Identification of Potential Minerals/Rocks in Sri Lankan Geological Terrain as Source of Potassium (K) Fertilizer

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Abstract

Due to the agricultural intensification in Sri Lanka, there is a high demand for potassium (K)-fertilizer inputs. However, in the Sri Lankan geological setting, the presence of major potash sources is minimum though the K- bearing minerals and rocks are abundant. Therefore, exploration of K-bearing mineral deposits is essential to cater the demand of K-fertilizer in the country. In this regard, this research is focused on investigating the K-bearing minerals and rocks in Sri Lankan geological terrain which can be used as K-fertilizers directly or as alternatives for currently available K-fertilizers. During sample collection, K-bearing minerals, such as feldspar and mica and K-bearing gneiss rock samples were collected from Matale, Kaikawala and Kadugannawa areas. Processed samples were subjected to analyse major oxide concentrations and K concentrations and surface topography. Analyses revealed that the highest actual potassium concentrations were presented in orthoclase feldspar (10.35 w/w%) and then biotite mica (9.95 w/w%) whereas other rocks showed the lowest. Based on the results, biotite mica (Kaikawala) and biotite gneiss (Matale) displayed the highest potential for K recovery, whilst the least potential for K recovery was shown in orthoclase feldspar (Kaikawala). However, further studies are recommended to develop this K-fertilizer and to assess whether its application is economically viable.

Keywords: AAS analysis, Biotite Gneiss, K-Fertilizer, K-bearing minerals, SEM, XRF

1. Introduction

The growth of the world's population and the simultaneous increase in food demand have driven us towards the expansion and intensification of agriculture [1]. High yield agriculture relies primarily on fertilizers since they replenish the nutrients. Therefore, fertilizers become a key focus to address the concerns on global food security [2],[3].

Potassium (K) is one of the prominent plant nutrients found in high concentrations in plants. It is the second most important macronutrient required by plants after nitrogen, and an adequate supply is essential for crop productivity [4]. Unlike many other plant nutrients, K is assimilated through the roots as K^+ and always remains in this chemical form [10]. It is present in the cell solution and serves as an activator of many cellular enzyme processes [9]. K is present as a positively charged ion (cation) in animal cells and plays a major role in maintaining the proper electrolyte ratio in cells [13]. Eating a variety of foods in a daily diet generally meets the K requirement of most people.

K is mainly found in igneous, sedimentary, and metamorphic rocks. It is mostly recovered in two types of sedimentary deposits (i.e. deeply buried marine evaporite deposits and surface brine deposits associated with saline water bodies) [5]. Underground salt deposits are the primary source of potash fertilizer [5]. There are many K ore deposits, which contain higher amounts of K across the world, such as the brines of the Dead Sea in Asia Minor, the Great Salt Lake in Utah (United States), and Qarhan (Chaerhan) Lake in China. Canada has the world's largest potash reserves (~31% of the total global potash reserves) followed by Russia, Belarus, China, Germany, Israel, and Jordan [6]. At present, 90% of the K production of the world is being used for agriculture [7].

Sri Lanka is an agriculturally oriented country that imports all its K requirements. Therefore, exploration for new sources of K ore deposits has a huge economic significance [8].

K- bearing minerals or rocks in Sri Lanka may contain considerable concentrations of potassium and it is important to explore these deposits to assess their potential as fertilizer prospects in the future [14],[15]. Therefore, this research focuses on assessing the potential of potassium in a few K- bearing minerals or rocks in Sri Lanka, namely feldspar (Kaikawala), mica (Kaikawala), biotite gneiss (Matale), and hornblende biotite gneiss (Kadugannawa).

2. Methodology

2.1 Study Area

Three main sampling locations were selected for this study, Kaikawala, Matale, and Kadugannawa. These locations are distributed in two geological terrains of Sri Lanka namely, Kadugannawa complex and Highland Complex (Fig. 1).

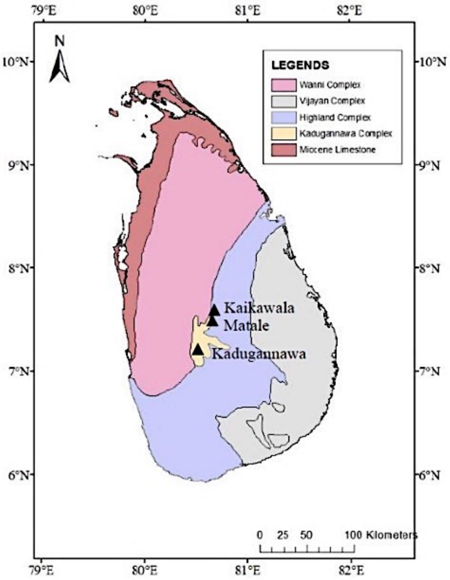

Figure 1- Study areas with respect to simplified geological map of Sri Lanka

2.2 Sample Collection

Samples were collected from the selected three locations (Figure 1). A total of 10 rock samples were collected, including Feldspar, Mica, Biotite Gneiss, and Hornblende gneiss. Every sample was collected into an airtight polythene bag. Sampling details of the locations are shown in Table 1.

Table 1: Sample location details

Sample Name	Location data (UTM)	
	Latitude	Longitude
KAI - F	7^0 30′ 19″	80^0 39′ 16″
KAI - P	7^0 30′ 19″	80^0 39′ 17″
KAI - X1	7^0 30′ 22″	80^0 39′ 17″
KAI - X2	7^0 30′ 21″	80^0 39′ 17″
KAI - FW	7^0 30′ 21″	80^0 39′ 16″
KAI - MI1	7^0 30′ 19″	80^0 39′ 18″
KAI - MI2	7^0 30′ 19″	80^0 39′ 18″
MT-BG1	7^0 25′ 45″	80^0 36′ 39″
MT-BG2	7^0 25′ 45″	80^0 36′ 38″
KD-BG	7^0 15′ 10″	80^0 30′ 22″

2.3 Sample Analysis

The flat smooth surfaces of mineral and rock samples were visually observed using a hand lens and their features were verified.

The samples were firstly crushed using the laboratory jaw crusher and then powdered using the laboratory tema mill. Samples were sieved through 63 µm sieve and the fractions under 63 µm were obtained. Then, representative sample were prepared via coning and quartering method prior to analyses.

Rock samples were then subjected to X-ray Fluorescence (XRF) analyses in the laboratory at Geological Survey and Mines Bureau. A 9.0 g of each sample was mixed well with 2.7 g of grinding pellets (binder) by grinding in an agate motor. Then, mixer was transferred into a 40 mm pellet die, and pressed the sample using 15 t of pressure. The finished powder pellets were subjected to analyse in the GEO-QUANT T analytical package of the S8-Tiger Wavelength Dispersive XRF Spectrometer for the XRF analysis.

Scanning Electron Microscopic (SEM) and Energy-Dispersive Spectrometric (EDS) analyses of samples (< 63 µm) were carried out using a Carl Zeiss EVO-18 instrument in the laboratory of Materials Science and Engineering, University of Moratuwa.

Concentrated HCl and Conc. HNO_3 (1:3 volume ratio) with 1 ml of H_2O_2 were used to digest 0.5 g of each sample for 2 hours. 1ml of each digested sample was filtered and then diluted to 100 ml using ultra-pure water. Diluted samples were subjected to the Atomic Absorption Spectroscopy (AAS) analysis in the laboratory of University of Sri Jayewardenepura.

3. Results

After the visual observation and in-situ field tests of rock samples, minerals and rocks were identified. Results obtained are shown in the Table 2. Table 3 indicates the present oxide percentages of samples obtained from XRF analysis. In addition, Table 4 shows the calculated actual percentage of potassium from the results of the XRF analysis. SEM images of the Biotite mica, Orthoclase feldspar, Biotite gneiss and Hornblende biotite gneiss are shown in Figures 2 to 5, respectively. In addition, EDS spectrum of these samples are shown in Figures 6 to 9 respectively. Table 5 shows the results of AAS analysis

Table 2: Results from visual observations and in-situ field tests of the samples

Location	Identified features	
Kaikawala - Biotite Mica (mineral)	Cleavage	perfect in basal sections
	Habit	platy
	Magnetic properties	none
	Reaction with acid	none
	Colour	black
Kaikawala - Orthoclase Feldspar (mineral)	Cleavage	90
	Lustre	vitreous
	Hardness	6 (between steel (5.5) and quartz (7)
	Magnetic properties	none
	Reaction with acid	none
Matale – Biotite Gneiss (Rock)	Identification of Minerals	biotite, feldspar, quartz,
	Bands	black and white alternative streaky bands
	Grain size	medium to coarse
Hornblende Biotite Gneiss (Rock)	Colour	black
	Identification of minerals	hornblende, quartz, feldspar
	Grain size	coarse grains

Table 3: Oxide percentage in K-bearing minerals and rocks from XRF analysis

Oxide (%)	Biotite Mica	Orthoclase Feldspar	Biotite Gneiss	Hornblende Biotite Gneiss
SiO_2	45.7	65.71	64.94	49.02
TiO_2	3.37	0.03	0.74	2.37
Al_2O_3	15.06	18.7	14.49	12.26
MnO	0.01	0.01	0.01	0.04
MgO	8.67	0.01	4.03	5.99
CaO	0.16	0.48	4.61	9.29
Na_2O	0.06	2.16	3.92	1.64
K_2O	12.22	12.57	2.4	2.83
P_2O_5	0.02	0.02	0.21	8.67
Fe_2O_3	13.99	0.3	4.64	7.69
LOI	2.65	0.81	0.94	0.26

Table 4: Calculated actual percentage of potassium from the results of XRF analysis

Sample from	K moles (mol)	K weight (g)	Present K (%)
Orthoclase Feldspar	0.0026	0.1035	10.35
Biotite Mica	0.0025	0.0995	9.95
Biotite Gneiss	0.0005	0.0197	1.97
Hornblende Biotite Gneiss	0.0006	0.0235	2.35

Table 4: Leached out K percentage from AAS analysis

Sample Location	Leach out K Percentage (%)
Orthoclase Feldspar	0.26
Biotite Mica	6.49
Biotite Gneiss	1.95
Hornblende Biotite Gneiss	0.90

- SEM images of the samples

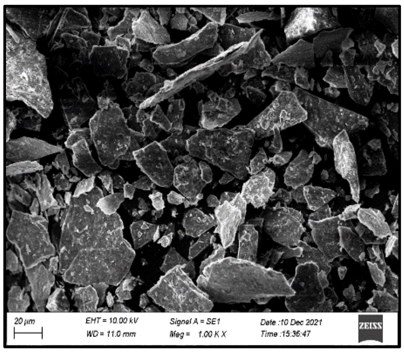

Figure 2- Biotite Mica (Kaikawala)

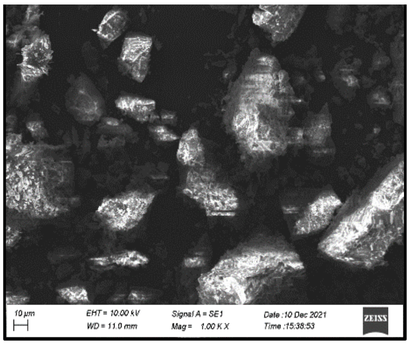

Figure 3- Orthoclase Feldspar (Kaikawala)

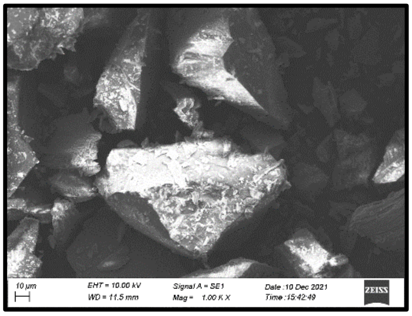

Figure 4- Biotite Gneiss (Matale)

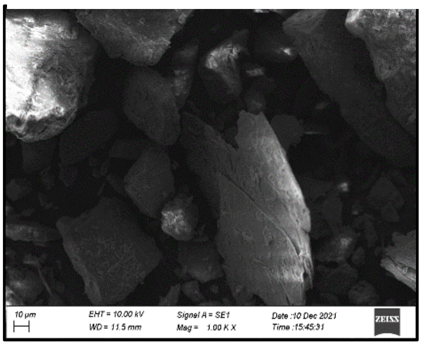

Figure 5- Hornblende Biotite Gneiss (Kadugannawa)

- EDS spectrum of the samples

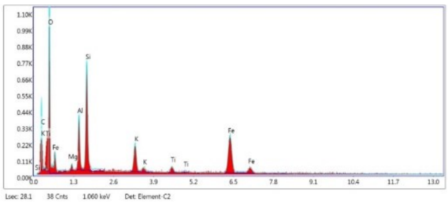

Figure 6- Biotite Mica (Kaikawala)

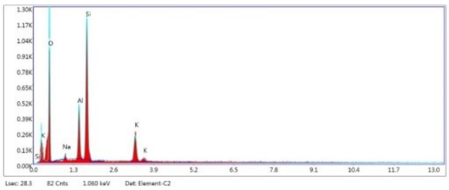

Figure 7- Orthoclase Feldspar (Kaikawala)

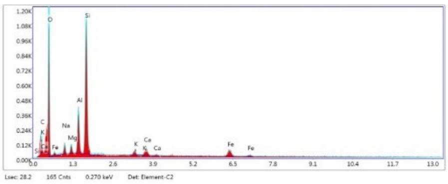

Figure 8- Biotite Gneiss (Matale)

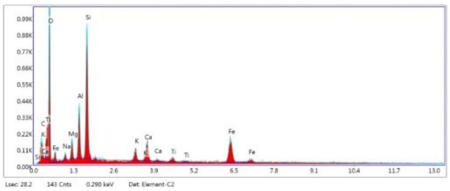

Figure 9- Hornblende Biotite Gneiss (Kadugannawa)

4. Discussion

Elemental characterization, and topographical features of the samples were evaluated by SEM and EDS analyses. In-Situ field tests and visual observations also used to confirm the mineralogy of the samples. From these analyses, the samples from Kaikawala were identified as biotite mica and orthoclase feldspar, the sample from Matale was identified as biotite gneiss and the sample from Kadugannawa was identified as hornblende biotite gneiss (Table 2). However, further mineralogical analyses using XRD is recommended to find the other accessory minerals in these samples.

According to the XRF results in Table 3, orthoclase feldspar and biotite mica from Kaikawala showed higher K2O percentages (12.57% and 12.22%, respectively) compared to the Malate biotite gneiss (2.4%) and Kadugannawa hornblende biotite gneiss (2.83%). Therefore, those minerals showed the highest K2O weight percentages when compared to rocks. However, compared to the biotite mica mineral, hornblende biotite gneiss contained low SiO2 content and high MgO (secondary nutrient). Present potassium concentrations of the samples were calculated using stoichiometry showed in Table 4.

According to the results from AAS analysis, leached-out potassium percentage was high for biotite mica (6.49%) for minerals and biotite gneiss (1.95%) for the rocks. The lowest leached out potassium percentage was obtained for orthoclase feldspar.

Even though orthoclase feldspar showed the highest potassium potential than biotite mica, its extractable amount of potassium was very low for aqua regia. Because potassium exists in a very weathering-resistant framework lattice in feldspars [12]. Therefore, K+ is not easily released and it is not easily available for plants. But, mica minerals have sheet silicate structure and K occupies Fe2+ in the interlayer position and Mg in the octahedral position. They easily break the bonds and release the potassium when reacting with the acid. Therefore, it is possible to extract a higher amount of potassium and other minor nutrients, such as Mg and Ca from mica minerals.

In regard to rocks, leached out potassium concentration of biotite gneiss from Matale is higher than the hornblende gneiss from Kadugannawa. Although these two rocks are under the type of gneissic rocks and have similar potassium weight percentages, their leachable potassium percentages varied due to several factors like weathering of rocks, the crystallographic structure of minerals, and silica percentages [2].

The highest leaching percentage occurred in the biotite gneiss rock (Table 4). It is considerably higher than the mineral leaching. The stable structure of the mineral and the ability of the gneissic rocks to dissolve in the lixiviant could be the reasons for this high leaching percentage.

Several literatures indicate that direct leaching of grounded rocks and minerals in various lixiviants (water, citric acid, HCl, HNO3, H2SO4 and NaOH) is inefficient [11]. Therefore, it is recommended to employ thermal treatment (e.g. heat treatment) and mechanical treatment (e.g. mica mechanical activation using various calcium additions) before leaching to enhance the K recovery from Mica and micaceous rocks. The thermal treatment parameters, such as temperature, time, and flux dosage, the mechanical treatment parameters, such as milling hours and speed, and leaching parameters, such as lixiviant concentration, solid to liquid ratio, temperature, and particle size should be optimized to obtain the maximum K recovery [11].

There are several types of organic fertilizers used in the agricultural sector of Sri Lanka. But their potassium contents are very low when comparing the plant K uptake requirements. When considering the applicability of our potassium resources, we can use our high potassium resources to mix with organic fertilizers like composts and increase the potassium percentage of the fertilizer. It is because usually, organic fertilizers contain potassium percentages of less than 2%.

According to the potassium mineral sources of Sri Lanka, the Biotite Mica source is applicable as a potassium source for the fertilizer due to its high leached concentration of potassium (6.49%) and high solubility characteristics. As a future implementation, the cost and benefit analysis of the fertilizer production using relevant potassium sources and check the economic feasibility is necessary. Furthermore, it is recommended to check the application feasibility to the crop by analysing the crop growth and productivity by adding fertilizers to some relevant plants.

5. Conclusions

When considering the minerals, the most promising K potential was shown in Biotite Mica (Kaikawala) (6.49%). At the same time, Biotite Gneiss (Matale) rocks revealed an intermediate potential for potassium that is higher than orthoclase feldspar. The highest leaching percentage (98.8%) was obtained for biotite gneiss rock from the Matale area.

Mix the leached solution with organic fertilizers shall be more beneficial to the plant growth since the potassium concentration of the leached solution is higher than organic fertilizers. However, further studies are recommended to study the entire geological terrain of Sri Lanka, to develop this K-fertilizer and to assess whether its applications are economically viable.

6. Acknowledgement

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7. References

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