Phosphorus (P) is an essential macronutrient required for plant growth and the entire food chain that follows, including human food security. It is a key ingredient in NPK fertilizers and is of particular importance to Indian agriculture. It has been reported that soils of more than 90% the districts have low to medium P fertility (Figure 1) indicating the necessity for P fertilization to produce optimum crop yields and sustain food security (Murlidharudu et al. 2011).

The world's main source of P is rock phosphate (RP), 82% of which is used as fertilizer, either directly or in the manufacture of single super phosphate (SSP), triple superphosphate (TSP), or di-ammonium phosphate fertilizers (DAP). The remaining 18% is used for other industrial purposes, such as detergents, insecticides, matches, fireworks, military smoke screens, incendiary bombs. Rock phosphate is a finite, non-renewable resource. The world reserves of RP are about 67 billion tonnes, located mainly in Morocco and Western Sahara (75%), China (6%), Syria (3%), South Africa (2%), and the remaining 19.17% were contributed by other countries. Large deposits have also been identified on the continental shelves and on seamounts in the Atlantic Ocean and Pacific Ocean. The world production of rock phosphate increased to 215 million tonnes in 2012 from 202 million tonnes in 2011. China (44%), Morocco (13%), USA (14%), Russia (5%) and Jordan (4%) were the major producers.

According to United Nations Framework Classification (UNFC), the total resource of rock phosphate in India was 296.3 million tonnes in 2010. Of these, the reserves constitute only 34.8 million tonnes and 261.5 million tonnes were remaining resources. The states where major P resources occur are depicted in Figure 2. Currently, exploitable reserves in India are present only in Rajasthan and Madhya Pradesh. Grade wise, rock phosphate that can be used in making P fertilizers is only 6%. Low grade account for 39%, followed by beneficiable (29%), soil reclamation (12%), blendable (9%), and unclassified and not-known grades (about 5%). Hence, conversion of low grade RPs into plant utilizable forms, would lead India towards self-reliance in P fertilizer consumption.

Apatite is the most abundant crystalline phosphate mineral present in India. Apatite is a group of phosphate minerals, usually referring to hydroxylapatite, fluorapatite and chlorapatite, which respectively, contain high concentrations of hydroxyl (OH\(^-\)), fluoride (F) and chloride (Cl\(^-\)) ions, in the crystal. The total resources of apatite as per UNFC system in
In 2010 are 24.23 million tonnes. Out of these resources, the reserves are only 2.09 million tonnes and 22.14 million tonnes are remaining resources. Of the total resources, the greater part (57%) is located in West Bengal followed by Jharkhand (30%) and Meghalaya (5%). The remaining 8% resources are available in Rajasthan, Andhra Pradesh, Gujarat and Tamil Nadu. Grade-wise, soil reclamation grade accounts for 45% followed by beneficiable grade (31%), low and non-beneficiability grade (18%) and blendable, others and not-known grades (6%). The resources of chemical fertilizer grade are over one percent.

The production of RPs in India started in 1970-71 with a production of 232.9 thousand tonnes (Motsara, 2002). It took a jump in 2012-13 with a total production of 2124 thousand tonnes. Close to 88% (1.87 million tonnes) of this was from Jhamarkotra mines in Rajasthan, by the Rajasthan State Mines and Minerals limited (RSMML), an undertaking of the Government of Rajasthan. About 52% of the total production of phosphorite/rock phosphate from Jhamarkotra was of grade 15-20% P$_2$O$_5$, 40% of 30-35% P$_2$O$_5$ grade, 4% each of 25-30% P$_2$O$_5$ grade and 20-25% P$_2$O$_5$ grade. At present, very small amount of RP is used for direct application. Out of the total production of 1.87 million tonnes of RP from Jhamarkotra (Rajasthan) only, 74,000 tonnes was distributed for direct application to soil. A portion of this is used in preparing fertilizer mixtures for plantation crops such as rubber.

India has very low indigenous availability of RP and so imported 6387 thousand tonnes of RP in 2010. Jordon was the largest exporter of RPs (2933 thousand tonnes) followed by Egypt (1036 thousand tonnes) and Morocco (918 thousand tonnes). Its import has been steadily increasing since 2002 (4944 to 6387 thousand tonnes in 2010). Imports of rock phosphate was 8.16 million tonnes in 2012-13 and that of phosphoric acid 1.83 million tonnes. The imports of phosphoric acid were mainly from Morocco (41%), Senegal (20%) and USA (16%).

The phosphatic fertilizers imports have steadily increased over time from 243.2 thousand tonnes in 1970s to 511.3 thousand tonnes in 1980s, 736.9 thousand tonnes in 1990s, 1.25 million tonnes in 2000s and 1.97 million tonnes in 2014-15. During 2014-15 India produced 1.50 million tonnes of RP (0.45 million tonnes fertilizer industrial grade) and imported 8.26 million tonnes. Similarly 1.65 million tonnes of phosphoric acid was produced indigenously and imported 1.80 million tonnes. During the same year India produced 2.3 million tonnes of sulphur and imported 1.63 million tonnes. Using those imported raw materials, India produced phosphatic fertilizers, SSP, DAP and complexes equivalent to 4.11 million tonnes of P$_2$O$_5$. In terms of total P$_2$O$_5$ production, indigenous RP
contributed 10.95% share while 45.25% was from imported RP and 43.8% from imported phosphoric acid.

The paucity of domestic raw material has been a constraint in the attainment of self-sufficiency of P in the country as indigenous RP supplies meet only 10% of the total requirement of P₂O₅ and 90% of the P requirement is met by imports. A policy has therefore been adopted which involves mix of three options, viz., domestic production based on indigenous / imported rock phosphate, imported sulphur and ammonia; domestic production based on indigenous / imported intermediates, viz., ammonia and phosphoric acid; and third, import of finished fertilizers. During 2009-10, roughly 72% of the requirement of phosphatic fertilizers was met through the first two options. Considering dependence of Indian fertilizer industry on the import of raw materials or finished P fertilizer products and soaring market prices, emphasis needs to be laid on efficient utilization of indigenous low grade rock phosphates.

As of now, the country has achieved 50% self-sufficiency in the production capacity of phosphatic fertilizers, even though raw-materials and intermediates for them are largely imported. This has been achieved through policy interventions and large investments in the public, co-operative and private sectors. The total installed capacity of phosphate nutrient in 2012 was 5.62 million tonnes while the production was 4.10 million tonnes compared to 4.22 million tonnes in 2011-12. The share of public and co-operative sector during 2012-13 was 1.61 million tonnes while that of private sector was 2.82 million tonnes. In India, most of the existing phosphatic fertilizer and phosphoric acid plants have been designed for high grade imported rock phosphate, mainly from Morocco and Jordan. The Indian deposits are relatively of low grade. Therefore, the fertilizer and phosphoric acid plants that may be set up as replacement to the existing plants will have to be designed to accept indigenous ores as a feed (Indian Minerals Yearbook, 2013).

According to FAO data up to 2009, China, India and Europe already consume about 60% of the global use of phosphate fertilizer (Figure 3). China is the largest consumer of phosphorus fertilizers in the world with 34% of world total and India is second with 19% of global consumption (FAOSTAT 2012, Figure 3). Between 2002 and 2009, global use of phosphate fertilizers increased by 12% (Figure 3). India showed the largest increase in phosphate use, almost doubling in quantity between 2002 and 2009 (80% increase). China also showed strong increases with 20% growth in phosphorus consumption between 2002 and 2009. Europe, in contrast, decreased use by about 20% from 2002 to 2009, reflecting market price increases and environmental restrictions. On a worldwide scale, population
growth, changes towards meat-rich diets, and growing demands for bio-energy crops will push an increasing demand for phosphate fertilizers in the future.

The installed capacity to manufacture phosphate fertilizers has reached to a level of 7.06 tonnes in respect of phosphate nutrient (P\textsubscript{2}O\textsubscript{5}) in the year 2014-15, making India the 3\textsuperscript{rd} largest fertilizer producer in the world. The current consumption of phosphatic fertilizers (in terms of P\textsubscript{2}O\textsubscript{5}) is 6.89 million tonnes. The projected phosphate fertilizers (P\textsubscript{2}O\textsubscript{5}) requirement in 2020-21, 2025-26 and 2030-31 would be 7.83, 9.01 and 10.69 million tonnes, respectively (FAI, 2016).

For manufacturing fertilizers the rock phosphate should have a minimum of 35\% P\textsubscript{2}O\textsubscript{5}. Even for blendable grade it should have a minimum of 25-30\% P\textsubscript{2}O\textsubscript{5}. But the domestic phosphate resources are mostly of low grade phosphate rocks and are inadequate in the country. Further India does not have full capacity for beneficiation of low grade phosphate ores. This will force the country to depend more and more on the imported high grade RP. To face the future challenges of phosphorus shortage, the following approaches are suggested:

1. Commercialize the available beneficiation technologies (washing, screening, de-sliming, magnetic separation, flotation and calcinations) to upgrade the P\textsubscript{2}O\textsubscript{5} content to at least 25-30\%.

2. Commercialize the available technologies for utilization of low grade indigenous rock phosphates as fertilizers. Develop new and economically viable technologies for utilization of indigenous low grade phosphate as fertilizers either directly or by developing some suitable composition.

3. Encourage utilization of indigenous rock phosphates as direct source of P in acid soils, particularly in peninsular region, North-East region and coastal areas.

4. Encourage acidulation and alkalization of low grade phosphate rocks for utilization as fertilizers.

5. Develop suitable composting technologies to utilize low grade phosphate rock and the mine tailings (8 to 10\% P\textsubscript{2}O\textsubscript{5} content being lost in the tailings) from beneficiation plants.

6. Isolate suitable species of microorganisms to solubilise/mobilize phosphorus from phosphate rocks and soils.

7. Use biotechnological approaches for breeding P efficient crop varieties which can mobilize more P from acid/alkaline soils.

8. Development and implementation of sustainable technologies and strategies for the recovery of P from the food system for reuse in agriculture must be encouraged. That is,
the safe and efficient extraction of P through precipitation, incineration, compost or other means from all waste flows from agriculture, food production, households and industry (e.g. crop residues, animal and human excreta, food waste, wastewater).

References

FAOSTAT (2012) http://faostat.fao.org/site/575/default.aspx#ancor Last access date 02/05/2012.


Figure 1. Map of phosphorus status of Indian soils
Figure 2. Locations of rock phosphate resources available in India

Figure 3. Phosphate fertilizer consumption in world and in China, India and Europe from 1961-2009.