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Introduction

Phosphorus (P) is an essential plant and animal nutrient. It is a common fertilizer used in agricultural production. Aside from agriculture, phosphorus is widely used for steel and alloy production, glass making, fine china, laundry detergents, sodas, toothpaste, cleaning agents, military weapons, matches, and many other items (Phosphate Forum, 2012). In the second half of the 20th century the demand for processed mineral phosphorus fertilizers derived from phosphate rock increased from three million tons in 1900 to 41 million tons in 1960 due to population growth and increased crop production. Since there is no substitute for phosphorus in an industrial agricultural system, and since it is a mined substance of finite quantity, several authors and groups have proposed that phosphorus production will peak and supplies will become limited, expensive, and highly contested (Cordell et al., 2009). According to a 2010 report by the Global Phosphorus Research Initiative, mined phosphate rock supplies are expected to peak around 2033, while other authors (United States Geological Survey [USGS], 2012) feel current reserves will last 300-400 years leaving little cause for concern.

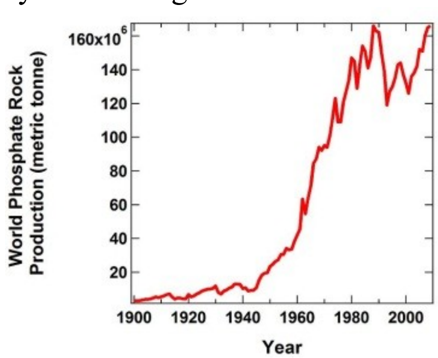

Figure 1. World Phosphate Production. Data from U.S. Geological Survey, accessed December 15, 2012, from http://minerals.usgs.gov/ds/2005/140/#phosphate

Phosphorus is found naturally in the soil but only a small portion of it is readily available for plant uptake. Phosphorus needs to be in the form of phosphate to be utilized by plants. Most phosphorus fertilizer comes from mined phosphate rock. The phosphorus is then transformed to either phosphoric acid or elemental phosphorus before being turned into fertilizer (United States Environmental Protection Agency [EPA], 2012). Phosphate rock is used directly as a fertilizer in organic production; but otherwise, relatively little is used directly due to limited soluble P content, high transportation costs, and the slow release rate.

Why Is Phosphorus Vital?

All living organisms need phosphorus. Humans need phosphorus, and agriculture depends heavily on the use of phosphorus for proper plant and animal growth. Phosphorus is needed to form the deoxyribonucleic acid (DNA) backbone and cellular membranes. It is also a vital constituent of adenosine triphosphate (ATP), a chemical compound that cells use to store or release energy (Lipmann, 1941; Levene, 1919; Astbury, 1947).

Phosphorus helps with the process of seed formation, root development, and the maturation of crops. It is the second most limiting nutrient for plant growth and it cannot be substituted by any other nutrient. Without phosphorus, commercial scale agriculture would not be possible (Raghothama, 2005).

Phosphorus Production

Phosphate rock resources occur principally as sedimentary marine deposits. These are found in northern Africa, China, the Middle East, and the United States. There are also igneous phosphorus sources found in Brazil, Canada, and Russia. Large phosphate resources have been identified on the continental shelves in the Atlantic and Pacific oceans with the global reserve of phosphate rock estimated at more than 300 billion tons. Production volume varies by country due to demand, infrastructure and equipment capabilities. In 2011, China had the highest mined production with 72 million tons, 2.5 times higher than the United States, the second largest producer (USGS, 2012). Between 2006 and 2010, Florida and North Carolina accounted for more than 85% of the total U.S. production. The balance of U.S. production was from Idaho and Utah (USGS, 2012).

Of the known, mineable P reserves, 90% are controlled by only six countries (Table 1). Approximately 70% of the global reserves are controlled by Morocco and the Western Sahara.

World consumption of phosphorus fertilizers is projected to grow 2.5% annually over the next few years with the largest increases in Asia and South America. Mining production is also projected to increase by nearly 20% in Morocco. New mines are also planned for Brazil, Australia, Namibia, and Saudi Arabia (USGS, 2012).

While the exact timing of peak phosphorus production might be disputed due the lack of veracity of the data, it is currently being noted that the quality of phosphate rock is decreasing, production costs are increasing, and purchase price is dramatically increasing (7-fold increase from 2007 to 2008). If P consumption continues at the current rate, global depletion of minable phosphorus supplies is anticipated within a century (Soil Association, 2010). Reuse, recovery and careful use of this “keystone” resource will become critical over the next few years (Cordell et al., 2009).

Table 1. Top countries with P reserves.

Country	Mine Production 2011 (thousand tons) (estimated)	Reserves	Percent of Reserve
Western Sahara and Morocco	27,000	50,000,000	70
China	72,000	3,700,000	5
Algeria	1,800	2,200,000	3
Iraq	Unknown	5,800,000	8
USA	28,400	1,400,000	2
Russia	11,000	1,400,000	2

Data from USGS, 2012.

Recovery Technologies

The leading technology for phosphorus recovery is through chemical precipitation in wastewater treatments. Divalent or trivalent metal salts are added to waste water, binding with the phosphorus and forming precipitates. The most common metals used are aluminum and iron. This method usually produces P bound as a metal salt, which can be filtered out of the waste stream for use in agriculture (Morse et al., 1998).

Crystallization technologies are also being used. This process is centered on crystallizing calcium phosphate. Crystallization occurs by adding a strong base like sodium hydroxide (Donnert et al., 2007).

Biological phosphorus removal is another way to remove P without the use of chemicals. Polyphosphate accumulating bacteria are added to a solution. The bacteria accumulate high levels of phosphorus in their cells. The bacteria are then separated from the treated water, and the bacteria biosolids are used as a fertilizer (Morse et al., 1998).

Recovering phosphate as struvite is a relatively new way to recover P from wastes. Struvite is a crystalline mineral that accumulates on the surface of equipment of anaerobic digestion and post-digestion processes in the wastewater treatment industry. Magnesium, ammonium and phosphate are used to create struvite. This process removes reactive phosphate from wastewater and binds it with magnesium to create a solid struvite crystal. Recoveries of up to 90% of the dissolved P have been reported. The struvite (Figure 2) can then be separated from the wastewater and used as a slow release fertilizer (Adnan et al., 2003).

Figure 2. Struvite recovered from animal waste.

Recommendations for Minimizing Usage

Although phosphorus does not disintegrate or disappear, it is being deposited in places where it can cause harm (e.g., waterways), or preclude its beneficial use. Minimizing the use of phosphorus is one way to reduce the detrimental and non-beneficial effects of phosphorus. The use of phosphate-free soaps and detergents is a practice that can greatly reduce the amount of phosphorus entering our waterways. In agriculture, management practices that prevent or minimize soil erosion and runoff are essential in keeping soil P where it is needed and preventing runoff of P into our waterways (Sims and Kleinman, 2005)

Phosphorus, an essential nutrient, is taken up by plants that are later consumed by humans and livestock and utilized in growth and maintenance. Any excess phosphorus is excreted. Feeding only the phosphorus needed, or using enzymes such as phytase that enhance phosphorus availability, can reduce the amount of P excreted in the manure (Miller, 2011). Applying animal manure to crop land is one way to return phosphorus so it can be used again.

The use of human excreta is another way to get P back into soil. It is estimated that only about 10% of the three million tons of P excreted by humans globally per year is returned to the soil. This loss of P from the system may pose problems in the future. In the past, the combination of human excreta with industrial effluent resulted in concentrations of heavy metals that posed problems for land application. Due to better technology, most municipal sludge is now suitable for land application (Syers et al., 2011).

Recycling of P by applying green wastes, compost, and manure to the soil is the key to maintaining the beneficial use of P. Monitoring of soil nutrient levels aids in minimizing the amount of P utilized. Management practices that reduce soil erosion and the loss of soil P, help maintain its beneficial use.

Keeping the P within the agricultural system and preventing the loss of P to locations where it is no longer accessible, is essential if we are to maintain our crop production levels into the future. Recycling of P from green wastes, compost, animal and human waste, and better monitoring of soil nutrients to minimize losses due to erosion and runoff, will help maintain P where it can be utilized beneficially. With careful P utilization, we can maintain our P resources well into the future.

References

Adnan, A., Mavinic, D.S., & Koch, F.A. (2003). Pilot-scale study of phosphorus recovery through struvite crystallization - examining the process feasibility. *Journal of Environmental Engineering Science,* 2, 315-324.

Astbury, W. (1947). Nucleic acid. *Symp. Soc. Exp. Biology* 1, 66-76.

Cordell, D., Jan-Olof Drangert, Jan-Olof, & White, S. (2009). The story of phosphorus: Global food security and food for thought. *Global Environmental Change*, 19(2), 292-305.

Donnert, D., Berg, U., Weidler, P.G., Nüesch, R., Song, Y., Salecker, M., Kusche, I., Bumiller, W., & Friedrich, F. (2007). Phosphorus removal and recovery from waste water by crystallization. *Geo- und Wassertechnologie*, August 13, 1-23.

Global Phosphate Research Initiative (2010). World phosphate reserves and resources report. Retrieved December 15, 2012, from http://phosphorusfutures.net/publications/GPRI_Statement_responseIFDC_final.pdf

Levene, P. (1919). The structure of yeast nucleic acid. *J Biol Chem,* 40(2), 415-424.

Lipmann, F. A. (1941). Metabolic generation and utilization of phosphate bond energy. *Adv. Enzymology,* 1, 99-162.

Miller, R. (2010). Phosphorus in dairy cattle diets. Utah State University Cooperative Extension. AG/Dairy/2010-01pr.

Morse, G.K, Brett, S.W, Guy, J.A., & Lester, J.N. (1998). Review: Phosphorus removal and recovery technologies. *Science of The Total Environment,* 212 (1) (March 5), 69-81.

Syers, K., Bekunda, M., Cordell, D., Corman, J., Johnston, J., Rosemarin, A., & and Salcedo, I. (2011). Phosphorus and food production. In *United Nations Environment Programme Year Book 2011*. Retrieved December 15, 2012, from http://www.unep.org/yearbook/2011/phosphorus_and_food_productioin.pdf

Phosphate Forum (2012). *Phosphate facts*. Phosphate Forum of the Americas. Retrieved December 15, 2012, from http://www.phosphatesfacts.org/uses.asp

Raghothama, K.G. (2005). Phosphorus and plant nutrition: An overview. In J. Thomas Sims, & Andrew N. Sharpley (Eds.), *Phosphorus: Agriculture and the Environment, Agronomy Monograph no. 46.* (pp. 355-378). Madison, WI, USA: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.

Sims, J. T., & Kleinman, P.J.A. (2005). Managing agricultural phosphorus for environmental protection. In J. Thomas Sims, & Andrew N. Sharpley (Eds.), *Phosphorus: Agriculture and the Environment, Agronomy Monograph no. 46.* (pp. 1021-1068). Madison, WI, USA: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.

Soil Association (2010). *A rock and a hard place Peak phosphorus and the threat to our food security*. Soil Association, November, 1-24.

United States Environmental Protection Agency. (2012). Fertilizer and fertilizer production wastes. Retrieved December 15, 2012, from http://www.epa.gov/radiation/tenorm/fertilizer.html

United States Geological Service (2012). Phosphate Rock Statistics and Information. Retrieved December 15, 2012, from http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/mcs-2012-phosp.pdf

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