More about Phosphorous

Last week I talked about the role of phosphorous in causing eutrophication (nutrient enrichment) of the lakes and introduced the concept of a limiting nutrient. Lakes are complex ecosystems and the phosphorous dynamics in lakes contribute to that complexity. This week I will try to shed a little light on that complexity and the difficulties in controlling phosphorous.

Phosphorous is a highly reactive chemical that is often involved in reactions where a lot of energy is transferred. For example, it is a primary component of military incendiary weapons and flares, fireworks, and matches. In living organisms it is used to transfer and store energy through reactions between ATP and ADP and a certain amount is necessary to support aquatic life. In aquatic systems, phosphorous can exist in several different states. Soluble reactive phosphorous (SRP) is dissolved within the water column, primarily in the form of orthophosphate ions, which are "bioavailable" in the sense they can be readily picked up living organisms and turned into organic matter. Organic phosphorous (OP) is phosphorous that is bound up into organic matter already and not bioavailable to another cell unless the first one dies and decomposes or is eaten and digested by another. Most of the rest of the phosphorous in aquatic systems is typically in particulate form, bound to suspended solids, primarily iron and clay minerals.

When phosphorous is in particulate form, it is not very bioavailable because the phosphorous is bound so strongly to the suspended minerals, especially iron oxide particles. Only a small amount of the phosphorous will dissolve into the water column before the solids settle out to the bottom. Under normal aerobic (plenty of oxygen in the water) conditions, the bioavailable phosphorous in the water column is constantly changing as some is washing in from streams and overland flow, some is being taken up by plants as they grow, some is entering the water from degrading organic material or overloaded septic tanks, and some is settling out to the bottom. The actual amount in the water column is the difference between what is coming in (inputs) and what is going out (outputs). Under these conditions it is relatively easy to control the phosphorous in the water column by limiting the inputs. As long as some is constantly leaving, the amount remaining in the water column will decrease. It's analogous to losing weight by going on a diet (limiting inputs) while making sure you do moderate exercise (outputs). This aerobic situation is typical in rivers and streams but lakes are usually more complex.

The most complicated situation for our lakes occurs in the summertime when the surface waters warm and the lake stratifies into a warm surface layer called the "epilimnion" and a colder, deeper layer called the "hypolimnion." I'll talk a little bit more about why this happens in future columns but anyone who swims in the lakes in the summer and dives down until the water suddenly changes temperature has experienced it first hand. Under these thermally stratified conditions, there is little mixing between the layers and the oxygen that is entering the lake from the atmosphere never makes it to the bottom of the lake. At the same time, organic matter continues to fall to the bottom and uses up oxygen as it decomposes. As a result, the bottom waters go anoxic (no oxygen). Under these conditions, the iron in the sediments is reduced from the ferric (+3) form, which is virtually insoluble to the ferrous (+2) form, which is highly soluble. When the iron dissolves, the phosphorous that had been bound up in the non-bioavailable particulate state is suddenly released into the water column as bioavailable SRP. If a mixing event occurs such as a sudden cooling of the surface water or a strong wind that can cause upwelling, this bioavailable phosphorous is suddenly stirred into the upper epilimnion where it can trigger an algae bloom because the limiting nutrient is no longer limited. This is when East Pond or North Pond suddenly turns green or the swimmers in Great Pond start complaining about Gloeotrichia. This phosphorous loading from the sediments is called "internal loading" and is more difficult to control. We will talk about some of these issues in future columns.