

Review

Depletion of phosphate rock reserves and world food crisis: Reality or hoax?

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Phosphate rock (PR) deposits are the major source of phosphate (P) fertilizers for soil fertility replenishment. The demand for P fertilizers in the year 2014 was 42,706,000 tons and was expected to reach 46,648,000 tons in 2018. Majority of PR deposits are found in only a few countries including Morocco, USA and China. There is however conflicting information on the extent of world PR reserves, therefore, complicating the ability to accurately determine their lifespan. Consequently, proper planning on the utilization of this resource is hampered. Two schools of thought have emerged in regard to the longevity of the PR reserves. Some argue that there is imminent depletion of this resource and the world should therefore be prepared for a looming food crisis. However, based on the most recent estimates of 290 billion tons of PR reserves, some scientists have predicted that the PR reserves will be depleted between the years 2311 and 2411 and therefore conclude that there is no immediate course of alarm. What is not in doubt, however, is the finiteness of PR reserves. Therefore, an approach that encourages society to adopt a sustainable utilization of this phosphate resource should be advocated as an insurance against food insecurity.

Key words: Food security, phosphate rock depletion, sustainable agriculture.

INTRODUCTION

Soil degradation and infertility are major constraints to sustainable agricultural production in many parts of the world. Phosphorus deficiencies in particular are widespread with P being second only to N in terms of deficient nutrients in most soils (Syers et al., 2011). Phosphorus rarely occurs in highly concentrated forms in the earth's crust. Therefore, P is a limiting nutrient to growth and production in marine, freshwater, and terrestrial ecosystems (Elser et al., 2007). Phosphorus is

an essential element in plant nutrition and plays several essential roles. It is important for photosynthesis, seed and fruit formation, root growth and development (Mengel and Kirkby, 2001; Marschner, 2012). Therefore, P deficiency interferes with photosynthesis, protein synthesis, respiration and biomass production in plants and adversely affects crop productivity in large areas of the world (Plenet et al., 2000).

The green revolution and the related increases in crop

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Table 1. World population forecast.

Year	Population	Yearly % change	Fertility rate	Population density (persons/km ²)
2017	7,515,284,153	1.11	2.50	58
2020	7,758,156,792	1.09	2.47	60
2025	8,141,661,007	0.97	2.43	63
2030	8,500,766,052	0.87	2.38	65
2035	8,838,907,877	0.78	2.35	68
2040	9,157,233,976	0.71	2.31	70
2045	9,453,891,780	0.64	2.28	73
2050	9,725,147,994	0.57	2.25	75

Source: World Population Forecast (2017).

production largely required a concurrent increase in the use of inorganic fertilizers of which P was a major component (Scholz and Wellmer, 2013). Phosphate rock (PR) is the main raw material for the production of commercial P fertilizers such as diammonium phosphate, triple superphosphate, monoammonium phosphate, and complex fertilizers including their mixes thereof (Khabarov and Obersteiner, 2018; Hellal et al., 2019). Minor sources of P are of organic origins such as manures, guano and human excreta. Modern agriculture also relies heavily on P addition to animal feeds (Cordell et al., 2009). Moreover, the production of biomass for biofuels also relies on P application, and thereby also tends to increase the global demand for P (Vos et al., 2011).

Phosphate rocks are finite, therefore none renewable through biological processes as in the case of nitrogen (Edixhoven et al., 2014). The major challenge facing humankind is therefore utilizing this limited resource in a way that promotes sustainable development to include intra- and intergenerational fairness (Mew et al., 2018). The likely depletion of PR is a serious matter, because the PR deposits took millions of years to form (Edixhove et al., 2014). Although the current geological P resources are still sufficient to meet the growing demand of the near future (Vos et al., 2011), just how much of the PR reserves are available for future use remains contentious (Baveye, 2015). In recent years, many researchers have claimed that world reserves of PR were getting depleted at an alarming rate while others have claimed that such apocalyptic forecasts were frequent in the past but have always been proven unfounded, making it likely that the same will be true in the future (Baveye, 2015). This paper reviews these contrasting viewpoints and the implications on the world's food security status.

WORLD PHOSPHATE FERTILIZER USAGE

Due to increase in world human population over the years, the demand for more food to feed this population has continued to increase. Between the years 2017 and

2050, world human population is expected to increase by about 29% (Table 1). In the year 2017, the world population was about 7.5 billion and is expected to rise to about 9.7 billion in the year 2050. However, the overall rate of growth will decline due to decrease in human fertility over the years to 2050 (World Population Forecast, 2017). To feed this population, increased fertilizer use by farmers will be needed to enhance food production. Up to 90% of worldwide phosphate production is utilized in agriculture in the form of feed and food additives, but mainly as phosphate fertilizers (Heckenmüller et al., 2014). The global use of fertilizers that contain N, P and K increased by 600% between the years 1950 and 2000 (International Fertilizer Industry Association, 2006). The world demand for P fertilizer is projected to increase from 41 151 000 to 45 858 000 tons between the years 2015 and 2020 (Table 2) (FAO, 2017). Demand for P fertilizer over the same period is expected to grow annually by 2.44% (FAO, 2017). Currently, a total of 200 to 265 million metric tons of marketable PR concentrate is mined (Geissle et al., 2018) and further processed to produce phosphorus fertilizer (83%) or industrial P (17%) (Prud'homme, 2016).

Africa has continued to lag behind in fertilizer use compared to other parts of the world. Its fertilizer use is about 17 kg/ha/year, compared to 85 kg/ha/year in North America, 96 kg/ha/year in Latin America and 196 kg/ha/year in Asia (International Fertilizer Industry Association, 2009). It is estimated that P fertilizer use in Africa is only about 5.1 kg/ha/year (Africa Fertilizer Summit, 2006). The low fertilizer use in Africa compared to other parts of the world is attributed to their high costs, lack of credit for many farmers, poor transport and lack of local production or distribution capacity (Africa Fertilizer Summit, 2006).

WORLD PHOSPHATE RESERVES

Scientists have, over the years, endeavoured to estimate the actual amounts of the world's PR reserves. Majority of PR reserves are found in Morocco, the USA and China

Table 2. World demand for P (P_2O_5) fertilizer nutrients years 2015-2020 in thousand tons.

Variable	Year					
	2015	2016	2017	2018	2019	2020
World	41 151	41 945	43 195	44 120	45 013	45 858
Africa	3 573	3 641	3 788	3 964	4 126	4 302
Americas	22 506	23 030	23 379	23 768	24 169	24 564
Asia	66 294	67 082	68 446	69 493	70 525	71 476
Europe	15 874	16 016	16 161	16 290	16 407	16 504
Oceania	1 779	1 806	1 833	1 861	1 888	1 917

Source: FAO (2017).

with very little in other countries (Table 3). The world PRs reserves were estimated to be 16 billion tons by van Kauwenbergh (2010) but this was deemed as an underestimation since not all deposits in the world were included. These estimates were revised upwards by the International Fertilizer Development Centre (IFDC) to about 60 to 160 billion tons (van Kauwenbergh, 2010) and are similar to those reported by the United States Geological Survey report (Jasinski, 2011). Morocco has the biggest phosphate resource with an estimated reserve of 50 billion tons. China, Morocco, the United States and Russia are the leading countries in phosphate production accounting for 79% of all the production. Other countries including Brazil, Jordan, Egypt and Saudi Arabia take up the rest of the production.

Recent estimates of global PR reserves as reported by the US Geological Survey (USGS) have increased from 16 000 Mega tons PR in 2010 to 65 000 Mt PR in 2011 and further to 67 000 Mega tons PR in 2014 (Edixhoven et al., 2014). Despite this upward trend, it is likely that the PR reserves are still underestimated since deposits with small quantities are not listed (Jama and van Straaten, 2006).

PREDICTED LIFESPAN OF THE EXISTING WORLD PHOSPHATE ROCKS RESERVES

Mineable reserves of PR ore are dynamic and future availability depends on prices, supply-demand functions, exploration, technology development and other factors (Scholz and Wellmer, 2013). The fact that there is no accurate information on the total amount of the existing PR reserves makes it difficult to predict how long they will last. Some in fact argue that it is impossible to predict future reserves of P or any other resource for that matter (Baveye, 2015). Nevertheless, this has not deterred other scientists from making predictions to determine their lifespan. The predictions made so far took into account the existing global reserves, quality, rate at which they are mined and demand by the users (Cordell et al., 2009; FAO, 2015). Numerous recent studies discuss phosphate rock extraction, and some even propose that a peak in

production could be reached in coming decades (Cordell et al., 2009; van Vuuren et al., 2010). Some of these studies have suggested an impending peak of PR production by use of curve fitting models where mathematical functions are fitted to historical world production data but studies using other methods reach completely different results (Walan et al., 2014). Also, a sudden increase in global reserve estimates is commonly used to dismiss these warnings, and has somewhat altered the debate.

The recent multiplication of estimated reserves is mostly based on an increase of the Moroccan reserve estimate which has resulted to Morocco currently making up most of the global reserves (Walan et al., 2014). This seems to be the basis of a recent report by IFDC that indicates that the deposits are likely to be depleted between the years 2311 and 2411 based on reserves of 60 to 160 billion tons of PR at the current rate of mining 160 to 170 million per annum and not soon as earlier thought (Edixhoven et al., 2014). Thus some like Ulrich and Frossard (2014) argue that this is a clear demonstration that we should not unduly worry about P depletion, nor think about modifying agricultural practices too drastically in anticipation of a possible scarcity of that nutrient in the future. It is unlikely however that the rate of PR mining will remain constant given the continuous increase in demand of P fertilizers over the years according to FAO (2015). As a result, some think the PRs are likely to be depleted sooner than expected (Cordell et al., 2009) with devastating consequences since PR-based fertilizers are irreplaceable in modern agriculture.

The depletion of PR reserves can however be delayed by increasing the efficiency along the value chain along mining, processing and utilization of the PR. Measures to improve sustainable P use will in addition require recycling of P in order to reduce the current P losses, minimize environmental impacts and conserve the finite resource (Schroder et al., 2010). In particular, greater recycling efforts are required on the farm through measures such as control of soil erosion, use of manures and crop residues because P recycling from urban wastes, such as for example struvite production from urban waste waters is too costly (Weikard, 2016).

Table 3. World phosphate reserves.

Country	Morocco	China	USA	Jordan	Russia	Brazil	Syria	Israel	South Africa	Tunisia	Australia	Egypt	Senegal	Togo	Canada	Other Countries
Billion tons	51000	3700	1800	900	500	400	250	230	230	85	82	51	50	34	50	600

Source: van Kauwenbergh (2010).

CONCLUSION

The major source of phosphorus for world food production is phosphate rocks. The demand for more food to feed the ever increasing human population has necessitated the use of more P fertilizers mainly the inorganic sources over the years. This has exerted increased pressure on the mining of PR deposits which are unfortunately finite. To facilitate proper planning of the utilization of PR sources, many attempts have been made to predict the quantities of existing PR deposits. However, these estimates are fraught with uncertainty as more deposits continue to be discovered. As a consequence, two diametrically opposed viewpoints on whether there is a looming crisis due to imminent PR depletion have emerged. The pessimists predict that the PR deposits will be depleted in the next few decades and that unless serious efforts are invested in the efficient utilization of the current deposits, the world could be faced with serious food and political crisis. There are others however who view such predictions as scaremongering with an aim of arm-twisting the donors to invest more in phosphorus research. They argue that the existing PR deposits can last for several hundreds of years. However, what is not in doubt among these view point is the finiteness of PR reserves. An approach that encourages society to adopt a sustainable utilization of phosphate resources should therefore be advocated.

CONFLICT OF INTERESTS

The authors have not declared any conflict of

interests.

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