Phosphorus: Essential to life—Are we running out?

April 2 2013, by Renee Cho, Columbia University

Fertilizing a corn field in Iowa. Credit: U.S. Department of Agriculture

Phosphorus, the 11th most common element on earth, is fundamental to all living things. It is essential for the creation of DNA, cell membranes, and for bone and teeth formation in humans. It is vital for food production since it is one of three nutrients (nitrogen, potassium and phosphorus) used in commercial fertilizer. Phosphorus cannot be

manufactured or destroyed, and there is no substitute or synthetic version of it available. There has been an ongoing debate about whether or not we are running out of phosphorus. Are we approaching peak phosphorus? In other words, are we using it up faster than we can economically extract it?

In fact, phosphorus is a renewable resource and there is plenty of it left on earth. Animals and humans excrete almost 100 percent of the phosphorus they consume in food. In the past, as part of a natural cycle, the phosphorus in manure and waste was returned to the soil to aid in crop production. Today phosphorus is an essential component of commercial fertilizer. Because industrial agriculture moves food around the world for processing and consumption, disrupting the natural cycle that returned phosphorus to the soil via the decomposition of plants, in many areas fertilizer must now be continually applied to enrich the soil's nutrients.

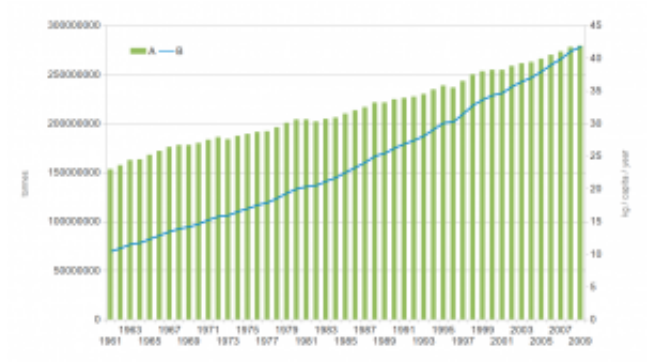
Most of the phosphorus used in fertilizer comes from phosphate rock, a finite resource formed over millions of years in the earth's crust. Ninety percent of the world's mined phosphate rock is used in agriculture and food production, mostly as fertilizer, less as animal feed and food additives. When experts debate peak phosphorus, what they are usually debating is how long the phosphate rock reserves, i.e. the resources that can economically be extracted, will hold out.

Pedro Sanchez, director of the Agriculture and Food Security Center (agriculture.columbia.edu) at the Earth Institute, does not believe there is a shortage of phosphorus. "In my long 50-year career, " he said. "Once every decade, people say we are going to run out of phosphorus. Each time this is disproven. All the most reliable estimates show that we have enough phosphate rock resources to last between 300 and 400 more years."

In 2010, the International Fertilizer Development Center determined that phosphate rock reserves would last for several centuries. In 2011, the U.S. Geological Survey revised its estimates of phosphate rock reserves from the previous 17.63 billion tons to 71.65 billion tons in accordance with IFDC's estimates. And, according to Sanchez, new research shows that the amount of phosphorus coming to the surface by tectonic uplift is in the same range as the amounts of phosphate rock we are extracting now.

The duration of phosphate rock reserves will also be impacted by the decreasing quality of the reserves, the growing global population, increased meat and dairy consumption (which require more fertilized grain for feed), wastage along the food chain, new technologies, deposit discoveries and improvements in agricultural efficiency and the recycling of phosphorus. Moreover, climate change will affect the demand for phosphorus because agriculture will bear the brunt of changing weather patterns. Most experts agree, however, that the quality and accessibility of currently available phosphate rock reserves are declining, and the costs to mine, refine, store and transport them are rising.

Ninety percent of the phosphate rock reserves are located in just five countries: Morocco, China, South Africa, Jordan and the United States. The U.S., which has 25 years of phosphate rock reserves left, imports a substantial amount of phosphate rock from Morocco, which controls up to 85 percent of the remaining phosphate rock reserves. However, many of Morocco's mines are located in Western Sahara, which Morocco has occupied against international law. Despite the prevalence of phosphorus on earth, only a small percentage of it can be mined because of physical, economic, energy or legal constraints.



Global meat consumption from 1961 to 2009. Credit: FAO

In 2008, phosphate rock prices spiked 800 percent because of higher oil prices, increased demand for fertilizer (due to more meat consumption) and biofuels, and a short-term lack of availability of phosphate rock. This led to surging food prices, which hit developing countries particularly hard.

With a world population that is projected to reach 9 billion by 2050 and require 70 percent more food than we produce today, and a growing global middle class that is consuming more meat and dairy, phosphorus is crucial to global food security. Yet, there are no international organizations or regulations that manage global phosphorus resources. Since global demand for phosphorus rises about 3 percent each year (and may increase as the global middle class grows and consumes more meat), our ability to feed humanity will depend upon how we manage our phosphorus resources.

Unfortunately, most phosphorus is wasted. Only 20 percent of the phosphorus in phosphate rock reaches the food consumed globally. Thirty to 40 percent is lost during mining and processing; 50 percent is wasted in the food chain between farm and fork; and only half of all manure is recycled back into farmland around the world.

Most of the wasted phosphorus enters our rivers, lakes and oceans from agricultural or manure runoff or from phosphates in detergent and soda dumped down drains, resulting in eutrophication. This is a serious form of water pollution wherein algae bloom, then die, consuming oxygen and creating a "dead zone" where nothing can live. Over 400 coastal dead zones at the mouths of rivers exist and are expanding at the rate of 10 percent per decade. In the United States alone, economic damage from eutrophication is estimated to be $2.2 billion a year.

Eutrophication in the Caspian Sea. Credit: Jeff Schmaltz, NASA

As the quality of phosphate rock reserves declines, more energy is necessary to mine and process it. The processing of lower grade phosphate rock also produces more heavy metals such as cadmium and uranium, which are toxic to soil and humans; more energy must be expended to remove them as well. Moreover, increasingly expensive fossil fuels are needed to transport approximately 30 million tons of

phosphate rock and fertilizers around the world annually.

Sanchez says that while there is no reason to fear we are running out of phosphorus, we do need to be more efficient about our use of phosphorus, especially to minimize eutrophication. The keys to making our phosphorus resources more sustainable are to reduce demand and find alternate sources. We need to:

- Improve the efficiency of mining
- Integrate livestock and crop production; in other words, use the manure as fertilizer
- Make fertilizer application more targeted
- Prevent soil erosion and agricultural runoff by promoting no-till farming, terracing, contour tilling and the use of windbreaks
- Eat a plant based diet
- Reduce food waste from farm to fork
- Recover phosphorus from human waste

Phosphorus can be reused. According to some studies, there are enough nutrients in one person's urine to grow 50 to 100 percent of the food needed by another person. NuReSys is a Belgian company whose technology can recover 85 percent of the phosphorus present in wastewater, and turn it into struvite crystals that can be used as a slow fertilizer.

Cow dung to be used as fertilizer drying in Punjab. Credit: Gopal Aggarwal http://gopal1035.blogspot.com

New phosphorus-efficient crops are also being developed. Scientists at the International Rice Research Institute discovered a gene that makes it possible for rice plants to grow bigger roots that absorb more phosphorus. The overexpression of this gene can increase the yield of rice plants when they are grown in phosphorus-poor soil. Rice plants with this gene are not genetically modified, but are being bred with modern techniques; they are expected to be available to farmers in a few years.

A breed of genetically modified Yorkshire pigs, called the Enviropig, has been developed by the University of Guelph in Canada to digest phosphorus from plants more efficiently and excrete less of it. This results in lower costs to feed the pigs and less phosphorus pollution, since pig manure is a major contributor to eutrophication. Last spring, however, the Enviropigs were euthanized after the scientists lost their funding.

The Agriculture and Food Security Center is working on food security in

Africa and attempting to eliminate hunger there and throughout the tropics within the next two to three decades.

Minjingu Mines & Fertilisers Ltd.. Credit: IFDC Photography

In the mountains of Tanzania along Lake Manyara, Sanchez' team has discovered deposits of "minjingu," high-quality phosphate rock that is cheaper and just as efficient as triple super phosphate (a highly concentrated phosphate-based fertilizer) in terms of yields of corn per hectare.

Minjingu deposits are formed by the excreta and dead bodies of cormorants and other birds that roost and die in the mountains, forming biogenic rock phosphate or guano deposits. Guano, the feces and urine of seabirds (and bats), has a high phosphorus content, and in the past was often used as fertilizer.

Sanchez' researchers have also discovered a common bush called the Mexican Sunflower that is an efficient phosphorus collector. It grows by the side of the road, fertilized by the excreta dumped there by farmers.

The farmers cut it down and use it as green manure, an organic phosphorus fertilizer which helps grow high-quality crops like vegetables.

The Agriculture and Food Security Center team also helps farmers contain erosion and runoff by encouraging them to keep some vegetative cover, either alive or dead, on the soil year-round. This is done through intercropping, leaving crop residue in the fields, contour planting on slopes or terracing.

"There is no data to support the idea of peak phosphorus," said Sanchez. "Just fears. New deposits are continually being discovered. We also have more efficient extraction that is getting more phosphate rock out of land-based sediments. And there is an enormous 49-gigaton deposit of phosphorus in the continental shelf from Florida to Maritime Canada that scientists have known about for years. Now there is some experimental extraction going on off the coast of North Carolina."

More information: Pedro Sanchez, author of *Properties and Management of Soils in the Tropics* published in 1976, which continues to be a bestseller, is currently working on *Tropical Soils Science*, an update of his previous work. It will be published by 2015.

Provided by Columbia University

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