



An overview of the global fertilizer trends and India's position in 2020

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Abstract

The growing world population is expected to reach 9.7 billion by 2050, which will increase the present demand for food by ~70%. Consequently, to boost agrarian production and achieve food security, within limited arable land, the effective use of fertilizers becomes critical. However, the economic efficiency of mineral fertilizers has fallen dramatically as the price hike in fertilizers became dearer than food. The current winds of global climate change due to continued emissions of greenhouse gases from human activities have been posing unprecedented challenges before the agriculture sector and fertilizer industry. The limited geological resources of raw material for the manufacture of fertilizers and market fluctuations of fertilizer minerals initiate wide-reaching competition and raise challenge of food security. It is observed since the last century that the production of fertilizer minerals has risen almost constantly; however, consumption varied greatly from one region to another. It remained constant or declined in Western Europe and North America, but increased rapidly in East and South Asia especially in China and India. The Asian share of global fertilizer consumption is more than 60% and growing rapidly. This supply-demand pattern influences mineral fertilizers' trade-flow and thereby global competition. Hence, there is a need to develop the fertilizer mineral sector and adopt policies and strategies to ensure materials security. The sustainable agricultural intensification and the agronomical proportions, timing, and placement with the right source are crucial factors which determine the sustainable utility of fertilizer minerals. In the wake of the above, we provide a critical appraisal of fertilizer minerals.

Keywords Fertilizer minerals · Food security · Sustainable development

Introduction

Fertilizer mineral is a world market commodity that is imperative for the economical production of viable crops. Its optimal supply improves soil characteristics and plays a significant role in plant growth, soil fertility, food security, environmental development, and sustainable agriculture. It is a key to boost the nation's economy where agriculture is the core occupational sector. It will secure the food supply for more than 8 billion people of the world by year 2025. Its availability in sufficient quantities and the correct balance is a prerequisite to close the gap between the nutrient supply from the soil and organic sources and the nutrient demand for optimum crop development (Brentrup 2009). The fertilizers especially

phosphorus (P) and nitrogen (N) are janus-faced; positive fertilizer, negative environmental problems. The inefficient and not demand-oriented use causes negative environmental problems. Particularly the overuse of N and P will produce eutrophication of waters and N might produce leaching problems to the groundwater as well as air pollution by the emission of nitrous oxide contributing to greenhouse effect. Thus, proper management of fertilizers has a direct impact on crop efficiency and productivity. However, current winds of global climate change have been posing unprecedented challenge before the agriculture sector and thereby on the fertilizer industry. The global supply and demand and market fluctuations of fertilizer minerals initiate wide-reaching competition and raise the challenge of food security (Roberts 1999). In 2019, the value of the fertilizer market reached US\$155.8 billion and it is expected to register a compound annual growth rate (CAGR) of 3.8% during the forecast period (2019–2024) (Williams 2019). The global population is expected to reach 9.7 billion by 2050 which will almost come to an end at 11.2 billion in 2100 (Roser 2020). This will drastically increase the food

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demand additionally by 70% (FAO 2012) leading to an increased dependency on fertilizer inputs (Brentrup and Palliere 2008; Dawson and Hilton 2011).

The demand for fertilizer minerals has a significant impact on the development of agriculture which is a core sector influencing several nation's economies like India; therefore, it indirectly contributes to the GDP. The worldwide economic scenario tends to affect agriculture and the demand for fertilizers. Therefore, it is necessary to critically evaluate the fertilizer minerals from the perspective of the world economic growth. Mineral fertilizer which greatly affects the soil (its physical, chemical, and biologic properties) and plants undergo various changes that influence the solubility of their nutrients, their permeability, and their availability to plants (The Great Soviet Encyclopedia 1979). The nature and intensity of the changes are mainly dependent on the properties of the soil. The efficacy of the fertilizer minerals is increased by irrigation and the use of advance cultivation technology. Incorrect use of fertilizer minerals may reduce soil fertility, kill plants and animals, and pollute rivers and other water bodies. Therefore, in this review, we provide global fertilizer minerals perspective in relation to economy, discuss various challenges before mineral fertilizer sector, future perspective of the development of mineral fertilizers, and finally, India's position in fertilizer minerals.

The fertilizers and fertilizer minerals

The fertilizer has been defined as a natural or synthetic, chemical-based substance that is used to enhance plant growth and fertility (Maximum Yield Inc. 2018). However, the fertilizer minerals are all inorganic, either synthetic (manmade fertilizers like urea) or naturally occurring (such as phosphate rock and potassium chloride), containing nutrients essential for the normal growth and development of plants. These are derived from naturally occurring raw materials which have been transformed into a more intake-friendly form by industrial processing (Scherer 2000). They comprise naturally occurring elements which are essential for sustenance of life. These are used to augment the supply of natural soil nutrients to satisfy high yield output demand for crops. They compensate for the nutrients lost by the removal of plant products or by leaching or gaseous loss (IFIA 2000).

Twelve essential nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn, B, Cu, Mo) were recognized which a plant absorbs from the soil (Fig. 1). These are known as macronutrients or primary nutrients (N, P, K), major nutrients or secondary nutrients (Ca, Mg, S), and micronutrients or trace elements (Fe, Mn, Zn, B, Cu, Mo) based on plant growth needs. Some of these nutrients are present in the soil solution complexes as positively charged cations (K, Ca, Mg, Fe, Mn, Zn, Cu) or negatively charged anions (P, S, B, Mo) and amphoteric (showing both

properties) such as nitrogen (Savoy 2012). The K and N are easily water-soluble, whereas N is easily lost through leaching; however, P is available to plants as soluble inorganic phosphate (Pi) (Hanlon et al. 2018). Phosphorus can be buffered in soil (see, e.g., Mew 2016); some of the P compounds are water insoluble and may be deficit or surplus in the soils (e.g., MacDonald et al. 2011). The Ca and Mg both increase soil pH; however, sulfur reduces soil pH (Oldham 2019). Sulfate in soils may occur as water-soluble salts, adsorbed by soil colloids, or as insoluble forms and is easily lost from soils by leaching (Tabatabai 1987). Despite the fact that plants need more quantity of some of the nutrients over others, they are all equally important. These are bio-essential and cannot be substituted. A shortage of anyone will lead to poor crop growth. German chemist Justus von Liebig's Law of the Minimum states, "yield is proportional to the amount of the most limiting nutrient, whichever nutrient it may be". It has described how plant growth relied on the scarcest nutrient resource, rather than the total amount of resources available (UN Industrial Development Organization 1998). Balanced application of fertilizers enhances the efficiency of nutrients (Rajani 2019). The fertilizers which supply only one of these primary plant nutrients are straight fertilizers, while those supplying multi-nutrient (NPK or NP/PK/NK) are complex fertilizers. The latter are high analysis fertilizers (more than 30 kg/100 kg of fertilizer) having uniform grain size and good physical condition (Rajani 2019).

Classification of fertilizers

- a) Following are the simple and rational ways of classifying fertilizers, namely, (i) based on source, (ii) based on consumption, (iii) based on physical state, and (iv) based on nature of fertilizers. *Fertilizer based on origin:* According to the origin, the fertilizers used in farming are classified into three types as follows (Fig. 1):
 - I) *Natural fertilizers:* These are also called as organic or traditional fertilizers. They are obtained from the natural biogenic substances, without adding any chemicals in them, such as dung and urine used by animals. Besides; the oil cake fertilizer, fish fertilizers, chilly salt fertilizers, and potassium fertilizers (e.g., kelp meal) are also included in this category.
 - II) *Chemical fertilizers:* These are also called as inorganic, synthetic, or mineral fertilizers. These are manufactured in factories by chemical synthesis. Several materials are used either separately or in combination with others to form mixed fertilizers. But in practice, the fertilizers containing nitrogen, phosphorus, and potash are widely used. They are further classified as straight and complex fertilizers as shown in Fig. 1.

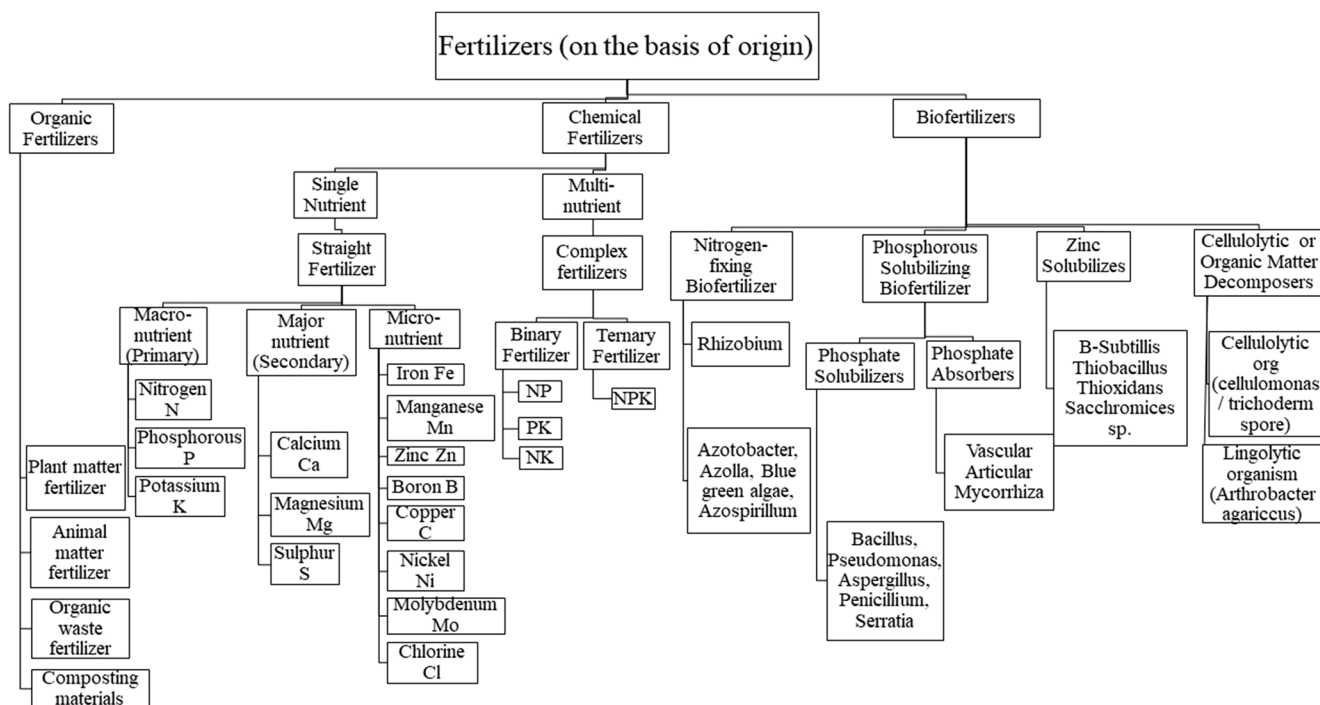


Fig. 1 Classification of fertilizers (Japan Fertilizer & Ammonia Producers Association, 2003; Savoy 2012; Abdulkarim et al. 2019)

- III) *Bio-fertilizers*: These are also called as microbial fertilizer or microbial inoculant. These bio-fertilizers contain biological components, living organisms that synthesize the atmospheric plant nutrient in the soil or build an environment that is beneficial to plant body in the soil or in the medium (in which the organisms are kept) (Youssef and Eissa 2014; Abdulkarim et al. 2019).
- b) *Fertilizer based on consumption*: Broadly there are four types classified on the basis of their consumption.
- I) *Direct fertilizers*: These are those which the green plants directly absorb from the soil, e.g., nitrogen, and phosphorous. The green plants may take all nutrients from these fertilizers.
- II) *Indirect fertilizers*: These are those which are mixed in soil to improve its mechanical, chemical, and biological properties; e.g., lime fertilizers are used to eliminate excess soil acidity; gypsum used for chemical improvement of soils (The Great Soviet Encyclopedia 1979).
- III) *Complete fertilizer*: The fertilizer which provides all the three primary nutrients—nitrogen, phosphorus, and potassium—for the healthy development of plants is termed as a complete fertilizer.
- IV) *Incomplete fertilizer*: The fertilizer which consists of only one of the two necessary nutrient elements is called incomplete fertilizer. Ammonium phosphate is one of the best examples of this fertilizer (Savoy 2012).
- iii) *Fertilizer based on physical state*: The fertilizers are classified into two types on the basis of physical state in which they are available in the market.
- I) *Solid fertilizer*: Solid fertilizers are found in several forms such as crystals (ammonium sulfate), powder (single superphosphate), prills (urea, diammonium phosphate (DAP), superphosphate), granules (holland granules), supergranules (urea supergranules), and briquettes (urea briquettes).
- II) *Liquid fertilizer*: Liquid fertilizers can be clear liquid fertilizers if the fertilizers are completely dissolved in water and suspension liquid fertilizers if the fertilizers are suspended as fine particles in water.
- iv) *Fertilizer based on nature of fertilizers*: Fertilizers on the application can alter the pH of soil.
- I) *Acidic fertilizers*: These fertilizers leave an acid residue in the soil. Acid-forming fertilizers are applied to alkaline soil as it lowers mix pH.
- II) *Basic fertilizers*: These fertilizers leave an alkaline residue in the soil. It can cause a mix pH to increase.

Global scenario of fertilizer minerals

The world fertilizer mineral industry is extremely heterogeneous. It has a chain network from the mining of raw materials to fertilizer production, transportation, distribution and trade.

Its main objective is to ensure the supply of primary and secondary minerals in the required quantities. Nevertheless, the planetary boundaries¹ that sustain a global climate conducive to human growth and well-being have been exceeded considering the flow of nitrogen and phosphorus. Though the application of N and P fertilizers increases the yields, the inappropriate use cause significant eutrophication. According to the proposed boundary, N and P applied to land per year should not be more than 62 million tons and 6.2 million tons, respectively (Moberg et al. 2015). However, the recent figures show N and P usage of about 150 million tons and 14 million tons per year and it is continuously rising. This increase in the flows of nutrients will cause a risk and destabilize the environmental system at the planetary scale (Steffen et al. 2015; Rockström et al. 2009).

Production and availability in global market

Several geological factors, structural features, and climatic conditions specify the availability of fertilizer minerals. Figure 2 shows the worldwide distribution of fertilizer minerals. However, the world reserves are varying due to geological conditions and different degrees of exploration intensity.

Considering a complete fertilizer NPK, the leading producer was Russia in 2019 citing an increase of 5.2% compared to 2018. In the case of phosphorous fertilizers, global phosphate rock reserves are estimated at 69 billion tonnes and about 240 million tonnes of phosphate rock mined worldwide in 2019 (IBM 2020; Pistilli 2020). Phosphate rock, the essential point of origin for phosphate fertilizers (UNEP IFA 2001; Geissler et al. 2019), is significantly available in certain regions of the world, notably Morocco and Western Sahara (72%), China (5%), and Algeria and Syria (3% each) (IBM 2020). Primary phosphates are produced almost exclusively by the mining of phosphate rock (PR) deposits of igneous or sedimentary origin (Mew et al. 2018). It occurs as high-grade ore (+ 30% P₂O₅), medium-grade ore (20–30% P₂O₅), and low-grade ore (15–20% P₂O₅) (Halder 2018). At present, China is the world's leading producer of phosphorus fertilizers followed by the USA, India, Russia, and Morocco (USGS 2019; FAO 2020a, b).

Potash which is an essential nutrient for protein synthesis aids plants to use water more efficiently. It increases soil fertility and improves soil texture, porosity, and permeability due to more or less uniform grain size (IBM 2018). There is no substitute for potassium as an essential plant nutrient; however, Na has the potential to replace K for some of its functions (USGS 2020; Wakeel et al. 2011). The primary ore minerals of potash are sylvite (primarily), brines, and langbeinite (IBM 2020). Besides, glauconite, which is commonly associated

with sand/sandstones, shale, marl, and occasionally with limestone is an elemental or common source of potash fertilizer (Rakesh et al. 2020). In 2018, the estimated global reserves of potash were 5.8 billion tonnes with Russia (34.3%) and Canada (20.6%) having the largest share percent of its reserves (USGS 2020; Garside 2019). Canada, Russia, and Belarus are the chief potash producer countries accounted for 26%, 19%, and 16% of total production, respectively, in 2019 together making up over half of the world production (FAO 2020b). Its production in Canada rose in 2017 and 2018 by 18.6% citing significant annual contribution (\$23 billion) of the fertilizer industry to the nation's economy (Fertilizer Canada 2018). Ammonia, with around 82% of the element, is considered as the richest source of nitrogen and is projected to rise from 2019 to 2025 in terms of revenue at a CAGR of 4.4% (Grand View Research 2019). Nitrogen from the air is the principal N-raw material for the production of ammonia. Haber-Bosch process produces nitrogen fertilizers from ammonia (NH₃) (Smil 2004). The availability of raw material makes the manufacture of ammonia and thus nitrogen fertilizer possible in a variety of locations (Skowrońska and Filipek 2014). Figure 3 throws light on the comparative availability for world fertilizer minerals in 2022. Biological N₂ fixation; however, is a feasible alternative to the increased use of commercially produced N fertilizers. Over the last 40 years, the production industry has been able to increase the practical economic size of ammonia and nitrogen fertilizer plants (UNEP 2016b). China has become the largest producer of nitrogen fertilizers followed by India, the USA, and Russia, and Egypt leads the consuming countries. In 2019, the best average annual growth in the production of nitrogen fertilizers was reported by Nigeria (+ 51.9% per year) and consumption by Guinea at + 48.4% per year (FAO 2020b). The key manufacturers of nitrogenous fertilizers in the market are Nutrien, Koch Industries, Yara International, OCI Nitrogen, and CF Industries Holdings, Inc. (Grand View Research 2019) (Fig. 4).

Consumption, demand-supply potential, and global trade

The global economic and fiscal state impacts agriculture and demand for fertilizer. The fertilizer industry has further responded to the resultant changes in demand by shifting production from areas with declining consumption to those with rapidly increasing consumption (Arovuori and Karikallio 2009). Therefore, there is a need to critically evaluate the fertilizer minerals from the perspective of world economic growth. Since the middle of the last century, the production of fertilizer minerals has risen almost constantly. Yet the consumption varies greatly from one region to another, with the highest consumption in East and South Asia, while comparatively lower in Africa (Kotschi 2015). In 2018–2019, the world fertilizer

¹ The planetary boundary (PB), a concept introduced in 2009, aimed to define the environmental limits within which humanity can safely operate (Steffen et al. 2015).

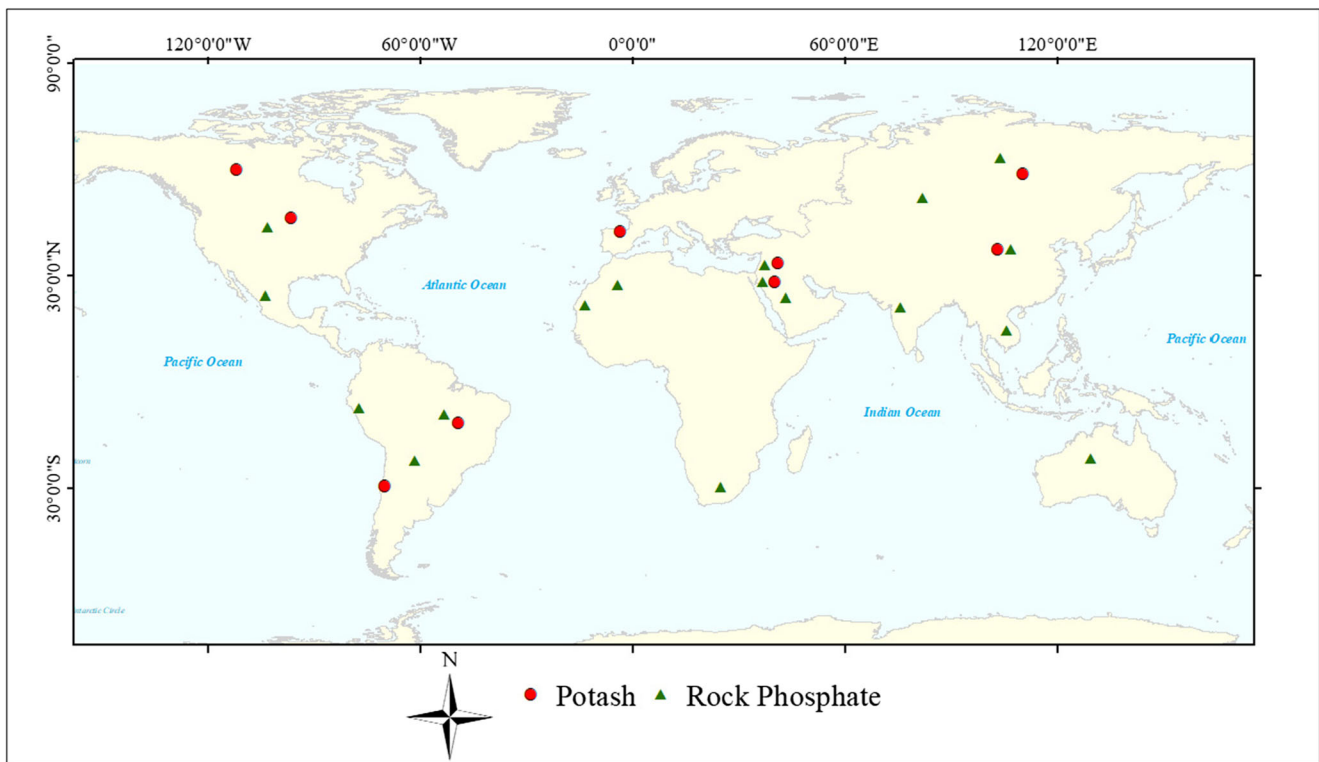


Fig. 2 Worldwide distribution of fertilizer minerals

consumption was at about 188 million tonnes (Factbook 2019). The per hectare usage of fertilizers in 2019 is determined as 34,707.51 kg in Singapore, 674.67 kg in Egypt, 519.35 kg in China, 270.07 kg in the Netherlands, 247.93 kg in the UK, 228.27 kg in Japan, 198.28 kg in Germany, 173.60 kg in

India, 142.86 kg in the USA, 124.84 kg in Italy, and 94.27 kg in Canada (World Bank 2020). Since 2014, Singapore recorded the best 5 years average growth at +101.2% per year, while Tonga witnessed the worst performance at -48.5% per year (FAO 2020b).

Fig. 3 Top five fertilizer minerals producing countries controlling more than 50% of the global production (Source: FAO 2020b; IBM 2020)

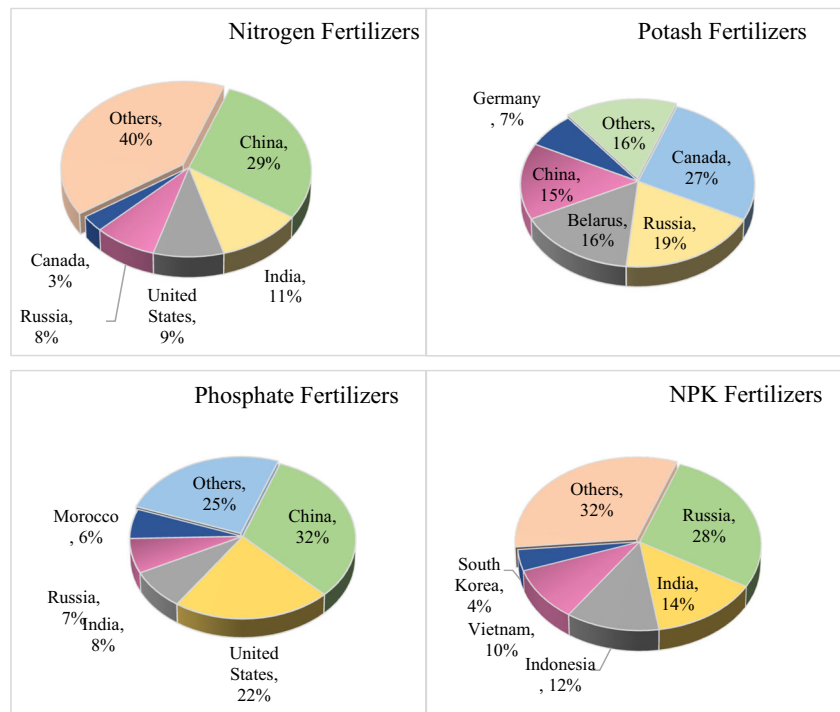
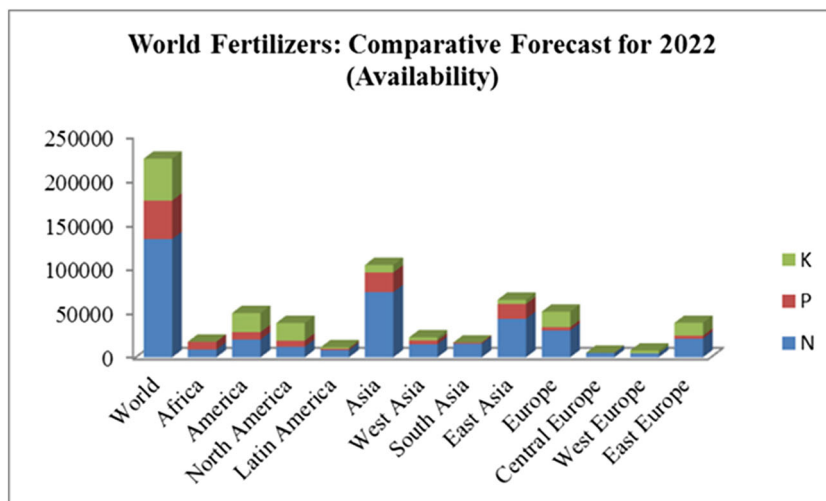


Fig. 4 Worldwide availability of fertilizer minerals (figures in thousand tons) (FAO 2019)



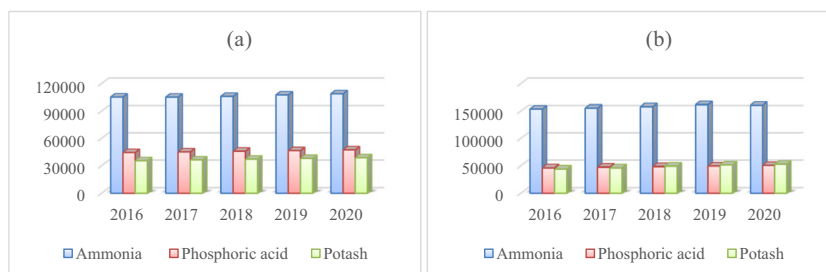
China is the world's largest grain producer and one of the top consumers of fertilizers (Reuters 2010; FAO 2020b), leading nitrogen, potash, and phosphate consumption for agriculture (FAO 2020b). More than 70% of the demand for fertilizer comes from East Asia, South Asia, and Latin America together. The Asian share of global fertilizer consumption is about 69% with China accounting for roughly half that share. The global consumption trend shows a gradual increase from the early 1960s through the mid-1980s and then drop down through the mid-1990s before starting to rise again. Particularly considering the status quo in different regions of the world, it is observed that the consumption remained constant or declined in Western Europe and North America but increased rapidly especially in China and India (Arovuori and Karikallio 2009). The fertilizer consumption in EU-27 countries in 2011–2012 was 10.5 million tons of N, 2.4 million tons of P_2O_5 , and 2.7 million tons of K_2O (Skowrońska and Filipek 2014).

Considering the demand-supply potential, the worldwide demand for nitrogen, phosphate, and potash is showing an annual increase by 1.2, 2.0, and 2.5%, respectively, between years 2011 and 2015 (FAO 2016). However, it is dropped by 1.0% (190 Mt) in 2018–2019 compared to 1.3% in 2017–2018. This drop-down in consumption represents adverse weather conditions in key agricultural and fertilizer-consuming areas (e.g., Central America and eastern Australia); depreciation of the currency in some fertilizer-importing countries, in

particular, Turkey and Pakistan; trade disputes between China and the USA and between Russia and Ukraine; sanctions against Iran; and increased focus on more effective fertilizer usage in developed countries (IFA 2019). According to the forecast, the world demand for fertilizers could reach 200 million tonnes by 2024, with annual growth of 1.2% in nitrogen, 1.7% in phosphates, and 1.8% in potash (Quinn 2020) and it is expected to reach about 324 million tonnes in 2050 (Drescher et al. 2011). Since the 1960s, China's grain production had increased more than eight-fold, while nitrogen fertilizer use has increased by about 55 times (Reuters 2010). In 2007, the global demand for mineral P was dominated by the USA (24%), China and nearby Asian countries (18%), and Africa (17%), with the rest of the world consuming the remaining 41% of mineral P supplies (Villalba et al. 2008; Childers et al. 2011). Now, the global market forecasts for P fertilizers estimate 22–27 million tonnes per year by 2050 for cropland and an additional 4–12 million tonnes per year for grassland (Mogollon et al. 2018; Bindraban et al. 2020). Figure 5a and b shows the world demand and supply potential for producing ammonia, phosphoric acid, and potash for the years 2016 to 2020.

Besides, there exist substantial irregularities in the concentration of fertilizers used. For example, in 2018, it varies from an average of 3779.49 kg per hectare in Kuwait, 516.96 kg per hectare in China, 92.70 kg in Canada to 8.49 kg in Bolivia and

Fig. 5 **a** World demand for ammonia, phosphoric acid, and potash, 2016–2020 (thousand tonnes), **b** World supply of ammonia, phosphoric acid, and potash, 2016–2020 (thousand tonnes)



just 2.07 in Uganda (FAO 2020b). The extensive manufacturing at most approving sites by just a few firms has turned mineral fertilizers into an internationally traded resource which most developing countries are forced to purchase using precious foreign currency (Kotschi 2015). In the present scenario, urea is the most traded fertilizer in the world markets with Russia, Qatar, and Oman the biggest exporters and the USA, Brazil, and India the biggest importers (FAO 2020b). China, Russia, Morocco, and the USA are the world's largest exporter of mineral P with Kuwait experiencing the highest cumulative annual growth of + 155.4% a year. The newest investment will continue to be in Africa, Asia, and Latin America where the capital investment per ton of product is often higher than that in Europe and North America, assumed on a potential balance of fertilizers, which is the difference between supply and total demand (Fig. 6). Also, in 2007–2008, the price of fertilizers grew between 500 and 700% in a 14-month period (Cordell et al. 2009; Gilbert 2009), and much of this increase was caused by similar increases in the price of mineral P (Childers et al. 2011). In the first quarter of 2019, fertilizer prices decreased by 5.4% following three successive quarterly rises, with urea and DAP prices falling sharply (Baffeswee and Koh 2019). This volatility in fertilizer demand and prices

reflects supply disruption and uncertainty about agricultural production, input costs, and environmental policies.

Utility of fertilizer minerals and the world economy

Fertilizer minerals supply essential plant nutrients and meet crop requirements in precise quantities. It needs a variety of elements for sustaining plant growth and their efficacy. The fertilizer industry is one of the causes of radionuclides (^{238}U , ^{232}Th , and ^{210}Po) and heavy metals (Hg, Cd, As, Pb, Cu, Ni, and Cu) in the environment (Sönmez et al. 2007; FAO 2009). The use of fertilizer minerals is a common strategy in agricultural biofortification to enhance the bioavailability of Se in soil (Mao et al. 2014). It ensures optimal agricultural production in inferior natural conditions (soil, climate). The proper management of plant nutrients as fertilizer minerals can improve the crop yield without disturbing the ecosystem. Adopting sustainable practices would be crucial to respond to climate change. For instance, the application of mineral fertilizer can produce higher yields under average climatic conditions but may result in lower yields when rainfall is highly variable or

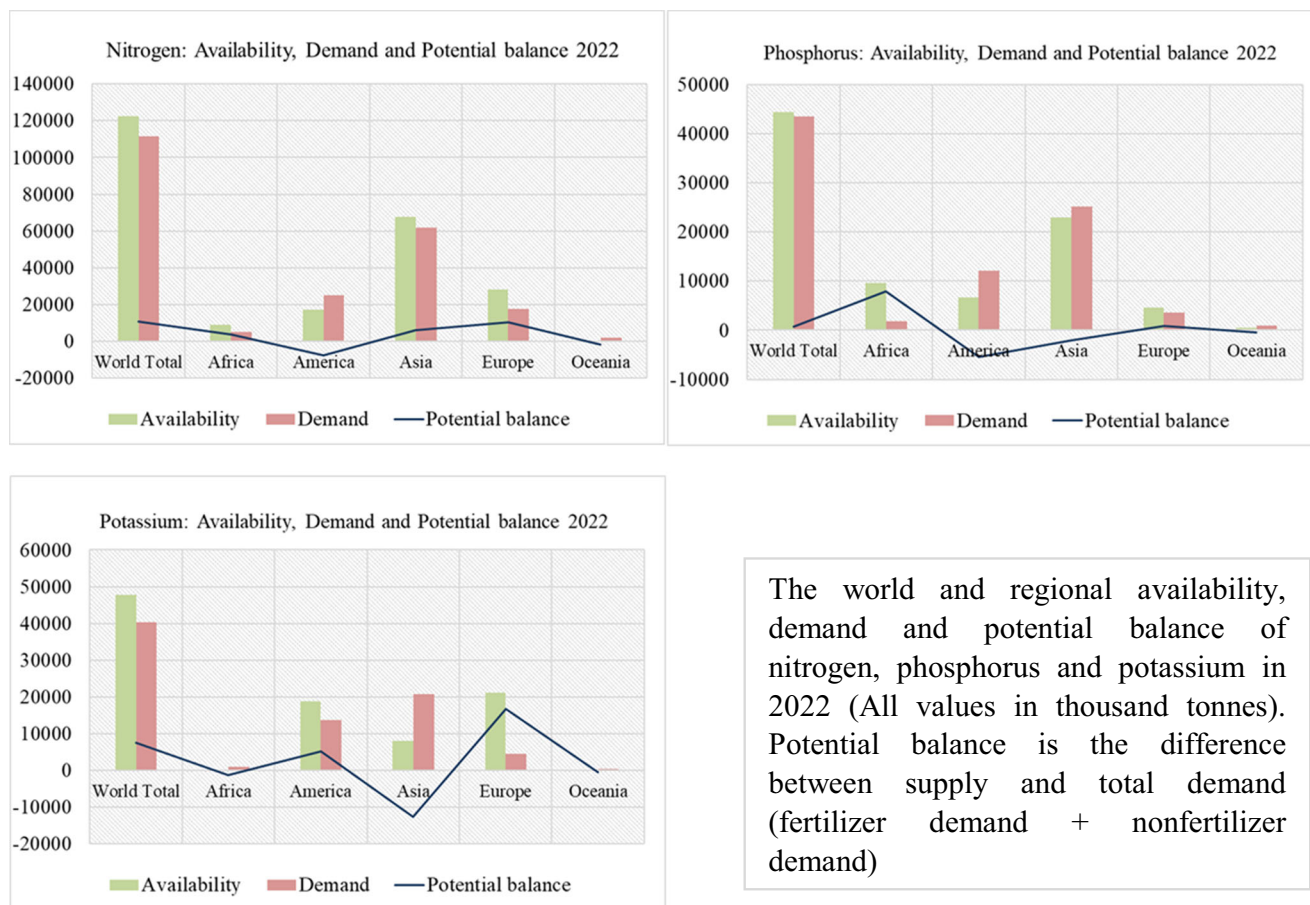


Fig. 6 Availability, demand, and balance of NPK fertilizers in 2022 (Data source: FAO 2019)

delayed (FAO 2017). In addition, crop rotation can produce lower yields under average climatic conditions but produce higher yields when high rainfall variability occurs (FAO 2017; Arslan et al. 2015). Therefore, a framework for managing nutrients, the use of 4 R (right source, right rate, right time, and right place) nutrients is very crucial (TFI 2018).

Governments have an important task in setting the institutional and regulatory framework for fertilizer minerals especially in developing countries (UNEP 2016a). Its objective is to make this critical input available to the farmers at affordable prices (FAO 2005). Governments of various countries are dynamically involved in supporting the fertilizer industry, and amendments in policies have been done from time to time to achieve self-sufficiency in the fertilizer sector. They are providing fertilizer subsidies to boost local productions. In some African countries, fertilizer subsidies are up to 70% of the funding assigned to agriculture (Kotschi 2013). However, subsidies have a short-term effect; they do not result in sustainable food security, and they are of minimal importance to economic profitability.

India's position in global scenario

In the past 50 years, the Indian fertilizer industry has grown in size and stature, and as such, it ranks second in the consumption and third in the production of fertilizers worldwide. The fertilizer production in India has increased by over 463 times from 1951–1952 to 2015–2016. The current production (2018–2019) of major fertilizers in India was about 41.4 million tonnes (Ministry of Chemicals and Fertilizers 2019). In 2018, the Indian fertilizer market was worth INR 5437 billion and is projected to reach INR 11,116 billion by 2024 (Business Wire 2019). There are 56 large size fertilizer plants in India manufacturing a wide range of nitrogenous, phosphate, and complex fertilizers (Mala 2013). Out of these, 30 units produce urea, 21 units produce diammonium phosphate (DAP) and complex fertilizers, 5 units produce low analysis straight nitrogenous fertilizers, and the remaining 9 manufacture ammonium sulfate as the product (Chand 2016). Besides, there are about 72 medium and small-scale units in operation producing single super phosphate (SSP) (IBM 2015a). By 2025, India would need 30–35 million tonnes of NPK from fertilizer minerals in addition to 10 million tonnes from organic and bio-fertilizer sources to produce the minimum food need of 300 million tonnes (Isherwood 2000). The distribution of fertilizer minerals in India is shown in Fig. 7.

In 2018, India has emerged as the second-largest producer of nitrogenous fertilizers (13.631 million tonnes) (FAO 2019). It meets 80% of its urea requirement through indigenous production but is largely import-dependent for its requirements of phosphate and potassic fertilizers, either as finished fertilizers or mineral raw materials. The paucity of mineral raw material

for phosphates has been a constraint in the attainment of self-sufficiency of the country. Indigenous rock phosphate supplies meet only 5–10% of the total requirement of P_2O_5 (Ministry of Chemicals and Fertilizers 2015). Its entire potash requirement for direct application and for production of complex fertilizers is met through imports (IBM 2015b; IBM 2020). However, the import is decreased by 10% to 4.6 million tonnes in 2018–2019 as compared to 5.11 million tonnes in 2017–2018 (IBM 2020). Besides, complex fertilizer is produced by the public sector, cooperative sector, and private sector players (FAI 2016). The present scenario of fertilizer minerals in India is described in Table 1. However, there are not sufficient resources of raw materials for indigenous production and supply is almost completely import-dependent.

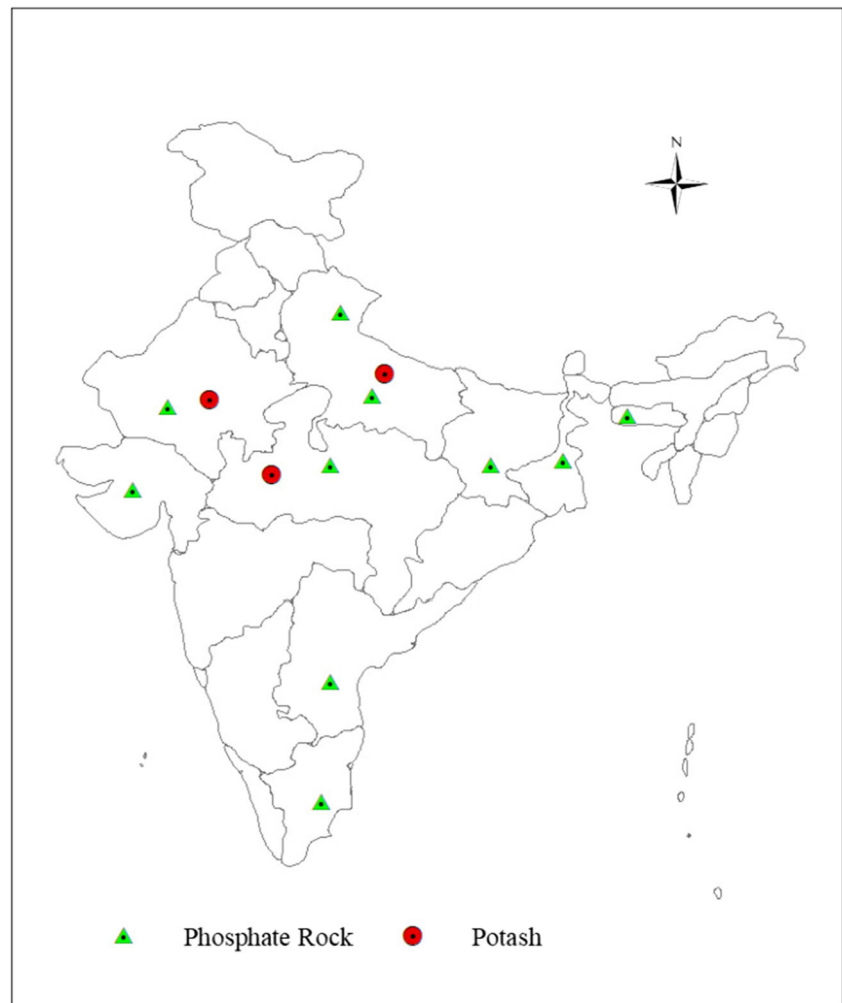
Challenges before mineral fertilizers industry

Since the ancient period, agriculture has undergone a series of advancements and led to an increasing dependence on the use of fertilizer minerals for increased productivity. Therefore, the development of production technology and infrastructure in the mineral fertilizer industry engendered several problems such as the increasing scale of fields and farms and the commensurate disappearance of landscape mosaics, loss of proximity and traceability of food production, loss of animal welfare, contamination of food by pesticides, and so on (Schröder 2014). Excessive and inadequate use reduce the eco-efficiency of crop production, mainly due to eutrophication in the former case and to inefficient land use in the latter (Brentrup and Lammel 2011; Skowrońska and Filipek 2014). For example, excess amounts of potassium fertilizers in the soil of Ca and Fe with Zn disrupt the balance of nutrients by the plants, and when it is applied, inadequate rates of productivity and quality have caused significant losses (Savci 2012). It also creates environmental threats by increasing greenhouse gas emissions (GHG) and changes in the global-warming potential (GWP). It not only accelerates soil acidification but also has the risk of contaminating underground water and the atmosphere and also weakens the roots of plants and making them to be easy prey to unwanted diseases (Chun-Li et al. 2010).

Furthermore, the excess use of mineral fertilizers destroys the core fundamental principles of agricultural production and jeopardizes future food security (Kotschi 2015). Frequent use of highly concentrated mineral fertilizers or imbalance in the nutrient ratio has negative ecological consequences as those outlined below.

- a) *Mining waste*: Production of phosphate for fertilizer generated wastes in very large volumes that are stored in huge piles called stacks, which usually cover hundreds of acres in the phosphate processing states. The agencies are investigating ways to minimize adverse environmental impact for the radioactive material of the phosphate industry.

Fig. 7 Fertilizer minerals: distribution in India
(Data Source: IBM 2017)



- b) *Groundwater contamination*: Minerals such as phosphorus and nitrogen in increased quantity can jeopardize water quality. Application of mineral fertilizers like NPK and urea in excess amount can lead to contamination of groundwater.
- c) *Deterioration in soil fertility*: There is an increasing concern about the sustainability of Indian agriculture because of deterioration in soil fertility (Singh 2017). Various factors led to the deterioration such as fixation of atmospheric nitrogen, followed by loss of nitrates, production of organic acids from decomposing organic matter, removal of alkaline products such as hay from the soil.
- d) *Influence on soil pH*: Change in soil pH may be advantageous or detrimental depending upon input of fertilizer minerals in agriculture. Slow and long-term leaching of fertilizer minerals in the soil can ensure optimum yield in agriculture but drastically influences the pH of soil. Out of all major nutrients, nitrogen is the main factor affecting soil pH. Intensive agriculture can even speed up soil acidification.
- e) *Health hazard*: The main environmental problem associated with fertilizer use is the contamination of water with

nitrates, phosphates, and chemical fertilizers. Mostly nitrogen from fertilizer and manure are eventually converted into nitrates by bacteria present in the soil. This nitrate gets leached out from soil into groundwater. High nitrate level in drinking water is considered dangerous for health.

Limited supply, rising global demand, and transportation costs escalate prices of fertilizer minerals, crop-commodity prices, and so the curbing of fertilizer exports by some countries. The lack of long-term and stable policy results in insufficient financial liquidity for the fertilizer manufacturing units. Thus, there needs an effective performance to increase production capacity through advanced technologies coupled with high production cost. This exposes them to price fluctuations in the global market (Kotschi 2015). Therefore, the availability, demand-supply factors, and the fluctuating prices of raw materials to produce fertilizers raise serious concern for the fertilizer industry. Compared to the price of food, the world market price for mineral fertilizers has risen disproportionately by over 250% from 1970 to 2011. Then, it showed declining trend from 2011 to 2016 and relatively stable between

Table 1 India's position of mineral fertilizers in the Global Scenario (Source: FAO 2019)

Fertilizer	Type of fertilizers	Grade	Rank of India in world consumption	Rank of India in world production	Export	Import
Nitrogen N	Ammonium sulfate	20.6% N	II	II	USA, Spain, Italy, Australia, Greece, China	–
	Calcium ammonium nitrate	25% N				
	Ammonium chloride	25% N				
	Urea	46% N				
Phosphorous P	Single superphosphate	16% P ₂ O ₅	II	III	UAE, Peru, China, Netherlands	Canada, Israel, Russia, Jordan, Germany
	Triple superphosphate	46% P ₂ O ₅				
Complex (NPK)	Urea ammonium phosphate	24-24-0	II	III	China, Jordan, Indonesia, Vietnam	Qatar, Saudi Arabia, UAE, Bahrain
		28-28-0				
		14-35-14				
	Diammonium phosphate	18-46-0				
		Ammonium phosphate sulfate				
	Mono-ammonium phosphate	20-20-0				
		Nitrophosphate				
	Nitrophosphate with Potash NP/NPK	23-23-0				
		20-20-0				
		15-15-15				
17-17-17						
14-28-14						
Potassium	No production	19-19-19	IV	–	–	Morocco, Egypt, Jordan, Peru
		10-26-26				
		12-32-16				
		–				

2016 and 2019 (Baffes and Koh 2018). However, in May 2020, fertilizer prices declined by 8.5% at or near 10-year lows as lower input costs and weak seasonal demand outweighed the gradual easing of supply bottlenecks (Baffes and Koh 2020). The high import dependence leads to massive exploitation in the international market which is cartelized by a few suppliers (Gupta 2014). So, there is an urgent need to bridge the increasing demand-supply gap.

Future perspective of mineral fertilizer development

In order to enhance fertilizer minerals' efficiency for sustainable agriculture practices, innovations are needed in the production and application of mineral fertilizers. The dominant acidifying fertilizers (especially urea, ammonium sulfate, and ammonium nitrate) should be replaced by physiologically neutral fertilizers (Kotschi 2013). Nemecek et al. (2011) emphasize that a 50% reduction in high application rates for mineral fertilizer decreases its negative impact to the greatest degree (per 1 ha) with respect to consumption of natural reserves of phosphorus-rich rock (by 48%) and potassium-rich rock (by 49%), acidification potential (by 36%), GWP (34%), eutrophication potential (by 31%), energy consumption (19%), and ozone formation potential (15%). Approachability of policymakers and collaborative data on the appropriate

techniques to farmers and of urging them to implement is important. Current approaches require a major overhaul in favor of the sustainable use of resources and simultaneously boosting production.

The strategic plan is needed to accelerate the access of millions of poor farmers to equally productive but less harmful mineral fertilizers and other complementary inputs. An adequate supply of credit to farmers and distributors is necessary to ensure the availability of fertilizers when and where these are required (Mala 2013). However, the introduction of a tax on certain chemical fertilizers or tax on mineral surpluses (e.g. in the Netherlands; see Final report: Study on Environmental Taxes and Charges in the EU, ECOTECH Research and Consulting 2001) is significant for health and environmental reasons. It provided an incentive to reduce generous and excessive "insurance" applications of fertilizer which were common practices among many farmers as a precautionary measure (Nielsen 2010). Access to some mineral fertilizers and tax on certain chemical fertilizers or mineral surpluses helps to maintain sustainable agricultural system. Besides, strategic issues such as fertilizer availability, a timeline for fertilizer importation and distribution, inadequate local capacity to manufacture fertilizer, high cost of transportation, poor transport infrastructure and access route need to be considered. As per the life cycle assessment of mineral fertilizers, an effective strategy for protecting the environment against the harmful effects of fertilizers is to attempt to seal the

nutrient cycle on a global, regional, and local scale (Skowrońska and Filipek 2014).

- a) *Optimizing BATs and safety practices*: The best available techniques (BATs) are generally those considered feasible and production units can be easily achievable. Also, the application of high nitrate, high potassium groundwater irrigation will decrease the need for mineral fertilizers and significantly reduce cultivation costs by proper handling of fertilizer and water (Datta et al. 1997).
- b) *Shifting from linear to a circular economy*: The circular economy is based on consuming materials and simply disposing them after their use. Shifting will improve business cost-efficiency. Here one person's waste will be other person's raw material. Nutrient recycling is an important element of a circular economy.
- c) *Long term use*: Commodity provides a better indicator of trends in availability than physical measures indicating how much is left in the ground for further references. It needs to reconsider long-run trends in real prices, real production costs, or other measures of what society has to give up to obtain another unit of fertilizer mineral. Utilization of all available geological information from all sources, such as geological mapping, petroleum exploration, groundwater work and mining-company investigations, may furnish clues to fertilizer mineral deposits.
- d) *Energy*: Minimizing the use of energy and lengthening the life of fossil fuel can reduce the cost of mining of the commodity being mined. Naturally occurring impurities from fertilizer raw materials have to be removed, where more research is needed.
- e) *Promote initiatives*: In order to create an enabling environment for public-private sector partnership in the development of the fertilizer industry, it is compliant to take initiatives for promoting fertilizer availability, access, and utilization. Furthermore, the existing nationwide marketing network of public infrastructure should be highly encouraged to build private sector capacity for fertilizer.
- f) *Collaborative efforts*: Mineral fertilizers harm the ecosystem, disrupt soil fertility, and are economically unviable for small-holder producers. It is, therefore, more important to develop a force of highly knowledgeable, experienced engineers, and skilled labor. However, the comprehensive assessment is not a one-way street, but collaboration with farmers and the general population can be a crucial part of innovation.

Conclusion

Fertilizer is an important ingredient for crop yields and agricultural productivity. In the next 30 years, the global population of 7.8 billion is set to hit a figure of 9.7 billion; thus, the

agricultural production needs an immense boost within a short span of time. The world fertilizer forecast shows a trend of increasing demand. Over the past few decades, use of fertilizer minerals has increased many folds. The overall supply-demand pattern influences fertilizer trade-flow and thereby global competition. Therefore, the consumer countries need to be alert on developing fertilizer mineral sector and initiate policies and strategies to ensure materials security for, at least, the foreseeable future. Improved application of NPK fertilizers will continue to play a key role in growing the yield of food grain. In India, the reserves of fertilizer minerals like phosphate rock are very limited, whereas needs are far above the domestic production and are in part reflected in its large import. So, the emphasis on securing access to sufficient, reliable, and affordable fertilizers is of paramount importance.

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