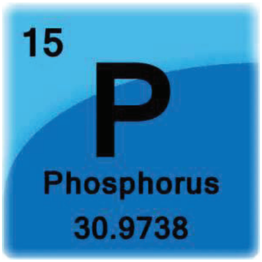
October 2016
Special 3 Part Series: Part 2

LAKE WINNEBAGO
QUALITY IMPROVEMENT ASSOCIATION
of Fond du Lac County



This is the second of three articles exploring phosphorus in the environment.

In the previous article, the chemistry of phosphorus was considered. In this article, we will look at phosphorus in rocks, soils and water and the phosphorus cycle.

The final part will review the role of phosphorus in living cells.

Alan Weir
Instructor at Fox Valley Technical College

Understanding Phosphorus, Part 2

Geology and the Phosphorus Cycle

As mentioned in the last article, phosphorus is usually found in our environment as the phosphate ion, PO_4^{3-}. However, ions are never found alone, negative ions are always paired with positive ions. In the most common phosphate bearing rock, phosphate is associated with calcium ions to make calcium phosphate, $Ca_3(PO_4)_2$. Other positive metal ions will combine with phosphate to make other compounds. With the exception of sodium, potassium and ammonium phosphates, the phosphates are generally insoluble, they will not dissolve in water. If the two ions start out dissolved in water, the metal phosphate compound will form a solid precipitate and fall out of solution. As mentioned previously, sewage treatment plants take advantage of this property and precipitate phosphates (from urine and feces) by adding metal ions during cleanup of the sewage. Ocean waters contain more calcium and aluminum ions than surface waters so phosphate ions that make it to the ocean will combine with these metal ions and fall to the ocean floor, making the phosphates unavailable to marine life. This also means that ocean waters generally have less phosphate than lakes, rivers, and streams. Most fertilizers contain the soluble ammonium phosphate as their source of phosphorus so the phosphorus is easily taken up by plants.

Biogeologic cycles follow an element as it cycles through the various components of the environment—the atmosphere, lithosphere (rock and soil), hydrosphere (surface and ground water) and biosphere (living organisms). Nitrogen, carbon, oxygen, sulfur and phosphorus each has its own independent cycle. Of these cycles, phosphorus moves most slowly through the different components. Phosphorus is also the only cycle without an atmospheric component. The majority of earth's phosphorus is locked in the lithosphere.

The phosphorus cycle begins in the lithosphere. Rocks that contain phosphates are known as apatite rock. These are generally sedimentary type rocks.

Frequently, marine fossils are found in these rock deposits. The first step of the phosphorus cycle is weathering of the rock to break it down into smaller pieces that will eventually become small enough to become part of soils. The smallest of these particles can become suspended in water, which is one way soils are eroded. At least some of the rock will truly dissolve, introducing phosphate ions into water. The result of this step is the movement of phosphorus from the lithosphere into the hydrosphere. Phosphate in water that is dissolved is available to aquatic organisms including algae. Phosphates adsorbed to soil particles are unavailable to organisms. Many times both total phosphorus and available phosphorus values are measured and reported for surface waters. Rock, soil, suspended and dissolved phosphorus is called "inorganic" because these forms are not part of living cells.

The next part of the phosphorus cycle is incorporation of phosphorus into plants and animals—the biosphere. Terrestrial plants are able to extract inorganic phosphate from both soil and water. Phosphorus in acidic soils is adsorbed to soil particles containing aluminum and iron particles. This phosphorus is loosely held by the metal and is available to plants. However, calcium in basic (alkaline) soils precipitates with the phosphate, the compound is insoluble and the phosphate is not available to plants. Once plants absorb phosphate it is chemically incorporated into organic molecules and the phosphate is now "organic." Animals get their phosphorus requirements from plants or other animals.

Aquatic plants and animals get their phosphorus requirement from the suspended and dissolved phosphorus from soils washed into lakes, streams and rivers. As noted earlier, phosphorus is what limits algae growth. Spring rains can wash phosphorus fertilizers off gardens, fields and lawns providing fuel for algae blooms. Leaves and branches, including wetland plants like cattails, sink to lake floors holding onto phosphorus. As these decay or when the lake bottom is stirred up, this phosphorus can get re-suspended or re-dissolved and become available for aquatic organisms.

Animals return phosphates to the soil through excretion (urine and feces). In addition, dead plant and animal tissues are broken down by bacteria and release phosphates into soils. As aquatic life dies, the phosphorus frequently precipitates to lake or ocean floors. This can be as calcium or aluminum phosphate precipitates, or as phosphate incorporated in bone. This is the final step of the phosphorus cycle, return of phosphate back into sedimentary rock.

Algae blooms on the surface of the Horicon Marsh.
Chuck Quirmbach/WPR

Excess phosphate in water bodies allows increased growth of algae and other aquatic plants. This consumes large amounts of dissolved oxygen and can block sunlight from reaching deeper waters, affecting other aquatic life. When the algae bloom is over and the algae die, the decay processes consume more oxygen. This can lead to water that is depleted in oxygen, known as an anoxic zone. There are anoxic zones at the mouth of the Fox River in Green Bay and in the Gulf of Mexico at the mouth of the Mississippi River. Blue-green algae, also known as cyanobacteria, produce toxins, like microcystin. This is how the algae bloom in the summer of 2014 contaminated Lake Erie, Toledo, Ohio's drinking water source.

Our choices can contribute to or minimize phosphorus levels in surface waters. Excess fertilization is one way. Soil can become saturated with phosphate and any more phosphorus will just wash off the soil. Removing crops or grass clippings removes phosphorus and other nutrients which then need to be replaced. Plant material left behind to decay returns nutrients to the soil. The more plant material that remains to decay means decreased requirement for fertilizers. Untreated storm water or sewage are other major sources of phosphate in surface waters. Phosphorus loads in runoff can be decreased with buffer zones and wetlands that also absorb other nutrients and contaminants.

More information:

http://biology.tutorvista.com/ecology/phosphorus-cycle.html

http://enviroliteracy.org/air-climate-weather/biogeochemical-cycles/phosphorus-cycle/

http://www.earthmagazine.org/article/mineral-resource-month-phosphate-rock