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ORIGINAL ARTICLE

Exploration of Secondary Deposit to Determine Manganese Ore Body

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ABSTRACT – Manganese ore is one of the most critical mineral commodities and irreplaceable in steelmaking. With the high demand for manganese ore, exploration to find manganese ore deposits is essential before large investments in mine development. The purpose of this study is to determine the content of secondary manganese through exploration in Ladang Sungai Terah Gua Musang with an area of 40.5 hectares. The area is located near the Permian-dominated zone which can be observed during plutonic igneous granites in the southwest and in the presence of phyllite, slate and shale with subordinate sandstone and schist. The significant secondary mineral found is manganese oxide or pyrolusite. The exploration method is by excavating the trial pit (TP) and bore hole (BH) drilling. The location of TP and BH are determined from anomalies data and outcrop and boulders presence at site. Results that obtained from the thirteen TP sampling showed that the deepest TPs are excavated at 4.0 m depth and the shallowest depth was at 3.6 m depth. The thickest manganese ore was at 0.4 m for TP 06. The highest-grade manganese was 54.3% at 3.8 meter depth of TP 01 located at north-west from BH1. The BH soil which obtained at 12.0 meter depth with silt clay and the presence of sand gravel. The BH soil was taken and homogenised prior testing in order to get representative result. The XRF analysis shown that the manganese ore was found at 55.90 % and second highest mineral was silica oxide which was 21.74 % followed by aluminium at 14.32 %. The calculation of manganese ore reserves was estimated at 157,545 tonnes of which the lifespan of manganese mining operations was estimated at only 10.375 months. Even the quality was high but it still not reaching the ore body It can be concluded that this area is not economical for commercial production of manganese ore and by pursuing this area will surely contribute to business risks, negatively impacting on potential profitability. Mining revenue calculated from estimated ore reserved in this area is not expected to cover costs such as the exploration working capital, property acquisition costs, mine development costs including development drilling and infrastructure development such as roads, utilities, plant and equipment costs which include mining equipment, mill and processing equipment and building, structure and many more.

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INTRODUCTION

Manganese ore is an important raw material in iron and steel production. It is essential by virtue of its sulphur-fixing, deoxidizing and alloying properties. Besides, manganese is also used in producing aluminium alloys and dry cell batteries. After a long period of inactivity, manganese mining was revived in 1978 in Kelantan producing 78,329 tonnes of manganese ores. For the period 1980 to 1995, no manganese mining activities were recorded until 1996 when a total of 13,000 tonnes of manganese was produced from Bukit Penchuri, Kelantan. The volume of manganese output from Malaysia depended on prices of manganese in the world markets. Since 2005, with an increase in manganese prices in the world, Malaysia's manganese output gradually increased during the past several years.

Ore body

Manganese (Mn) is a hard, brittle, grayish-white metal widely distributed in the Earth's rocks. Manganese is the twelfth most abundant element in the earth's crust (0.096%). Manganese rarely exists in its pure, elemental state but instead combines with other elements in nearly 300 different minerals. Generally, the manganese deposits occur in various grades, size and origin including different oxides manganese ores (Narejo *et al.*, [1]). According to Emerson *et al*. [2], primary

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manganese minerals occur in sedimentary, hydrothermal, and metamorphic environments. The largest primary deposits are to be found in sedimentary beds; the major secondary deposits are residuals derived by oxidation of primary sediments.

Manganese also used as an alloy with metals such as aluminum and copper. Important non-metallurgical uses including battery cathodes, soft ferrites used in electronics, micronutrients found in fertilizers and animal feed, water treatment chemicals, and other chemicals such as those used as a colorant for automobile undercoat paints, bricks, frits, glass, textiles, and tiles. The product “manganese violet” is used for the coloration of plastics, powder coatings, artist glazes, and cosmetics [3].

Prospecting and Exploration

Prospecting is the systematic process of searching for a mineral deposit by narrowing down areas of promising enhanced mineral potential. The objective is to identify a deposit which will be the target for further exploration. Reserves estimated for the deposits are with a low level of confidence. Estimates of quantities are inferred, based on interpretation of geological, geophysical and geochemical results [4].

Geological Mapping

Geological maps provide exploration agencies or companies with regional geological and geophysical information so that target areas considered having a better prospect in terms of mineral deposits may be identified. The cost of undertaking geological surveys, many of which will not prove to be prospective, is high. Geological surveys provide exploration and mining companies with pre-competitive geo-scientific data that is designed to encourage the company to undertake further exploration. Geological methods rely on the identification of rocks and minerals and an understanding of the environment in which they are formed.

These surveys aim to find what rock types occur at or close to the surface and how these rock types are related to each other i.e. their boundaries, ages and structure. Based on known “environments for mineralization” or models for mineralization, regional geological surveys can be used to define smaller areas in which more detailed studies can be undertaken. A geological survey can be undertaken using a number of methods depending on the size of a region and the amount of information that is required. The aim of this paper is to evaluate the present of manganese ore for commercial production. This study also focusing on conducting the site exploration as to estimate the manganese ore reserved. The benefit of this study was extended to analyse mineral characteristic as to determine manganese and other significant mineral concentration.

RESEARCH METHODOLOGY

Figure 1 shows the plan for the manganese exploration area. Figure 2 presents the research flow of this project. This section also present the material and equipment used for this study, the site selection, the site exploration, the trial pits, the boreholes, site sampling process and process for mineral characterizations.

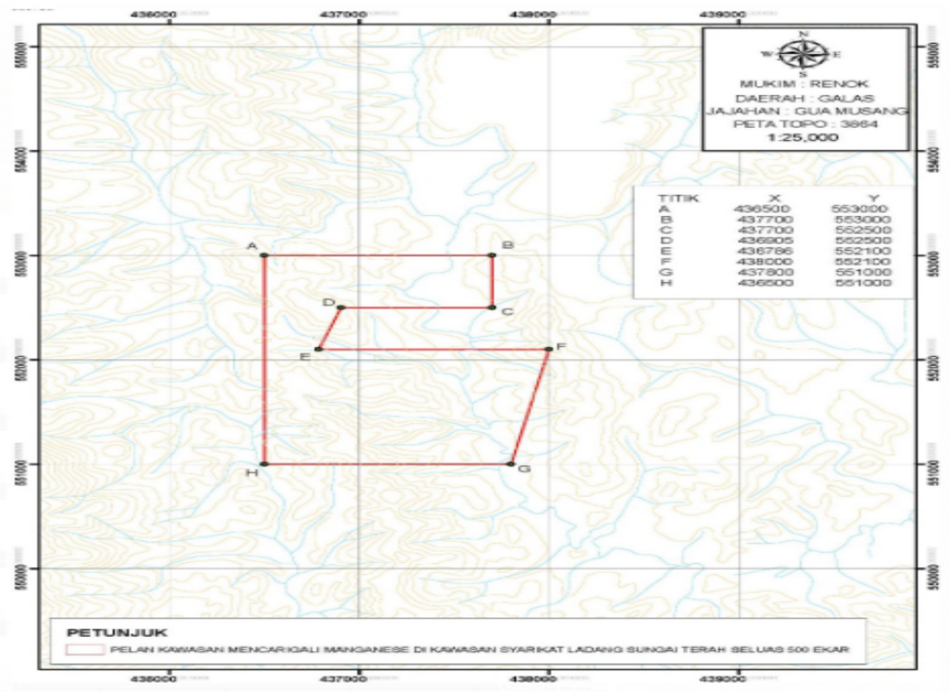

Figure 1: Plan for Manganese Exploration Area [4]

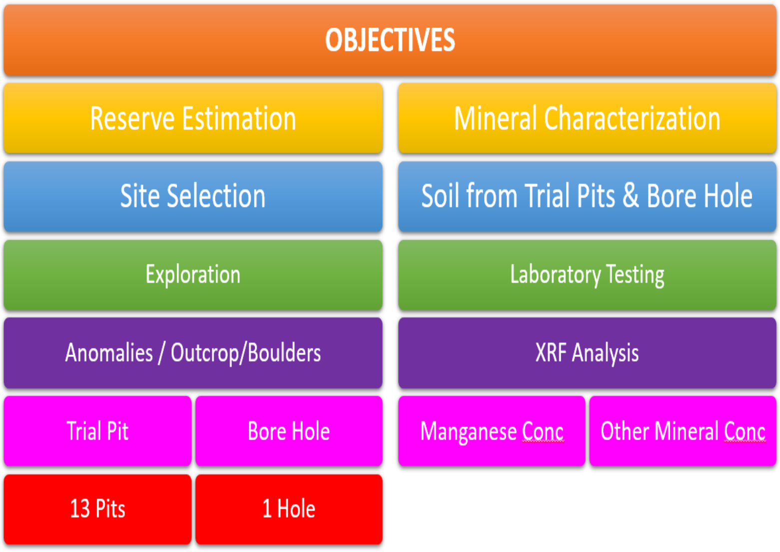

Figure 2: Flowchart of Research Methodology

Material and Equipment

The description under this topic includes site selection, type of exploration and laboratory analysis for mineral characterization. There are two (2) types of exploration which consists of trial pit and bore hole that been used at the site for investigation The excavation of test pits and drilling of boreholes are perhaps the most widely used means of invasive subsurface geotechnical investigation and were applied during the exploration of secondary manganese deposits at Ladang Sg Terah, Gua Musang.

Site Selection

Referring to Geological Map of Peninsular Malaysia, the geological formation in regional scale shows the landslides near the contact zone dominated by Permian aged. The plutonic igneous granite massive of the Permian age is noted within the south-western area. Figure 3 shows major faults occurred along north-south direction. Phyllite, slate and shale with subordinate sandstone and schist. The ore deposits are found in the immediate neighbourhood of faults and are thicker and richer in manganese at points close to the faults. Based on geological survey map information, preliminary scouting in the form of pit boring had been done before any detailed site investigation will later conducted if there is a need for it. Indications of Manganese mineralization are visible from the surface occurrences by experienced prospectors and miners.

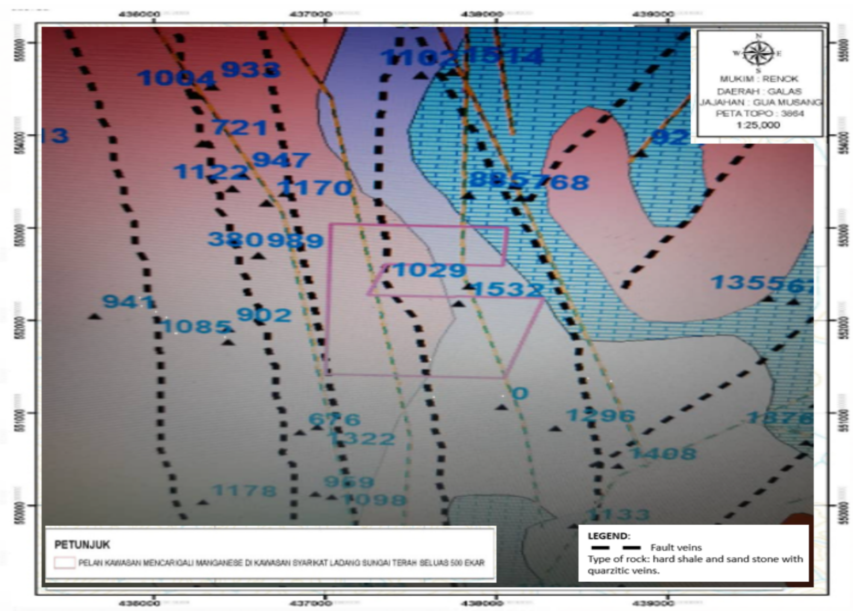

Figure 3: Major faults occurred for Project Area

Site Exploration

Methods used for site exploration are trial pit and bore holes drilling. These methods were chosed because process of mineralization was due to weathering of relevant granitic rocks formations, thus, some trial pits and wash boring with diamond drilling shall suffice to give an affirmative reserve that is viable and mineable. There are several important criteria for trial pit location which are:

1. Anomalies data: The anomalies which found at site with other group of metal minerals. These anomalies were used as indicator for site sampling.
2. Outcrop and boulders presence at site. Figure 4 shows boulders found at the site area. An outcrop is bedrock that is exposed on the Earth's surface. The outcrops normally covered by a mantle of soil and vegetation. However, the rock may crop out, or be exposed, in places where the overlying cover is removed by tectonic uplift or erosion. The outcrops are useful in providing direct observation and sampling at site. The outcrops at site are consisting of manganese and associated minerals.

Figure 4: Site Photography showing boulders found at Project Area

Trial Pits

Test pits are commonly used for exposing and soil sampling for mineral. Typically, the view of the pit will be square, rectangular, or circular. The investigations were carried out with an excavator or backhoe, with the depth dependent on machine size and ground stability. The excavation process also provides access for in-situ and field testing and acquisition of samples for laboratory testing. Trial pits were excavated by hydraulic excavator 350 Komatsu as shown in Figure 5 and activities trial pits excavated as displayed in Figure 6.

Figure 5: Site Photography showing Hydraulic Excavator 350 Komatsu

Figure 6: Site Photography showing trial pit at site

Bore Holes

Bore holes were done by using diamond drilling as shown in Figure 7 and extracted at 12.0 meter depth. The diamond bit is mounted onto a core barrel which was attached to the drill stem connected to a rotary drill. Water was injected into the drill pipe, so as to wash out the rock cuttings produced by the bit and also to reduce the heat produced due to friction which causes less wear and tear of the bits. The size of boreholes was such that all the requirements of the sizes in sampling, in situ testing, etc were satisfied. In this instance, the sizes of the boreholes were 100.0 mm in diameter at 12.0 meter depth. Sampling was done at a depth indicating the presence of manganese. From drilling process, a small diameter core of rock from the ore body will be withdrawn. The drill uses a diamond drill bit to drill through the rock.

Figure 7: Site Photography showing Bore Holes Diamond Driller

Site Sampling Process

The exploration for ore deposits using trial pit method as shown in Figure 8. For trial pit, excavation was done at maximum depth of 4.0 meter. Total of thirteen trial pits were excavated and samples were taken from each trial pits as demonstrated in Figure 9. The samples are labelled individually then sent to laboratory.

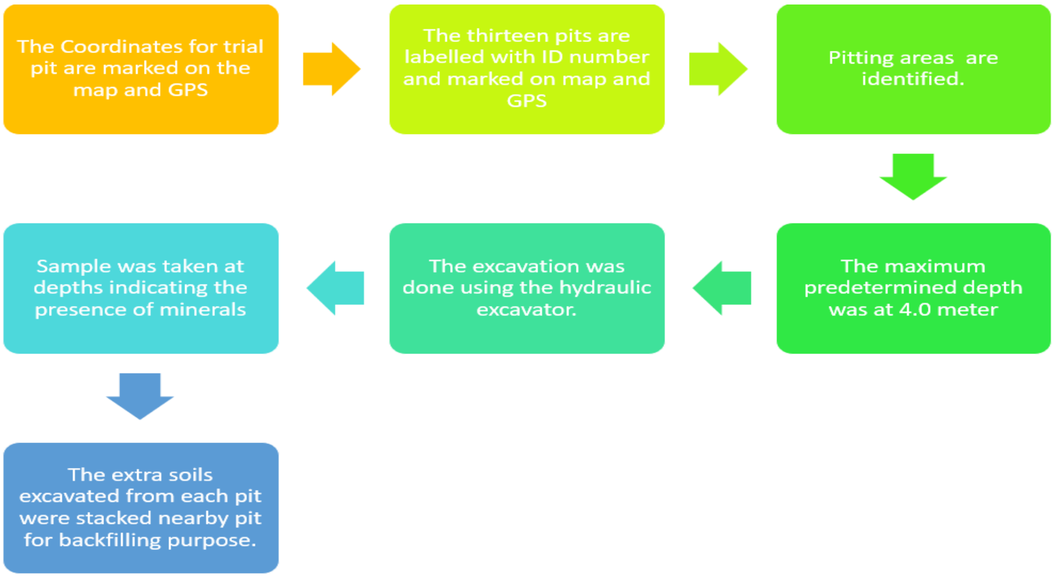

Figure 8: Process flow for Trial Pit sampling

Figure 9: Site Photography showing sampling inside Trial Pit

Mineral Characterization

X-ray fluorescence spectrometry (XRF) has been routinely employed for simple and convenient determination of major and minor elements in solid and powder samples without dissolution treatment. XRF analysis of solid sample can be achieved by implementing more intensive sample preparation, correct QA/QC techniques and correct use of the XRF. Solid samples, like soil, are not homogenous and require more preparation in order to obtain the best data possible. Solid sample materials must first be ground and mixed into a powder. At this point, the soil can be placed directly into a sample cup and followed by simply tapping the sample cup to level and compress the powder after filling. Sieving, drying and homogenization of soil samples removes many of the sampling errors caused by grain size effects, moisture content and other matrix effects, and increases the accuracy and reliability of the results. One of the most common methods of preparing samples for XRF analysis is by making pressed pellets as illustrated in Figure 10. This process is particularly popular as it produces high quality results, is relatively quick and is a low-cost approach.

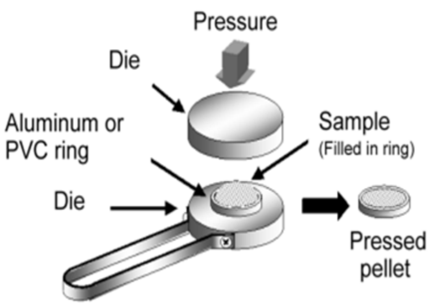

Figure 10: Pressed pellet preparation [5]

RESULTS AND DISCUSSION

The basic parameters for ore reserve estimation are thickness and area - quantitative indicator of form size, volume of the mineral deposit, distribution in the deposit and specific gravity indicator for tonnage estimation. The individual soil sample was taken from each thirteen trial pits. The location of these thirteen trial pits were identified from anomalies data, outcrops and boulders at the site.

Reserved Estimation

Average of 2.0 kg sample was sent to laboratory for chemical analysis using the XRF. At site, each sample was taken at depth indicating the presence of minerals. Figure 11 shows the depth for each trial pits.

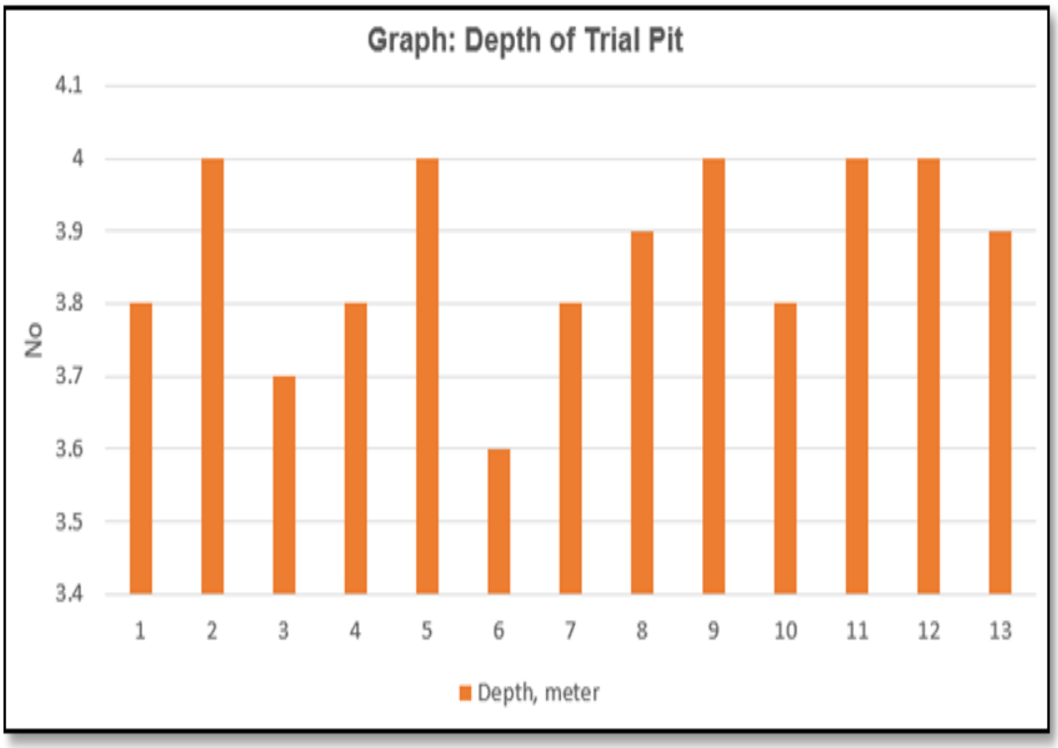

Figure 11: Depth of Trial Pit (meter)

The workable area for the said area was estimated to be about 40.5 hectares, provision for dump, access roads, infrastructures, plants and buildings. Therefore, the estimated reserves of manganese ore estimated to be around tonnes as per calculated in Table 1. Table 2 present the life of operation calculation.

Table 1 Reserved estimation of Secondary Manganese Calculation

Description	Figure
Estimated Workable Area	40.5hectares = 405,000.00m^2
Average Depth	3.89 m
Total Workable Volume	1,575,450.00 m^3
Estimated Ore Content	5%
Total Ore Reserve	78,772.5m^3
Specific Gravity	2.0
Total Estimated Ore Reserved	157,545 tonnes

Table 2: Life of operation calculation

Description	Figure
Daily Plant Capacity for 8 hours operation	73 tonnes/hr
Monthly Plant Capacity for 26 days operation	15,184 tonnes
Total Estimated Ore Reserved	157,545.0 tonnes
Estimated Life of Operation	10.375 months

Mineral Characterization

Mineral characterization in this project involves the study of chemical composition for minerals at Ladang Sungai Terah, Gua Musang. The grade of ore refers to the concentration of the desired material it contains. The value of the minerals in the soil must be calculated against the cost of extraction to determine whether it is sufficiently high grade to be worth mining. Figure 12 shows the grade for manganese tested from each trial pits. The results showed that the highest manganese grade, 54.3 % was at Trial Pit 1, the lowest was 31.3 % for Trial Pit 4 and average manganese grade was 44.98 %.

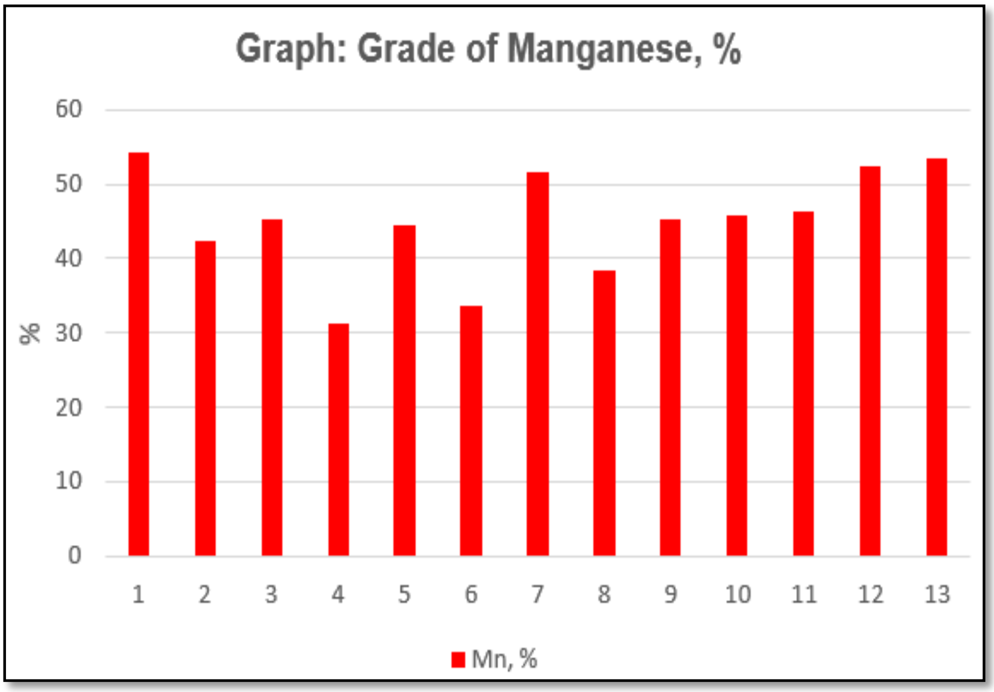

Figure 12: Manganese Grade (%) for soil from Trial Pit

Beside trial pit, soil sample was also taken from bore hole. 2.0 kg soil was collected at the depth of 12.0 meter, labelled and sent to laboratory for chemical analysis. The sample had been homogenised prior testing in order to get representative result. The borehole sampling revealed two layers across the site overlying from top soil till depth of 7.5 meter with silt clay and the presence of sand and gravel till depth of 12.0 meter. The result for chemical analysis is shown in Figure 13, where the manganese ore was found at 55.90 % and second highest mineral was Silica Oxide which was 21.74 % followed by Aluminium at 14.32 %.

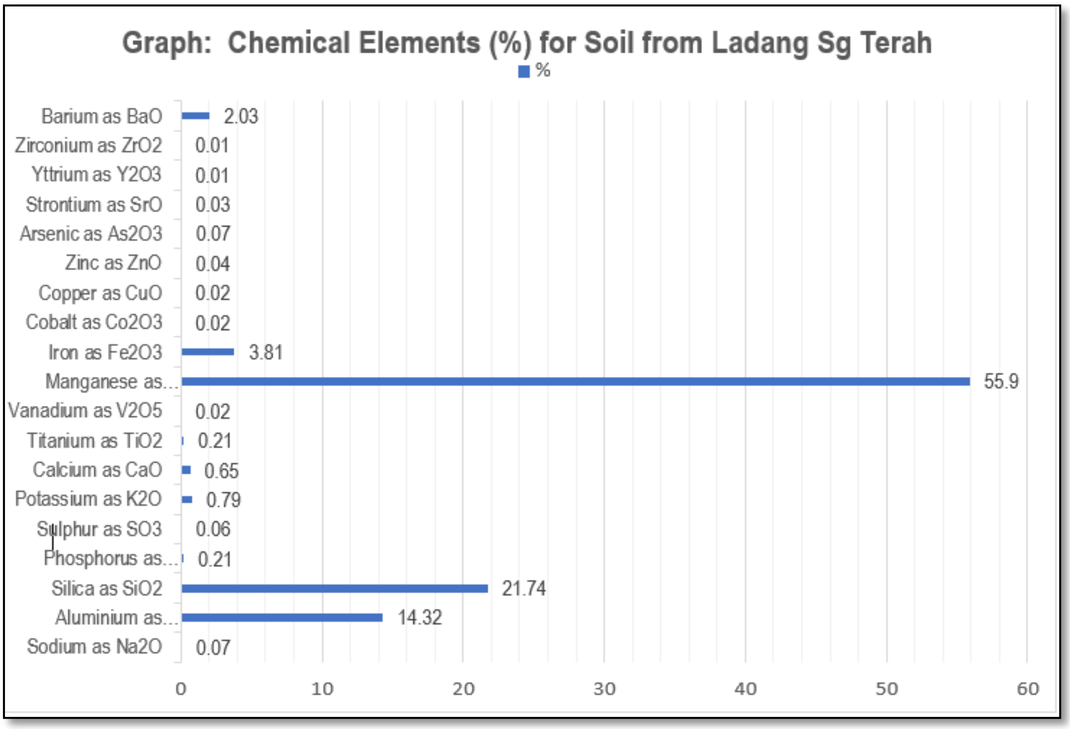

Figure 13: Chemical Elements (%) for Soil from Bore Hole

CONCLUSION

The ultimate objective of this research was to establish a better understanding on degree of acceptable risk for better decision-making by mining project planners, operators and investors. During this study, the two objectives have been addressed. The investigation was done on the soil from Ladang Sungai Terah, Gua Musang to estimate the manganese ore reserved by conducting site exploration with the determination of manganese and other significant mineral concentration.

This study has performed exploration to identify the potential mineral and has quantified the mineral reserved and tested the ore grade. Even the quality is high but it is still not reaching the ore body. The results have obtained through exploration and it can be concluded that this area is not economical for commercial production of manganese ore and by pursuing this area will surely contribute to business risks, negatively impacting on potential profitability. Mining revenue calculated from estimated ore reserved in this area is not expected to cover costs such as the exploration working capital, property acquisition costs, mine development costs including development drilling and infrastructure development such as roads, utilities, plant and equipment costs which include mining equipment, mill and processing equipment and building, structure and many more.

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