EPPAWALA ROCK PHOSPHATE DEPOSIT

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Geological survey department of Sri Lanka discovered the Eppawala rock phosphate (ERP) deposit in 1971. It is located at Eppawala in the Anuradhapura district of the North-Central province, about 26 km from Kekirawa junction and about 240 km from Colombo. The Eppawala area is a lowland plain with a local relief of 90 m above mean sea level (MSL). The area of the phosphate deposit is distinctively marked by high relief, the average being about 140 m above MSL. The reserves were estimated to be 40 million mt of rock phosphate (Jayawardena, 1976; Dahanayake, 1995) as its northern part. The Southern part of the deposit is yet to be explored. The rock phosphate deposit is exposed in the form of six hills covering a surface area of almost 10 Sq. km.

GEOLOGICAL SETTING

The phosphate deposit is overlying an apatite-rich carbonate rock associated at points in conformity and at other points in crosscutting relationship with precambrian gneisses and charnockite (Jayawardena, 1988). Dahanayake and Subasinghe (1988; 1989 and 1990) while describing the parent rocks of Eppawala phosphate as apatite marble, recognized the presently mined portion of the deposit as a phoscrete-type phosphorite. In the phosphorite weathering profile large appetite crystals can be observed (Amarasekera*et al.*, 1981) in the lowermost parts *in-situ* in the parent carbonate rock (Amarasekera and Ismail, 1983) on the downward slope of the hillrock in the loose residual siliceous -aluminous matrix and in the core of the hillrock embedded in hard siliceous-ferruginous matrix (Amarasekara and Ismail, 1983).

The large apatite crystals have been noted to contain chlorfluorapatite $[Ca_{10}(PO_4)_6 (Cl, F)_2]$ (Gunawardena, 1987). In addition, the presence of hydroxylapatite $[Ca_{10}(PO_4)_6 OH_2]$ has been also reported by Tazaki*et al.* (1987). The loose matrix consists of a secondary phosphate such as francolite $[Ca_{9.77}$

$Na_{.17}$ $Mg_{.07}$ $(PO_4)_{5.92}$ $(CO_3)_{.68}$ $F_{2.27}$] that has formed from primary hydroxyl chlor apatite due to weathering that crumbles the primary crystal to a fine material due to a process of grain diminution (Dahanayake and Subasinghe, 1990). Crandallite [$CaAl_3(PO_4)_2(OH)_5 . H_2O$] and clay minerals mainly kaolinite are associated with this loose matrix. The hard matrix shows a gradation of sizes for primary apatite crystals. The hard matrix consists mainly of quartz (SiO_2), goethite [FeO(OH)], hematite (Fe_2O_3) and Ilmenite ($FeTiO_3$) (Dahanayake, 1995). The mineral composition of ore samples is given in table 1.

Table 1. Composition of ERP (wt %)

Composition	Sample 1	Sample 2	Sample 3
P_2O_5	37.0	36.4	36.4
CaO	49.1	48.3	48.5
Fe_2O_3	4.3	4.6	4.8
Al_2O_3	1.4	1.9	1.9
MgO	0.05	0.13	0.20
Na_2O	0.14	0.18	0.14
F	2.4	2.5	2.6
Cl	0.63	1.05	1.1
CO_2	1.1	1.0	1.2
SiO_2	1.03	1.0	0.8
MnO_2	0.44	-	0.67
TiO_2	0.90	0.42	0.66
SrO	0.04	0.70	0.38
BaO	0.007	0.25	0.15
CrO	0.028	0.02	0.01
Cr	0.01	0.01	0.01
Cu	0.01	0.01	0.013
AS	-	-	0.004
U	-	-	0.0018
Cd	-	-	0.0005
V	0.001	0.01	0.0004
Hg	-	-	0.10
Fa	-	-	0.10
Total C	-	-	0.58
Total S	-	-	0.03
Sulphate sulphur	-	-	0.03
NAC soluble P_2O_5	-	-	2.8

(Source: IFDC,1980)

GEOCHEMISTRY

The Eppawala rock phosphate deposit consists of yellow to green coarse primary apatite crystals in a finer brownish secondary phosphate-rich loose/ hard matrix. The primary apatite crystals appear to have been transformed due to a process of grain diminution (Dahanayake and Subasinghe 1990). Crandallite, hematile, goethite, quartz, rutile, ilmenite and magnetite are associated with the matrix, which is for the most part unconsolidated. The matrix can be hard and contains primary apatite crystals from a few microns to several cm (Dahanayake, 1995).

The primary apatite crystals, which are distributed in the phosphate ore in different sizes, are relatively unweathered or fresh and can be handpicked in large quantities. Primary apatite crystals contain 35 to 42% P_2O_5, average being around 40%. The total P_2O_5 of the matrix varies from 25-35% (Dahanayake and Subasinghe, 1991). The combined iron and aluminum (R_2O_3 = Fe_2O_3 + Al_2O_3) content of primary apatite crystals is very low and lies around or less than 5%. This value can exceed 20% for the matrix. The 2% citric acid solubility of primary apatite is around 3.9% P_2O_5 and it is around 2.7% P_2O_5 for the commercial product which is the mixture of ground primary apatite and matrix (Dahanayake, 1995).

ORE GRADE

Various institutions that analyzed Eppawala rock phosphate (ERP) samples report that in addition to P, they contain such impurities mainly as Fe_2O_3, Al_2O_3, MnO, Cl, etc. (Dinalankara, 1995). The presence of significant amounts of Cl, in the phosphate raw material would cause serious corrosion problems in conventional wet process acid (WPA) plants (Jayawardena, 1988). In the Eppawala deposit, apatite crystals contain about 18,000 ppm Cl (Dahanayake, 1995).

SUITABILITY OF ERP FOR HIGH-GRADE P FERTILIZER MANUFACTURE

Phosphoric acid is the intermediary product in the manufacture of high analysis phosphate fertilizers such as triple superphosphate (TSP), diammonium phosphate (DAP) and mono-ammonium phosphate (MAP).

To convert the phosphate rock to phosphoric acid by the wet process, the rock is reacted with sulphuric acid and gypsum, which is the main byproduct in this chemical reaction and act as a natural filter through which the phosphoric acid passes in the acid reactor

Although the Eppawala rock phosphate is high in P_2O_5, high chloride content and high iron and aluminum contents will pose serious problems in processing the rock to phosphoric acid (54% P_2O_5). High chloride content will cause serious corrosion problem in the acid reactor, pumps and pipes of the phosphoric acid plant.

The high iron and aluminum (Fe_2O_3 + Al_2O_3) in the rock will drastically reduce the filtration rates in the acid filter, as these impurities will form coagulants. The industry standard for iron and aluminum in rock for phosphoric acid manufacture by wet process is 4% and the ERP averages almost 8-9% (Jayawardena, 1988). Therefore, ERP is not suitable for manufacture of phosphate fertilizer by wet process.

PRESENT OPERATION

Eppawala phosphate deposit is currently mined as a small scale mining project catering to local rock phosphate demand by a fully government-owned company namely Lanka Phosphate Ltd (LPL). This company owns the mining as well as its exploration rights.

The ore is mined by opening up a series of benches at various levels using both heavy machinery and by drilling/blasting. Dozers and excavators are used to mine the weathered profile and 80% of the annual production is supplied from this zone. Drilling and blasting are restricted to the hard leached zone.

At the crushing plant, the run of mine ore is reduced to less than 2.0 cm by two crushers and it is further reduced to 100 mesh size at the grinding plant by two ring roller mills and two ball mills. The mill output is collected in 50 kg polypropylene bags, stored and delivered to customers to use as P fertilizer. The production in 1998 using semi modern machinery was 36,598 mt (NFS, 1998) and at the current rate of production, the phosphate deposit can be mined for about 10 centuries (Dahanayake, 1995).

SALES

Three fertilizer products, namely, Eppawala rock phosphate (ERP), imported rock phosphate (IRP) and triple superphosphate (TSP) supply Sri Lanka's annual phosphate requirement. The latter two are imported from various countries. There are several fertilizer blending plants in Sri Lanka and most of them are leading customers of LPL. They either sell ERP as a straight fertilizer or produce different NPK mixtures using ERP. At present a mt of ERP is sold at Rs. 4,100.00 while the IRP is sold at Rs. 7,500.00 and the TSP at Rs. 19,200.00 (NFS, 1998).

SOLUBILITY

Solubility is one of the most important factors governing the quality of rock phosphate for direct applications. Solubility is the measuring gauge of phosphate reactivity, which varies from one material to another. In general, igneous phosphate deposits are typically low in citric acid solubility (<5.3% P_2O_5) and, solubility is higher for sedimentary deposits (Van Kauwenbergh, 1991). The Eppawala ore contains both sedimentary phosphate (froncolite in the matrix) and non-sedimentary phosphate minerals. Dahanayake and Subasinghe (1991) showed that a lower reactivity for the francolite dominant matrix than for the primary apatite. This may be due to the low carbonate substitution in the froncolite and also to the high content of impurities in the matrix.

Various crop research institutes in Sri Lanka have recommended direct application of ERP for certain soil and crop conditions as it is agronomically and economically beneficial alternative to the imported and expensive high analysis phosphate fertilizers. Application has been fairly confined to long-term crops such as tea, rubber and coconut.

Coconut

The Coconut Research Institute (CRI) recommends that 50% P requirement of adult coconut palms be met with ERP. Imported rock phosphate (IRP) is used for immature plants and nursery.

Rubber

The Rubber Research Institute (RRI) recommends 100% replacement of IRP with ERP for mature rubber and 50% for immature rubber. IRP is used at nurseries.

Tea

The Tea Research Institute (TRI) recommends 100% substitution of ERP for IRP in both mature and immature tea. Diammonium phosphate (DAP) is used for tea nurseries.

Rice and Vegetables

ERP is considered as a poor source of P fertilizer for short-term crops such as rice (Nagarajah *et al.*, 1979; Wijewardena, 2001 unpub.) and vegetables (Wijewardena and Amarasiri, 1990; Wijewardena, 1998; Wijewardena and Yapa, 1998 and Wijewardena, 1999). Vegetables differ from most perennials as they have a short growing period of about 2 to 4 months. They generate very high quantity of biomass rapidly taking up large quantities of P. They are also shallow rooted and thus have to obtain their P requirements from a small volume of soil. These conditions necessitates that vegetables should receive a relatively large supply of P in a short time from the soil or added fertilizers for satisfactory growth. Therefore, rock phosphate is not suitable for direct application as source of P fertilizer for potato and vegetables.

A series of long-term experiments conducted in the upcountry however, revealed that ERP solubility could be increased by the following methods and subsequently utilized as a source of P for vegetables.

1. Partially acidulate ERP with industrial grade sulphuric acid (Wijewardena and Yapa, 1998).

2. Combine ERP with poultry manure (Wijewardena 1994; Wijewardena, 1997 and Wijewardena, 2001 unpub.).

3. Combine ERP with TSP (Wijewardena, 1999).

PARTIAL ACIDULATION OF ERP

Partial acidulation of rock phosphate (PAPR) represents an alternative method for using local rock phosphate deposit that is too low in reactivity to be used as rock phosphate but may also be unsuited (for either technical or economic reason) for the production of conventional fertilizer. Acidulation of rock phosphate with sulphuric acid to produce single superphosphate (SSP) or with phosphoric acid to produce TSP has been known over the last few centuries as an effective means of increasing the solubility of P from apatite.

As opposed to these products in which a rock phosphate is treated with the theoretical quantity of acid required to fully convert insoluble phosphate minerals to water soluble monocalcium phosphate monohydrate (MCP), PAPR utilize only a portion of the quantity of acid required to fully convert the apatite to MCP. The % PAPR refers to the proportion of acid used to prepare the PAPR in relation to the quantity of' acid, which would be required to produce superphosphate from the particular rock phosphate. Thus, 50% sulphuric acid acidulation refers to the use of 50% of the H_2SO_4 requirement to produce SSP.

Partially acidulated rock phosphate used for direct application may produce some water soluble P, which has an immediate value to fast growing crops such as potato and vegetable. This method improves the agronomic as well as the economic value of ERP, which is considered unsuitable to produce soluble P fertilizer by wet process. Results of a long-term experiment demonstrated that 30% PAPR could be used for potato and vegetable cultivation as effective as TSP (Wijewardena and Yapa, 1998). This method has been extensively used in many countries to improve their local rock phosphate efficiency.

PRESENT SITUATION

The ERP is of considerable value to Sri Lanka because phosphate deposits are non-renewable and dwindling resources in the world. World's phosphate resources will be exhausted in 100 - 150 years (NSF, 1999). Eppawala rock phosphate is a mineral resource of immense value to Sri Lanka and its exploitation must be carefully planned to serve the national interests. After careful consideration of all the relevant factors and the scientific information available on this deposit, the "National Science Foundation Committee" (NSF) appointed by the minister of science and technology in 1999 made the following recommendations regarding the development of this deposit:

1. Complete and comprehensive geological/geochemical study to establish the total extent and the quality of the deposit.

2. Mining of rock phosphate should be done at a controlled rate so that deposit could be utilized by several generations.

3. Most feasible P fertilizers could he manufactured are SSP and PAPR.

4. Environmental safeguards must be strictly enforced in ERP related projects.

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