sustains life on Earth. Its composition, properties, and functions interact to support ecosystem health, food production, water regulation, and climate stability.

2.4 Digestion method

Digestion methods are commonly used in analytical chemistry to break down complex samples into simpler forms for subsequent analysis. These methods involve the use of various reagents and conditions to dissolve or decompose sample matrices, releasing analytes of interest in a form suitable for quantification or characterization. Acid digestion is one of the most widely used methods for sample preparation in analytical chemistry. In acid digestion, the sample is typically treated with strong mineral acids, such as nitric acid (HNO3), hydrochloric acid (HCl), sulfuric acid (H2SO4), or a combination of these acids. Acid digestion is effective for dissolving inorganic materials and converting metals into soluble ionic forms. The digestion process can be performed using various techniques, including open vessel digestion, closed vessel digestion (e.g., microwave-assisted digestion), and reflux digestion (Pansu, M., & Gautheyrou, J. 2006)

2.5 Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES)

Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) is an analytical technique used for the simultaneous quantification of multiple elements in a variety of sample types. It is widely employed in environmental, pharmaceutical, geological, agricultural, and metallurgical analysis due to its high sensitivity, precision, and accuracy. ICP-OES operates on the principle of atomic emission spectroscopy. It involves the generation of a high-temperature plasma (typically > 6000°C) by inducing a radiofrequency (RF) electromagnetic field in an inert gas (usually argon). The high temperature of the plasma ionizes the sample, breaking chemical bonds and converting the elements into their constituent ions. As the excited ions return to their ground state, they emit characteristic wavelengths of light (emission lines) that are unique to each element. The emitted light is then dispersed by a spectrometer and detected by photomultiplier tubes or charge-coupled devices (CCDs). The intensity of the emitted light at specific wavelengths is proportional to the concentration of the corresponding element in the sample (Hieftje, G. M., & Montaser, A 2002).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

In order to collect and store samples for soil quality studies, a range of instruments are required. During the sample collecting excursion, equipment such as a scoop, plastic bags, aluminium foil, GPS, and a storage box were used. Laboratory apparatus and equipment such as an oven, microwave digestion apparatus, furnace, laboratory sieves, micropipette, beakers, centrifuge tubes, crucibles, scales and ICP-OES are required. Chemical reagents such as, hydrochloric acid (HCl), nitric acid $HNO3$, hydrogen peroxide $H2O2$, and hydrofluoric HF.

3.2 Methods

3.2.1 Sampling

Soil sample was collected from 3 location at Cameron higlands ,Brincang and Lojing on October 2023. The maps of three location was shown on figure 3.1 and 3.2. The samples, which were obtained from the several horizons—O, A, E, B, and C—were placed individually and sealed in distinct sample bags.

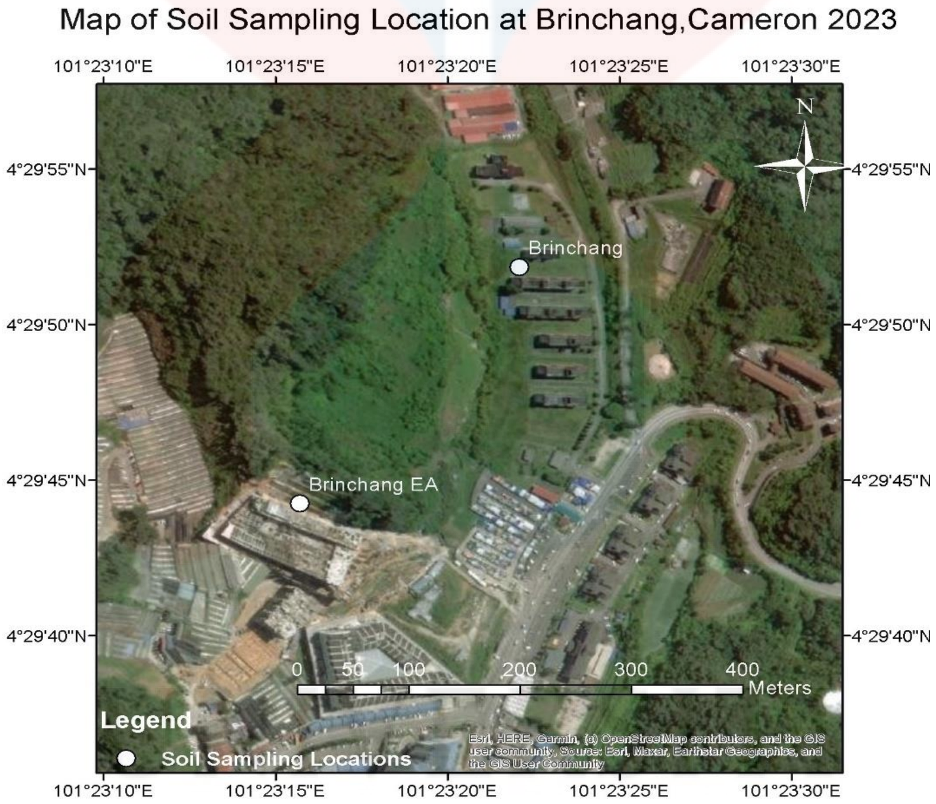

Figure 3.1 Location of sampling at Cameron Highland

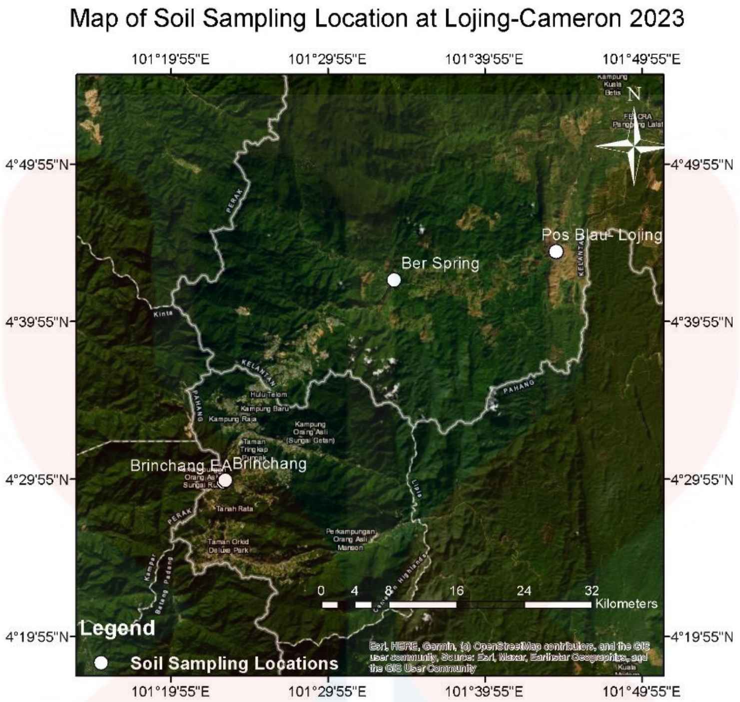

Figure 3.2: Location of sampling at Lojing

3.2.2 Sample preparation

Following a day of oven drying at 105°C, all of the samples were weighed once they had reached a certain weight. Subsequently, a hammer was used to break up the materials into small pieces.

3.2.3 Grain size analysis

Sieve set was used for this grain size analysis. When using the sieve method for soil analysis, the grain size refers to the particle size distribution of the soil after it has been ground and passed through a series of sieves of varying mesh sizes. The selection of the appropriate grind size for the soil from 13 stages which are above 4 mm, 2 mm – 4mm, 1mm- 2mm, 850µm-1mm, 740µm-630µm, 540µm-630µm, 450µm-540µm, 320µm-450µm, 240µm-320µm, 125µm-240µm, 63µm-125µm, 32µm-63µm and below 32µm. The collected sample were poured into sieve set then agitated gently to facilitate the passage of soil particles through the sieves. After a specified duration of sieving , sieves from the stack were removed and weigh each soil particles that have on every stage.Then the soil retained on each sieve were weighed using weighing scale. The sample then were recorded for grain size analysis.

3.2.4 Organic Matter analysis

The organic matter content was determined using the Loss on Ignition (LOI) method on the 32-63 µm. The precise determination of the organic matter content in soil samples is achieved through a rigorous set of stages known as the LOI technique. The 32-63 µm soil fraction was first precisely weighed into crucibles that had been pre-weighed based on the results of the grain size study. The soil sample-filled crucibles were subsequently heated to a regulated temperature, usually between 400°C and 550°C, in a muffle furnace. Carbon dioxide and other volatile chemicals are released when the organic stuff in the soil samples burns during heating. The heating procedure is continued until only inorganic leftovers remain after all organic stuff has been fully oxidised. The formula Loss on Ignition(LOI) for identify the organic matter is shown below.

$$\%\mathrm{LOI} = \frac{Inial\ weight - Final\ weight}{Initial\ weight}$$

3.2.5 Rare Earth Element (REE) and heavy metals analysis

The analysis was carried out using digestion method and Measure and A technique involving HF, H2O2, and HNO3 was used to digest soil samples for the measurement of organic matter content utilising the 32–63 µm soil fraction. To guarantee that all organic and inorganic components in the soil samples are completely dissolved, a careful set of procedures are involved in the digestion process. First, each soil sample from the 32–63 µm soil fraction was precisely weighed and placed into digestion tubes in amounts of 0.5g. Then, because these chemicals are toxic and corrosive, a fume hood was used to prepare a mixture of HF, H2O2, and HNO3. A predefined volume of the HF-H2O2-HNO3 mixture was added to the soil samples in the digestion vessels to begin the digestion process. By dissolving silicate minerals, HF is added to aid in the liberation of bound organic molecules and trace elements. As an oxidising agent, H2O2 facilitates the oxidation of certain metals and the breakdown of organic materials. Acting as a potent oxidising acid, HNO3 helps dissolve metals and change organic nitrogen into nitrate. Following a secure closure, the digestion jars holding the soil samples and the digestion mixture were heated under controlled conditions. The soil samples were thoroughly digested and strong responses were prevented by gently heating the materials. Generally, to speed up the digestion process, a mix of microwave digestion and hotplate cooking methods may be used. Gases were released and soluble metal and mineral complexes were formed in the digestion solution as a result of the soil samples' chemical breakdown during digestion. The sample was fully digested when the heating process was stopped and the digestion solution turned clear or colourless. To guarantee complete mixing and dissolving of the added reagents, the solution was heated once again after the addition of boric acid and other acids.The digested solutions were transferred to a falcon tube for the ICP-MS analysis after being allowed to cool to ambient temperature. Due to the hazardous nature of the digesting reagents, careful handling and disposal procedures were followed to ensure environmental compliance and safety.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Grain size Analysis

The grain size of soil refers to the diameter or size of the individual particles that make up the soil. Soil particles can range in size from large gravel particles to tiny clay particles. The grain size of soil is typically categorized into three main classes based on the diameter of the particles. First is sand. Sand particles have diameters ranging from 0.05 millimeters (mm) to 2.0 mm. Sand particles are visible to the naked eye and feel gritty when rubbed between the fingers. second is Silt particles have diameters ranging from 0.002 mm to 0.05 mm. Silt particles are smaller than sand particles and feel smooth when rubbed between the fingers. They are often barely visible to the naked eye. Lastly, is Clay particles have diameters smaller than 0.002 mm. Clay particles are the smallest soil particles and cannot be seen with the naked eye. They feel sticky and plastic-like when wet and hard and compacted when dry.The relative proportions of sand, silt, and clay particles in a soil determine its texture, which in turn influences various soil properties such as water retention, drainage, fertility, and workability. Various categories depending on the size of individual particles define the soil particle size distribution. The coarse sand (2mm-4mm), coarse sand (1mm-2mm), medium coarse sand (710µm-1mm), medium sand (500µm-710µm), fine sand (355µm-500µm), very fine sand (125µm-250µm), and coarse silt (63µm-125µm) are the first in the classification. Pebbles and granules greater than 4mm are the first to be classified. Soil scientists use various methods, including sedimentation, sieving, and laser diffraction, to determine the grain size distribution of soil samples. This information is essential for understanding soil behavior, classifying soils, and making informed decisions about soil management and engineering applications.

Sample / size	4000µm And above (g)	2000µm-4000 µm (g)	1000 µm-2000 µm (g)	710 µm-1000 µm (g)	500 µm-710 µm (g)	355 µm-500 µm (g)	250 µm-355 µm (g)	125 µm-250 µm (g)	63 µm-125 µm (g)	32 µm-63 µm (g)	Total (g)
LBS01-O(S)	57.1342	21.4353	74.0982	43.3344	34.7054	23.2564	25.1868	52.4491	25.7845	8.2215	365.6059
LB01S0-A	0.3680	16.6537	72.7625	46.3910	37.3989	26.6383	28.5118	43.1761	18.8245	10.6617	301.3865
LBS01-O1P1	0.1395	11.0262	90.4799	73.1021	53.2596	37.2252	39.4377	70.4082	32.2011	29.6641	436.9436
LO01S0-O	67.3673	169.6553	168.4580	190.9288	165.7698	129.4346	104.4446	77.3062	23.9540	9.2065	1106.5251
LO01S0-C	76.4153	158.1890	211.8700	128.0638	89.2658	58.1504	55.8800	141.4495	63.9856	17.2172	1000.4866
CB02S0-A	167.8589	143.5968	205.6854	169.4694	131.1571	140.9287	119.1883	74.3980	25.8555	3.8808	1182.0189
CB02C-1	-	40.2964	91.7354	60.5844	51.0068	43.5339	80.8533	207.0850	69.1012	5.1834	649.3818
LO01-S0-B	3.3307	38.6536	70.6662	31.7439	27.5375	21.2745	23.5232	59.3910	19.2474	2.6161	297.9841
CB02M2-2	32.5753	28.0700	44.4597	19.8100	12.2778	6.7360	5.9346	7.8354	2.0236	5.3477	165.0701
CB02M-1	52.4952	117.5603	199.8073	134.0251	107.0520	76.2780	66.1268	85.5682	50.7013	20.87011	889.6142
CBO1SO-OCBMCO	2.7978	46.0997	202.6810	153.8896	135.7670	109.8040	111.4396	140.7097	102.9861	25.4391	1031.6136
CBOISO-B(EA)	23.2379	141.6733	209.3198	87.5390	63.1782	47.9700	47.2347	105.2763	68.5118	11.7403	805.6813
L001S0-A	2.6360	31.4892	85.8667	94.7326	207.0966	190.4762	188.3729	203.0350	32.1689	53.6953	1090.1694
LB01S0-O	0.3688	31.5400	183.0289	164.6253	109.9789	81.1158	90.6231	199.7232	65.1349	55.6570	981.7959
LOO1R	-	-	-	-	-	-	-	-	74.0782	8.0032	82.0814
LOO1R-2	-	-	-	-	-	-	-	-	44.7178	14.0746	58.7924

Table 4.1: Data for grain size of soil

The soil sample collected from Lojing and Cameron Highland has different types of particle size. Based on Table 4.1, that have 16 sample which is 10 sample from lojing and 6 sample from Cameron Highlands have different weight for each particle saiz. Start with sample from lojing which is LBS01-O(S) size particle of 1000 µm-2000 µm have high percentage from total particle in this sample with 20.27% while the lowest was from 32 µm- 63 µm with only 0.02%. This shows that the soil in this area mostly consists of particle size coarse sand. Weathering processes, including physical and chemical breakdown of rocks and minerals, can influence soil particle size. Mechanical weathering, such as frost action and abrasion, can break down rocks into coarse sand particles (Brady, N.C., and Weil, R.R. 2016). Moving to second sample from Lojing, LB01S0-A sample have high percentage from size 1000 µm- 2000 µm with 24.14% from total weight of sample while the Third sample which is LBS01-O1P1 have high percentage falls within 1000 µm-2000 µm with 20.71% while the lowest was from size 4000 µm and above consist from total sample. This area also consists of coarse sand. Fourth sample from L0001S0-O have high percentage falls within 710 µm-1000 µm with 17.25% from total sample. While the lowest percentage came from 32 µm-63 µm size with 0.83%. this show this area of soil consist medium sand this might due to breakdown of specific rock types that are rich in quartz, such as sandstone or quartzite. Over time, weathering processes break down these rocks into sand-sized particles, contributing to the presence of medium sand in the soil (Blatt, H., 1980). For sample L001S0-C highest percentage from total sample is 1000 µm-2000 µm with 21.18% while lowest percentage from 32 µm-63 µm with 1.72%. this area consist of particle size from coarse sand. Next for sixth sample L001-S0-B have highest percentage falls within 1000 µm-2000 µm with 23.71% from total sample while the lowest percentage falls within 32 µm-63 µm. this area of soil also consist of coarse sand. For sample L001S0-A highest percentage of soil came from size 500-710 µm with 19.05% while the lowest percentage is 4000 µm aand above with 0.24% from total sample. This area soil consist of medium sand. Eighth sample from lojing LB01S0-O have highest percentage from size 1000-2000 µm with 18.64% from total sample while lowest percentage came from size 4000 µm and above with 0.04% from total sample. This shows this area soil also consist of coarse sand. Last but not least for sample L001R and L001R-2 the highest percentage of this both sample came from 63 µm with each 90.25% and 76.06% and the lowest percentage from size 32 µm-63 µm with 9.75% and 23.94% respectively. these two samples have the highest and lowest percentage in the same sample because These two areas doesnt have the others particle size rather than coarse silt and fine silt.

For the sample from cameron highland this consists of 6 samples. with the first sample CB02S0-A. The highest percentage from this sample was 1000 µm-2000 µm with 17.40% from total sample while lowest percentage was 32 µm-63 µm with 0.33% from total sample. This show the soil from this point of location contains more coarse sand. Second sample, CB02C-1 size particle range from 125 µm-250 µm have highest percentage among all size of sample with 31.89%. the lowest percentage for this sample was range from 32 µm-63 µm with 0.8% from total sample. This show this area in Brincang has high content of very fine sand. This due to Physical and chemical weathering processes act on rocks and minerals, breaking them down into smaller particles. In areas with low to moderate weathering rates, such as arid or semi-arid climates, very fine sand may accumulate as a result of the gradual breakdown of larger rock fragments over time (Montgomery ,2007). Third sample at Cameron highlands which is CB02M2-2 show the highest percentage came from range 1000um-2000um with 26.93% while the lowest percentage was range from 63um-125um with 3.24%. show this area more consist of coarse sand. For the fourth sample which is CB02M-1 the highest percentage came from size particles range from 1000um-2000um with 22.46% while the lowest percentage was range from 32um-63um with 2.34%. This area more consist of coarse sand. Regarding sample number five, CB01S0-0CBMC0. The highest percentage of the sample was range from 1000um-2000um with 19.64% from total sample while the lowest percentage is 4000um and above with 0.27% from total sample. The final sample from Cameron Highland, CB01S0-B(EA) show the highest percentage was range from 1000um-2000um with 25.98% from total sample while the lowest percentage of sample was range from 32-63um. This area consist of coarse sand mostly.

In general, 16 samples taken from points in the Lojing and Cameron Highlands areas on average contain soil particles of the coarse sand type. soil consisting of coarse sand has distinct properties and characteristics that influence its behavior and suitability for various purposes. Coarse sand particles create large pore spaces within the soil, leading to excellent drainage and aeration(Weil, R.R. 2016). Water infiltrates quickly through coarse sand soils, reducing the risk of waterlogging and facilitating oxygen movement to plant roots. This property is advantageous for crops that are susceptible to root rot in poorly drained soils. While coarse sand promotes rapid drainage, it also has limited water retention capacity. Sandy soils with coarse sand content may require frequent irrigation, especially during dry periods, to maintain adequate moisture levels for plant growth. Water and nutrients can leach quickly through sandy soils, requiring careful management to prevent nutrient depletion and environmental pollution.

4.2 Organic Matter Analysis

Organic matter is a fundamental component of soil that plays a crucial role in supporting terrestrial ecosystems and agricultural productivity. Comprising a diverse array of plant and animal residues in various stages of decomposition, organic matter serves as the lifeblood of soil, influencing its physical, chemical, and biological properties. From improving soil structure to fostering nutrient cycling and supporting biodiversity, organic matter is essential for maintaining soil health and ecosystem sustainability.

To ascertain the amount of organic matter in 16 samples taken from different places in Lojing and Cameron Highlands, the loss of ignition technique was applied. Table 4.2 displays the weight of the crucible, the beginning weight of the sample, the final weight of the sample following the furnace operation, and the projected loss on ignition %.

sample	**Cruciable weight(g)**	**Initial weight of sample(g)**	**Final weight of sample(g)**	**Loss of Ignition(&)**
LBS01-O(S)	**21.0876**	**0.1113**	**0.0836**	**24.89**
LB01S0-A	**21.8812**	**0.1041**	**0.0669**	**35.73**
LBS01-O1P1	**21.0236**	**0.1039**	**0.0694**	**33.21**
L001S0-O	**21.4836**	**0.1122**	**0.1023**	**8.82**
L001S0-C	**22.1033**	**0.1372**	**0.1272**	**7.28**
CB02S0-A	**20.6097**	**0.1255**	**0.0920**	**26.70**
CB02C-1	**16.7975**	**0.1645**	**0.1321**	**19.70**
L001-S0-B	**21.1538**	**01101**	**0.0949**	**13.81**
CB02M2-2	**24.2774**	**0.1305**	**0.1121**	**14.09**
CB02M-1	**16.7975**	**0.1215**	**0.0994**	**18.19**

CB01S0-0CBMC0	**15.9501**	**0.1011**	**0.0885**	**12.46**
CB01S0-B(EA)	**21.5895**	**0.1591**	**0.1211**	**23.88**
L001S0-A	**21.4242**	**0.1140**	**0.0705**	**38.16**
LB01S0-O	**21.3655**	**0.1852**	**0.1660**	**10.36**
L001R	**21.2854**	**0.1585**	**0.1505**	**5.05**
L001R-2	**21.2728**	**0.1035**	**0.0989**	**4.44**

Table 4.2: organic matter data on sample 32 µm -63 µm

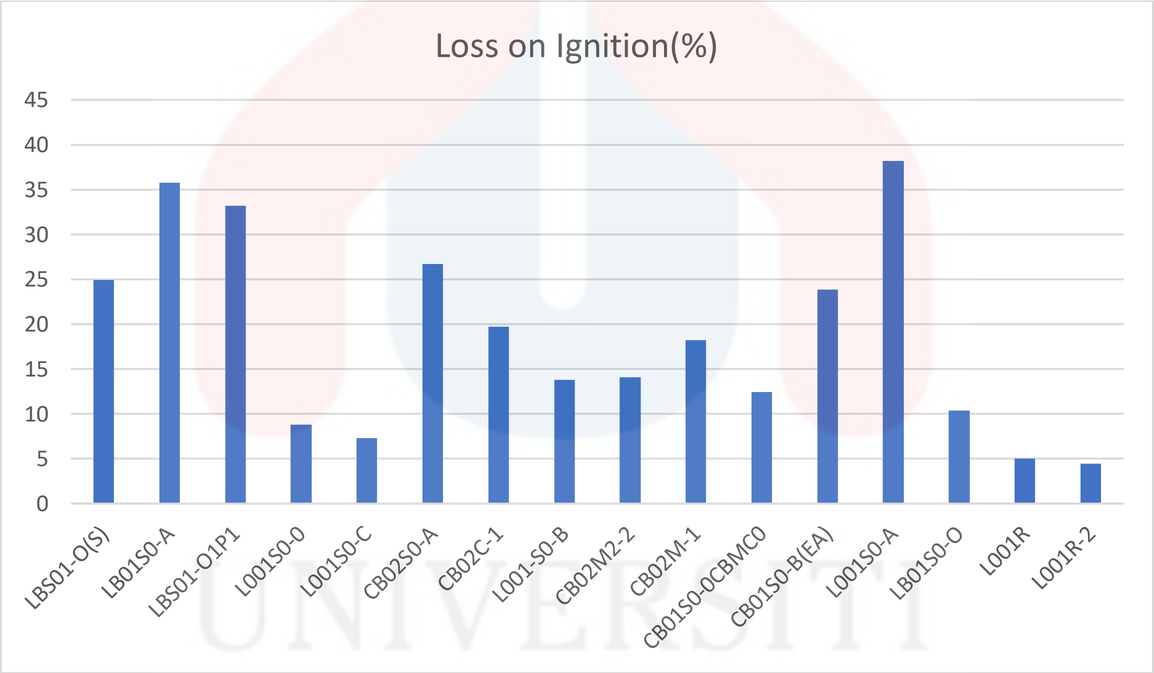

Figure 4.2: Loss On Iginition(LOI) percentage for sample from Lojing and Cameron Highlands

According to Table 4.2 and figure 4.2 the highest percentage of Loss On Ignition for sample from Lojing was L001S0-A point with 38.16%. This show that a substantial portion of the soil sample's weight is comprised of organic matter and volatile components. Higher LOI values generally indicate soils with higher organic matter content. This sample tend to have better fertility, improved soil structure, increased water retention capacity, and enhanced nutrient cycling capabilities. The lowest percentage of Loss On Ignition for sample from Lojing was L001R-2 point with 4.44%. This show that only a small fraction of the soil sample's weight is comprised of organic matter and volatile components. Lower LOI values generally indicate soils with lower organic matter content. This sample with lower organic matter content may have reduced fertility, poorer soil structure, lower water retention capacity, and limited nutrient cycling capabilities compared to soils with higher organic matter content.

Next for sample from Cameron Highlands, the highest percentage of Loss On Ignition was CB02S0-A with 26.70%. This show The weight of the soil sample is mostly composed of volatile components and organic materials. Soils with a greater organic matter content are often indicated by higher LOI readings. Higher levels of organic matter in soils are often associated with greater fertility, improved soil structure, increased ability to hold water, and improved nutrient cycling. The lowest percentage of Loss On Ignition for sample from Cameron Highlands was CB01S0-0CBMC0 point with 12.46%. This show that 12% of the initial weight of the soil sample was lost during the heating process. This loss primarily consists of organic matter, such as plant residues, roots, and microbial biomass, as well as volatile compounds like water, carbon dioxide, and other gases.

The LOI value provides important information about the organic matter content and quality of soil samples, which is critical for understanding soil fertility, structure, and overall health. The LOI value reflects the proportion of organic matter present in the soil. Higher LOI values indicate soils with greater organic matter content, while lower values suggest soils with lower organic matter content. Organic matter plays a crucial role in soil fertility by serving as a source of nutrients for plants. Soils with higher organic matter content typically have better fertility and nutrient-holding capacity, supporting healthy plant growth and crop productivity (Blair et al., 1995).

4.3 Rare Earth Element(REE) and heavy metals analysis on soil sample range 32um-63um

4.3.1 Rare Earth Element(REE)

Rare earth elements (REEs) are a group of 17 chemically similar metallic elements found in the Earth's crust. Despite their name, rare earth elements are relatively abundant in the Earth's crust, but they are often dispersed and not commonly concentrated in economically exploitable deposits. Table 4.3.1 shows the content of the 5 main ree elements in 16 samples taken from point at Lojing and Cameron Highlands.

Soil sample / Element	Lanthanum (LA)	Cerium (Ce)	Gadolinium (Gd)	Erbium (Er)	Ytterbium (Yb)
LBS01-O(S)	6.543	10.454	5.894	3.147	0.849
LB01S0-A	0.091	3.991	6.535	3.725	0.694
LBS01-O1P1	5.424	8.283	7.068	3.136	0.952
L001S0-O	2.262	16.071	14.393	5.104	0.316
L001S0-C	1.211	7.243	5.817	3.112	0.030
L001-S0-B	1.323	9.183	3.336	1.037	0.295
L001S0-A	1.264	6.295	9.544	4.843	0.968
LB01S0-O	4.941	14.279	7.985	3.892	1.002
L001R	1.944	7.597	3.516	1.797	0.525
L001R-2	2.936	16.236	5.040	4.288	0.784
CB02S0-A	0.039	4.030	8.259	4.156	0.736
CB02M2-2	0.001	9.838	2.765	1.392	0.302
CB02M-1	3.702	24.679	2.565	4.505	0.258
CB01S0-0CBMC0	0.092	4.917	0.759	0.709	0.094
CB02C-1	9.810	25.180	4.857	4.397	2.219
CB01S0-B(EA)	1.512	9.687	2.089	1.573	0.295

Table 4.3.1: Data for 5 main Rare Earth element (REE) in soil sample

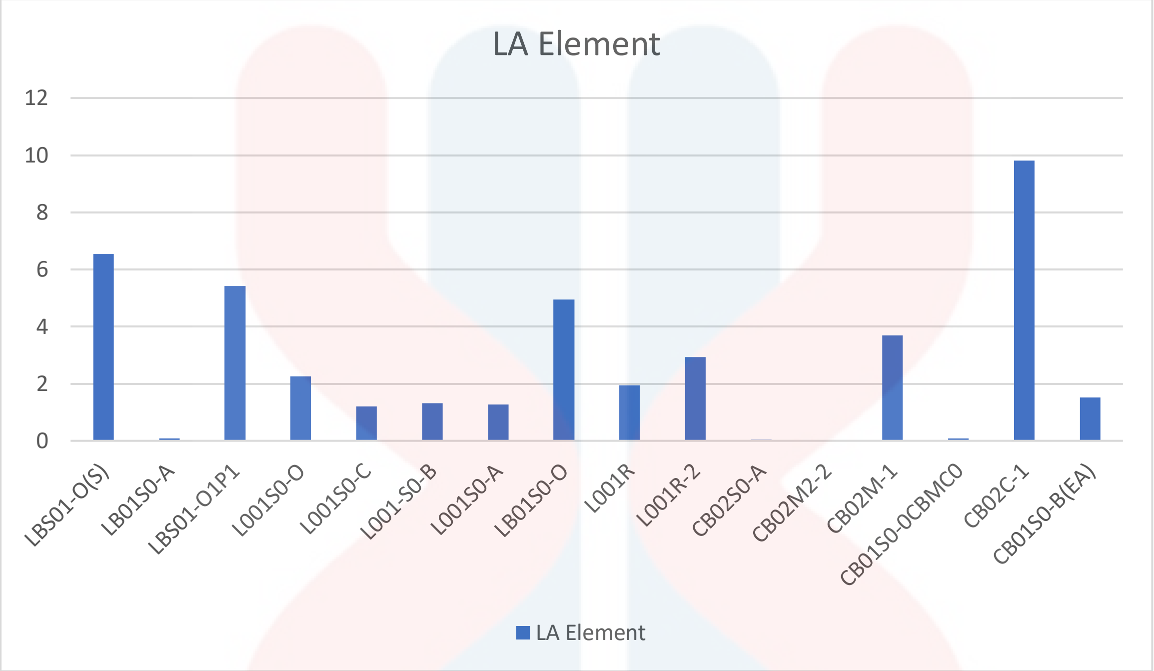

Figure 4.3.1 Lanthanum(La) element in soil sample

Lanthanum is a chemical element with the symbol La and atomic number 57. it was first element in the lanthanide series. Lanthanum is a silvery-white, soft, ductile metal that is highly reactive and readily oxidizes in air. According to Figure 4.3.1 Highest La element found in sample from Lojing was sample LBS01-O(S) with 6.543. This show A soil sample containing 6.543 parts per million (ppm) of lanthanum means that for every million parts of the soil sample, there are approximately 6.543 parts composed of lanthanum. Lanthanum, being a rare earth element, is naturally present in the Earth's crust, and its presence in soil is not uncommon (Bigham et al., 1994). While the lowest La element found in sample from lojing was CB02M2-2 with only 0.001. In Cameron Highlands point ,the highest La element was found in sample CB02C-1 with 9.810. while the lowest was from sample CB02M2-2 with 0.001. Lanthanum is naturally present in soil due to the weathering and erosion of lanthanum-containing minerals in geological formations.

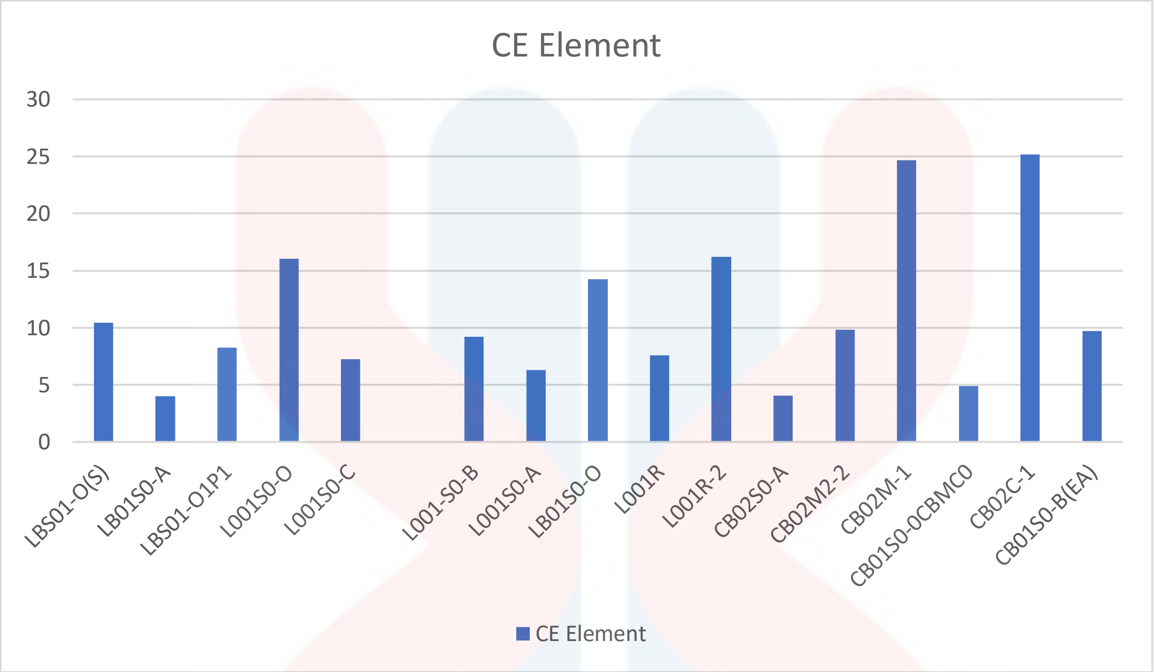

Figure 4.3.2 Cerium (Ce) element in soil sample

According to Figure 4.3.2 Highest Ce element found in sample from Lojing was sample L001R-2 with 16.236. This show the soil sample containing 16.236 parts per million (ppm) of cerium (Ce) indicates the presence of this rare earth element in the soil. Cerium, like other rare earth elements, occurs naturally in the Earth's crust and can be found in various geological formations. The lowest was found in sample LB01S0-A with 3.991. In Cameron Highlands point, the highest Ce element was found in sample CB02C-1 with 25.180. while the lowest was from sample CB02S0-A with 4.030. The concentration of cerium in soil can be influenced by geochemical processes such as weathering, leaching, and mineral dissolution (McBride, 1994).

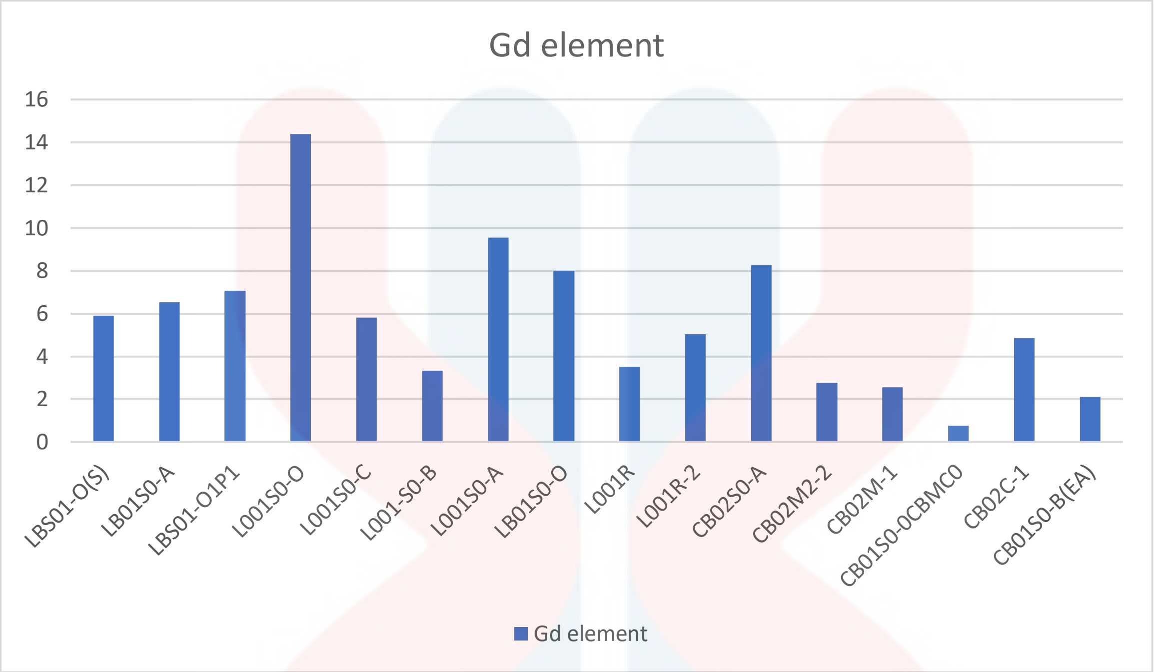

Figure 4.3.3 Gadolinium (Gd) element in soil sample

According to Figure 4.3.3 Highest Gadolinium (Gd) element found in sample from Lojing was sample L001S0-O with 14.393. This indicates A soil sample containing 14.393 parts per million (ppm) of gadolinium (Gd) indicates the presence of this rare earth element in the soil. The lowest was found in sample L001-S0-B with 3.336. In Cameron Highlands point, the highest Gd element was found in sample CB02S0-A with 8.259. while the lowest was from sample CB01S0-0CBMC0 with 0.759. Gadolinium is generally considered to have low toxicity, elevated levels of gadolinium in soil may indicate contamination from anthropogenic sources such as mining activities, industrial processes, or the use of gadolinium-containing products.

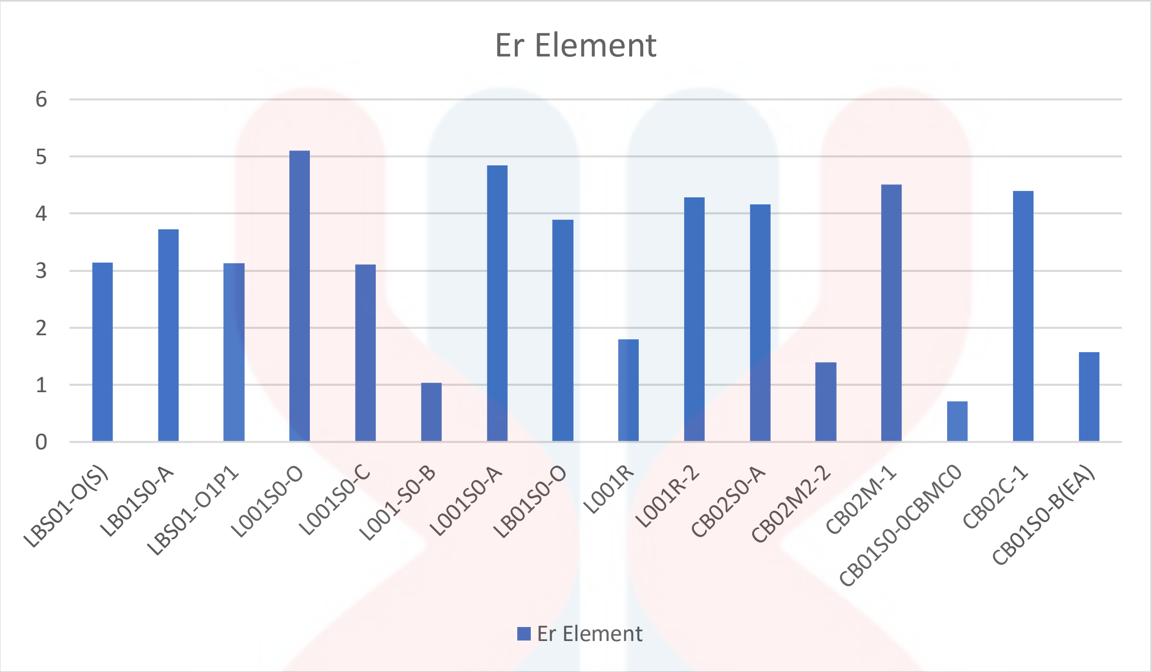

Figure 4.3.4 Erbium(er) element in soil sample

According to Figure 4.3.4 Highest Erbium (er) element found in sample from Lojing was sample L001S0-O with 5.104. This show the soil sample containing 5.104 parts per million (ppm) of erbium (Er) indicates the presence of this rare earth element in the soil. Erbium, like other rare earth elements Erbium is naturally present in soil due to the weathering and erosion of erbium-containing minerals in geological formations. Erbium is commonly used in various applications due to its unique properties, including its ability to absorb light in the infrared range. The lowest was found in sample L001-S0-B with 1.037, not much erbium is present in this sample. In Cameron Highlands point, the highest er element was found in sample CB02M-1 with 4.505 . while the lowest was from sample CB01S0-0CBMC0 with 0.709. erbium is generally considered to have low toxicity, elevated levels of erbium in soil may indicate contamination from anthropogenic sources such as mining activities, industrial processes, or the use of erbium-containing products.

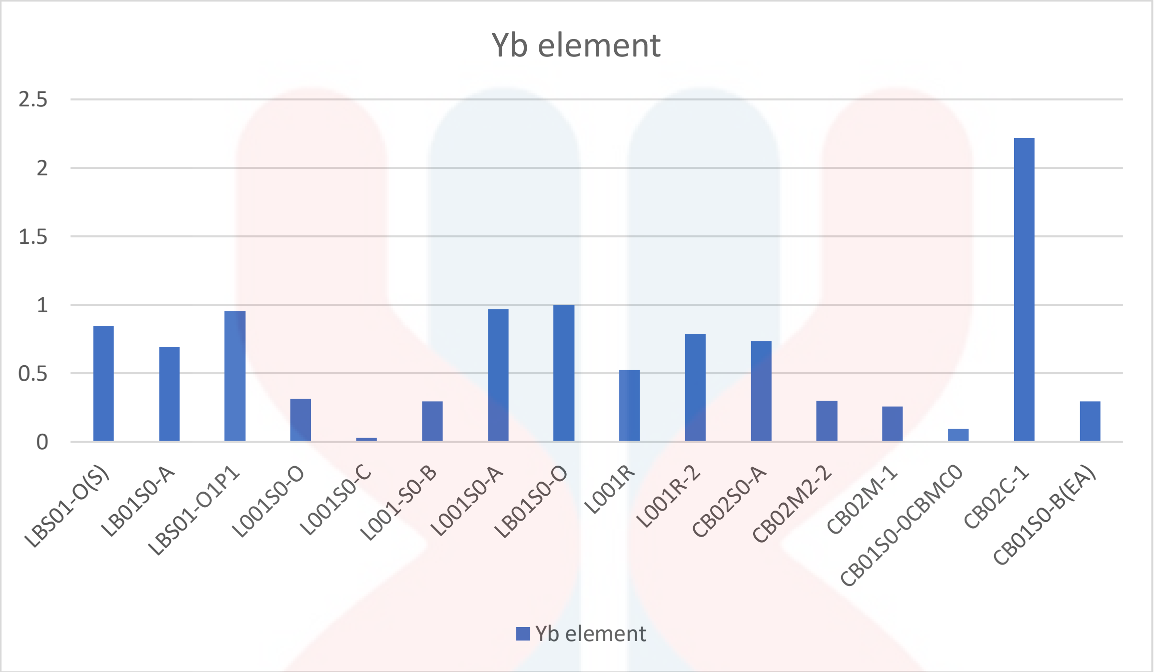

Figure 4.3.5 Ytterbium (Yb)element in soil sample

Ytterbium is a chemical element with the symbol Yb and atomic number 70. It belongs to the lanthanide series of rare earth elements. Ytterbium is a soft, malleable, and ductile metal with a silvery-white color. According to Figure 4.3.5 Ytterbium (Yb) element found in sample from Lojing was sample LB01S0-O with 1.002. This show the soil sample containing 1.002 parts per million (ppm) of ytterbium (Yb) indicates the presence of this rare earth element in the soil. The soil could be from a wide range of environments, including agricultural land, forested areas, grasslands, or urban areas. The lowest yb element from lojing was found in sample L001S0-C with 0.030. In Cameron Highlands the highest yb element was found in sample CB02C-1 with 2.219. while the lowest was sample CB01S0-0CBMC0 with 0.094. The presence of ytterbium in the soil sample is a natural occurrence and may not have any immediate implications for soil quality or environmental health.

4.3.2 Heavy metal

Heavy metals are a group of metallic elements that have relatively high atomic weights and densities. They are naturally occurring in the Earth's crust and are present in various environmental media, including soil, water, and air. Table 4.3.2 shows the content of the 5 main Heavy metal in 16 soil samples taken from point at Lojing and Cameron Highlands.

Soil sample Element	Chromium (Cr)	Iron (FE)	Manganese (mn)	Nickel (Ni)	Lead (Pb)
LBS01-O(S)	96.623	22249.995	218.403	36.929	96.186
LB01S0-A	59.028	35176.307	118.052	21.028	82.951
LBS01-O1P1	109.431	26457.209	375.730	71.092	165.281
L001S0-O	62.795	40879.054	2013.335	34.493	92.209
L001S0-C	47.213	34307.417	46.345	28.714	83.880
L001-S0-B	47.801	13807.375	62.221	26.893	91.932
L001S0-A	38.346	43046.636	40.387	26.080	42.746
LB01S0-O	118.114	29460.352	309.351	47.746	185.753
L001R	26.867	19422.437	79.984	12.713	55.807
L001R-2	67.480	36517.866	166.556	24.018	64.906
CB02S0-A	66.666	37461.839	135.708	22.518	30.902
CB02M2-2	68.126	11449.701	72.551	12.459	81.560
CB02M-1	22.720	7506.318	63.828	13.163	56.320
CB01S0-0CBMC0	11.143	2894.474	21.043	6.523	38.968
CB02C-1	25.714	6413.260	13.394	8.106	35.297
CB01S0-B(EA)	24.329	13873.010	124.643	12.328	51.849

Table 4.3.2: Data for 5 main heavy metal in soil sample

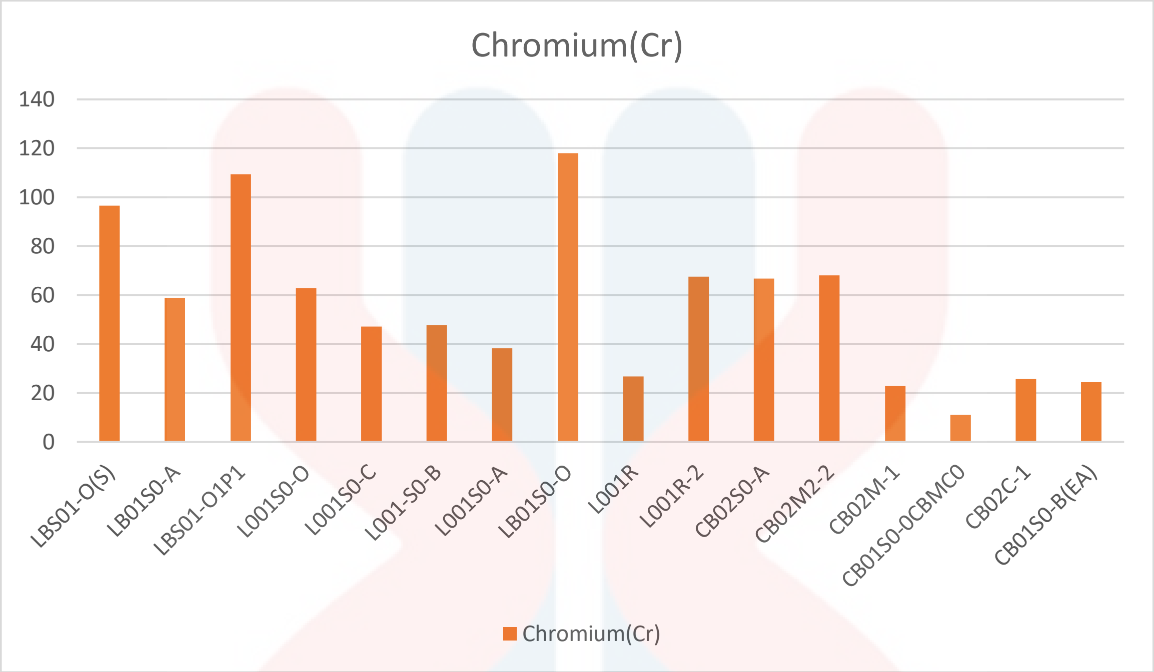

Figure 4.3.6 Chromium (Cr) in soil sample

Chromium is a chemical element with the symbol Cr and atomic number 24. It is a hard, shiny, silvery metal with a bluish tint. Chromium is relatively rare in the Earth's crust, occurring in various minerals, including chromite, chromate, and ferrochrome. It is primarily mined as chromite ore, which is then processed to extract chromium metal or used in the production of chromium compounds. Referring to the data presented in 4.3.6, it has shown the highest sample that contain chromium from lojing area was LB01S0-O with 118.114. The presence of high chromium in this area is caused by Weathering and erosion of chromium-containing rocks and minerals that release chromium into the soil. The lowest sample that contain chromium from lojing area was L001R with 26.867. From Cameron Highlands site the highest chromium was found in CB02M2-2 sample with 68.126. while the lowest chromium was found in sample CB01S0-0CBMC0 at 11.143. The presence of chromium in soil, particularly in elevated concentrations, can have environmental and health implications. Certain forms of chromium, such as hexavalent chromium (Cr(VI)), are of particular concern due to their toxicity and carcinogenicity.

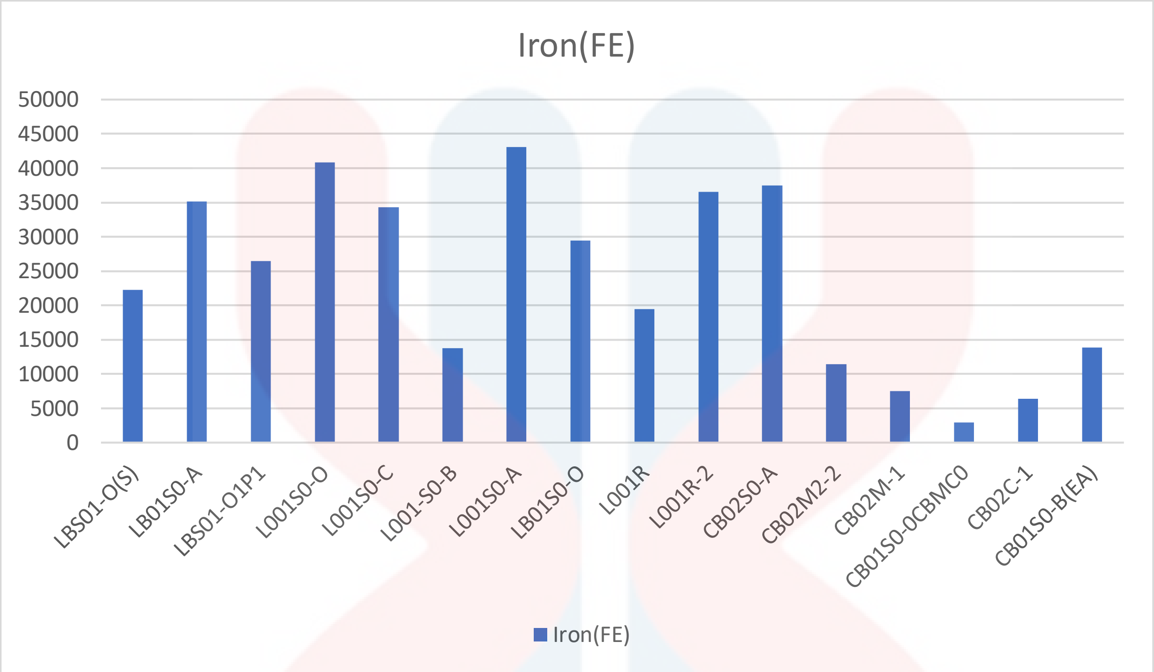

Figure 4.3.7 Iron (FE) in soil sample

Iron (Fe) is a chemical element with the symbol Fe and atomic number 26. It is one of the most abundant elements on Earth and is essential for various biological, industrial, and geological processes. Iron is a silvery-gray metal with a relatively high density and melting point. It is malleable, ductile, and ferromagnetic, meaning it can be magnetized. Referring to figure 4.3.7, the highest content of iron from Lojing point was found in sample L001S0-A with 43046.636. while the lowest was from sample L001-S0-B at 13807.375. At Cameron highlands point the highest sample that contain iron was CB02S0-A at 37461.839, while the lowest at CB01S0-0CBMC0 (2894.474). the presence of iron in soil sample may be caused by Iron particles that transported over long distances in the atmosphere as dust or aerosols. Atmospheric deposition of iron-containing particles contributes to the input of iron into soils, particularly in regions affected by wind erosion or industrial activities.

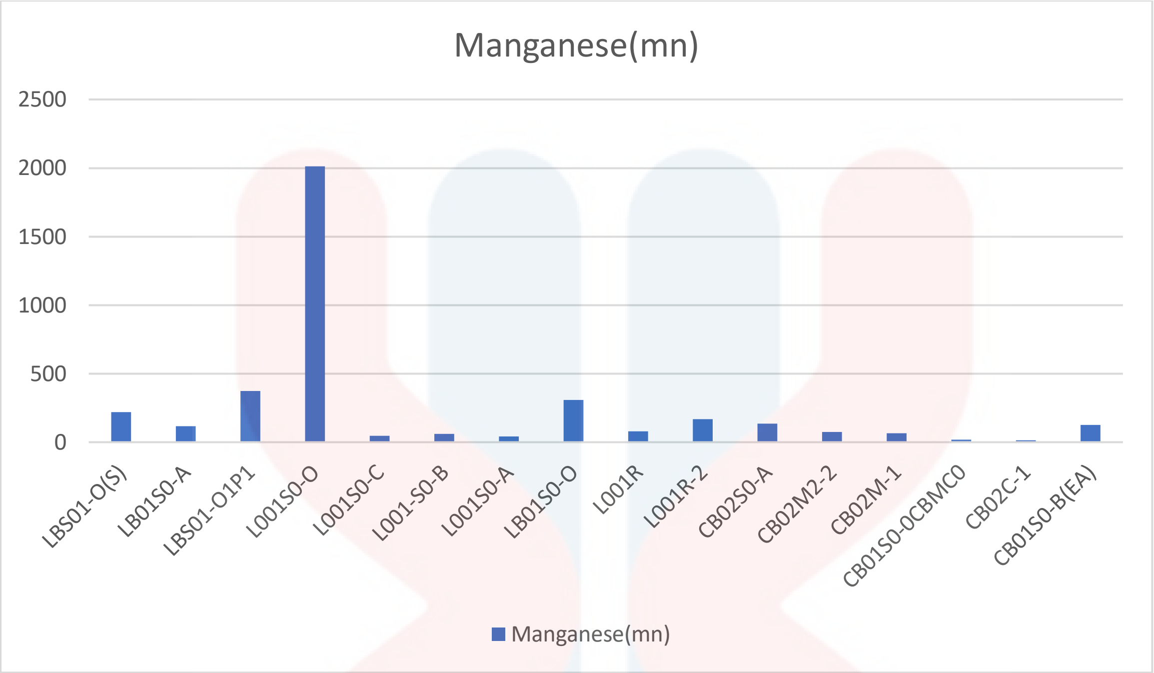

Figure 4.3.8 Manganese(mn) in soil sample

Manganese (Mn) is a chemical element with the symbol Mn and atomic number 25. It is a silvery-gray metal that resembles iron but is harder and more brittle. Manganese is an essential trace element for all living organisms. Based on figure 4.3.8 the data show that the highest presence of manganese in soil at Lojing was L001S0-O with 2013.335. the lowest was at L001S0-A with 40.387. At Cameron Highlands point the highest presence of manganese was at CB02S0-A with 135.708 while the lowest at CB02C-1 with 13.394. Manganese is naturally present in soil, water, and air, and its concentration can vary depending on geological and anthropogenic factors. While manganese is an essential nutrient for plants and animals, excessive exposure to manganese can be toxic.

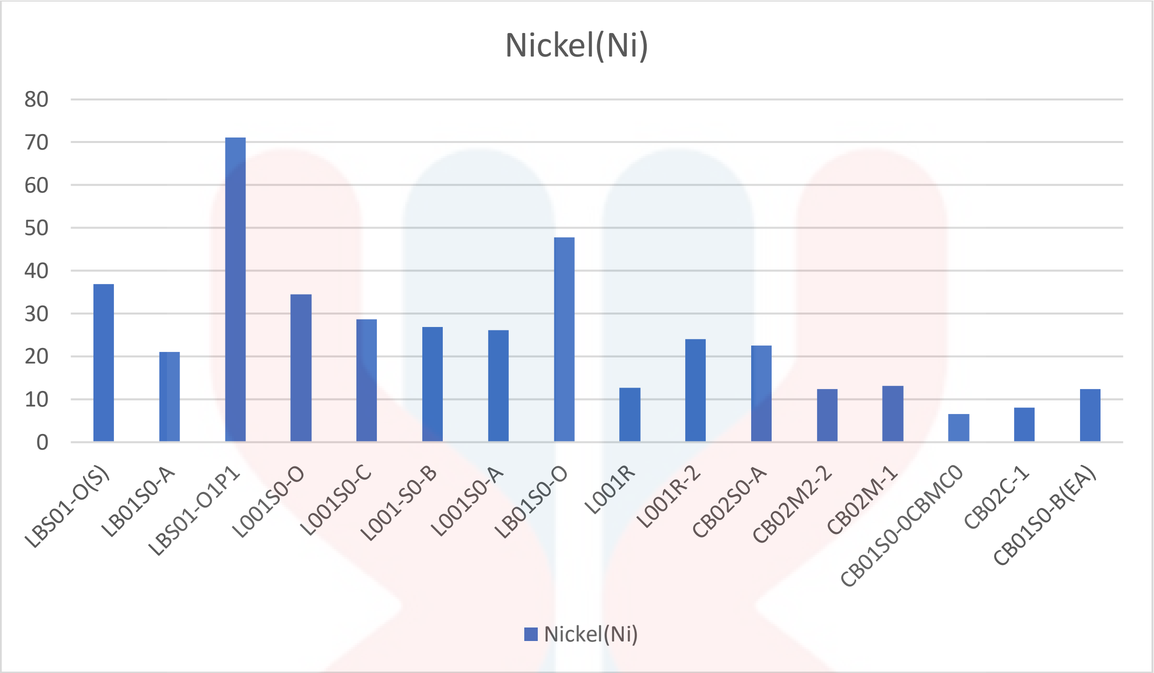

Figure 4.3.9 Nickel(Ni) in soil sample

Nickel (Ni) is a chemical element with the symbol Ni and atomic number 28. It is a silvery-white, lustrous metal with a slight golden tinge. The variation displayed in figure 4.3.9 indicates that the highest presence of Nickel in soil at Lojing was LB01S0-O with 47.746. the lowest was at L001R with 12.713. At Cameron Highlands point the highest presence of Nickel was at CB02S0-A with 22.518 while the lowest at CB01S0-0CBMC0 with 6.523. Nickel can be released into the environment through natural processes, such as weathering of rocks and volcanic activity, as well as anthropogenic activities, including mining, smelting, industrial emissions, and waste disposal. Nickel contamination in soil, water, and air can have environmental and health implications, particularly in areas with high industrial activity or mining operations.

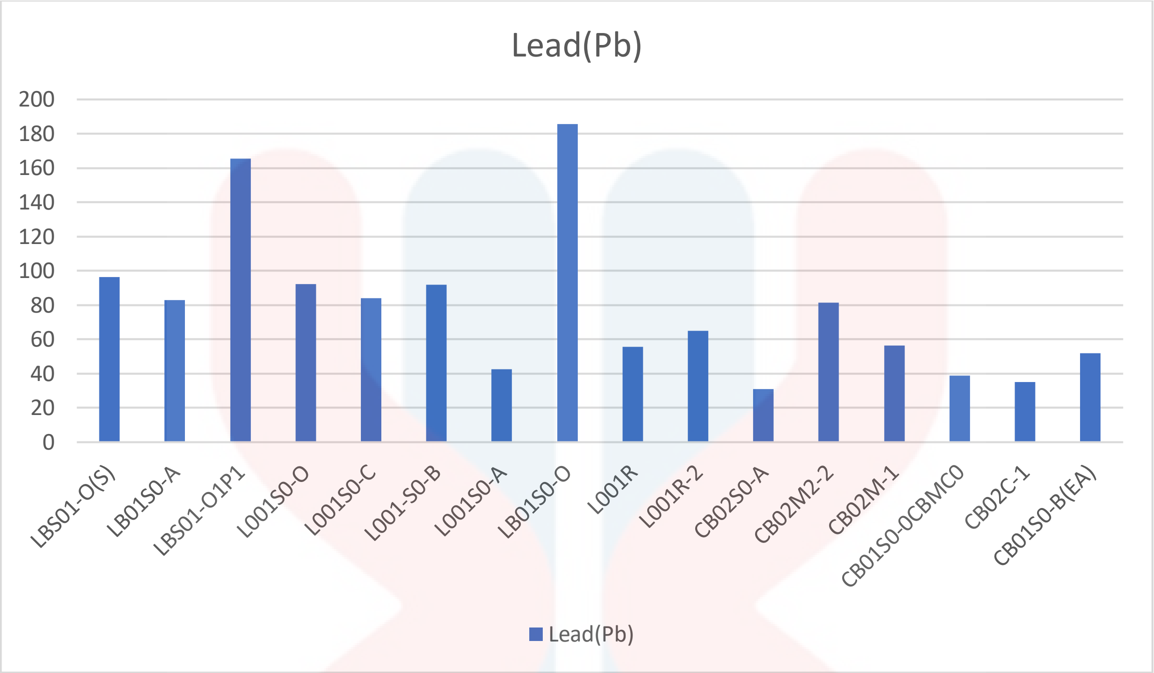

Figure 4.4.1 Lead (Pb) in soil sample

Lead (Pb) is a chemical element with the symbol Pb and atomic number 82. It is a dense, soft, and malleable metal with a bluish-white color when freshly cut. Referring to the data presented in 4.4.1 it has shown the highest sample that contain lead from lojing area was LB01S0-O with 185.753. while the lowest was at L001S0-A with 42.746. for Cameron higlands the highest was recorded at sample CB02M2-2 with 81.560, while the lowest recorded at sample CB02S0-A with 30.902. Lead is toxic to humans and other organisms, even at low levels of exposure. It can cause serious health problems, particularly in children and fetuses, including neurological damage, developmental delays, learning disabilities, and behavioral problems. Industries such as mining, smelting, metal processing, battery manufacturing, and waste incineration can release lead into the environment through emissions, runoff, and waste disposal. Areas with past or present industrial activities may have higher levels of lead contamination in soil.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study of heavy metal and REE distribution in soil from Cameron Highlands and Lojing indicates significant variations in the concentrations of these elements across different sampling sites. The presence of heavy metals such as lead, cadmium, manganese, iron and nickel, as well as REEs like lanthanum, cerium, erbium, Ytterbium and gadolinium, reflects both natural geological processes and anthropogenic activities in the area. In general, elevated concentrations of heavy metals and REEs were observed in soils sampled from areas with intensive human activities, including agriculture, mining, and industrial operations. These activities can lead to the release of heavy metals and REEs into the environment through processes such as atmospheric deposition, runoff, and waste disposal, contributing to soil contamination. The distribution patterns of heavy metals and REEs in soil may also be influenced by factors such as soil properties, land use practices, topography, and geological formations. For example, areas with acidic soils, high organic matter content, or proximity to mining sites may exhibit higher concentrations of certain heavy metals and REEs. Overall, the findings underscore the importance of continued monitoring and management of soil quality in Cameron Highlands and Lojing to mitigate the potential environmental and human health risks associated with heavy metal and REE contamination. Strategies such as soil remediation, land-use planning, and pollution control measures may be necessary to safeguard ecosystems and public health in the region.

5.2 Recommendations

Implement a long-term monitoring program to regularly assess the concentrations of heavy metals and REEs in soil across different land use types and geographic areas within Cameron Highland and Lojing. This will help track changes over time and identify emerging hotspots of contamination. Beside that, Conduct detailed investigations to identify specific sources of heavy metal and REE contamination in the study area. This may involve assessing the influence of nearby industrial facilities, agricultural practices, mining activities, and urban development on soil quality. Last but not least, Develop and implement remediation strategies to mitigate soil contamination in areas where elevated levels of heavy metals and REEs are identified. Remediation techniques may include soil washing, phytoremediation, chemical immobilization, and land reclamation practices tailored to the specific contaminants and soil conditions.

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APPENDIX A

APPENDIX B

APPENDIX C