

About the Chemistry Data You Will be Collecting

Phosphorus and Chlorophyll

Phosphorus is a nutrient that is important for the growth of plant life in freshwater lakes. Under certain conditions, excess phosphorus can cause algae to grow out of control or “bloom”, making a lake look like pea soup. An analysis of phosphorus often includes both soluble reactive phosphorus and total phosphorus. Soluble reactive phosphorus is the form that is biologically available and is used by phytoplankton and **macrophytes** (rooted plants) for growth. Its concentration varies widely in most lakes over short periods of time as plants take it up and release it. Total phosphorus is considered a better indicator of a lake’s nutrient status because its levels remain more stable than soluble reactive phosphorus. Total phosphorus includes soluble phosphorus and the phosphorus in plant and animal fragments (particulate phosphorus) suspended in the lake water.

A concentration of total phosphorus below 20 micrograms per liter for lakes and 30 micrograms per liter for impoundments should be maintained to prevent nuisance algal blooms (Shaw et. al. 2000).

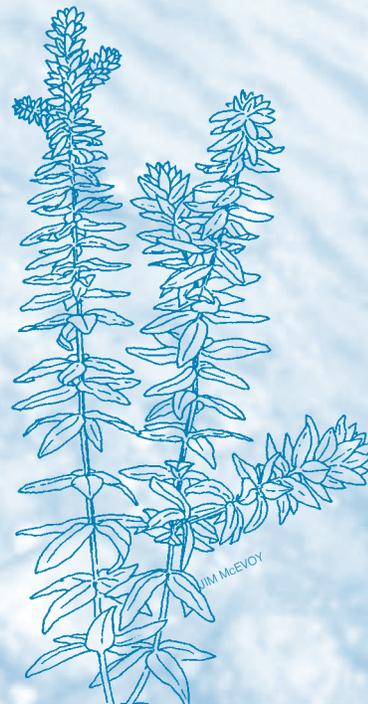
Phosphorus originates from a variety of sources, many of which are related to human activities. Major sources include human and animal wastes, soil erosion, detergents, septic systems, and runoff from farmland or lawns (Shaw et. al. 2000).

Upon entering a lake, phosphorus may be immediately taken up by algae or bacteria and become part of the food chain. If the water is well oxygenated, it may form an insoluble compound with iron and sink to the bottom. Even if algae take up the phosphorus, it will eventually fall to the bottom of the lake as part of a dead critter higher in the food chain. Whatever the vehicle, most of the phosphorus that comes into the lake, eventually ends up on the bottom of the lake (Knight 2005).

Once phosphorus has settled out into the deeper parts of the lake, it is generally unavailable for plant growth. Particulate phosphorus that settles into the littoral zone or particulate phosphorus in shallow lakes may



MACROPHYTE • *Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects. Overabundance of such plants, especially problem species, is usually related to shallow water depth and high nutrient levels.*



Phosphorus: Around the Lake in 180 Days

by Susan Knight, PhD, University of Wisconsin Trout Lake Station

Too much of a good thing almost always leads to problems. This is especially true when it come to nutrients and lakes. Lakes need some nutrients, such as nitrogen and phosphorus, or they would be as bare as water-filled bathtubs. Nutrients are necessary for algae and plants, which in turn fuel the entire lake food web from tiny zooplankton to feisty crayfish and from fish fry to trophy muskies. But with too many nutrients, and especially too much phosphorus, the algae multiply so fast that the lake's tiny herbivores, the zooplankton, cannot keep up and the lake turns a not so tempting green. Where do the algae get the phosphorus that allows them to multiply so dramatically? Most people know that lots of phosphorus comes from outside the lake every year, but in many lakes, much of the phosphorus stimulating algal growth is recycled from within the lake.

When phosphorus enters a lake from outside it is called external loading and it is easy to see or understand the sources. The phosphorus may come from a readily identifiable source, called a point source, such as a pipe from an upstream wastewater treatment plant. It may come from less conspicuous, or non-point sources, such as runoff from fertilized lawns or as leachate from ineffective septic systems. Both point and non-point sources of phosphorus increase the total amount of phosphorus in the lake.

Upon entering a lake, phosphorus may be immediately taken up by algae or bacteria and become part of the food chain. Or, if the water is well oxygenated, it may form an insoluble compound with iron and sink to the bottom. It may also attach to organic particles, again sinking to the bottom. Even if algae take up the phosphorus, it will eventually fall to the bottom of the lake as part of a dead algal cell, in excreted fecal material or as part of a dead critter higher in the food chain. Whatever the vehicle, most of the phosphorus that comes into the lake, eventually ends up on the bottom of the lake. If the phosphorus stayed at the bottom, and we could control the external loading, we could more successfully control runaway algal growth. But, it doesn't stay put and that leads to trouble.

As summer or winter progresses, bacteria are busy decomposing all the dead organic stuff that has

been raining down to the bottom of the lake. Decomposition consumes oxygen and the bottom of the lake becomes anoxic, meaning there is no dissolved oxygen in the water. (This can also lead to winter and summer fish kills but that is a story for another day). Phosphorus bound to the iron in oxygen-rich waters is released as free phosphate (the most biologically valuable form of phosphorus) under these anoxic conditions. By the end of summer, the bottom layer of water is anoxic but rich in phosphate. This phosphate might stay entrenched at the bottom forever if not for the change of seasons.

As summer turns to fall, the surface waters begin to cool. This cool water sinks because cool water is more dense than warm water (until the temperature approaches the freezing point). As the cooler, denser water sinks, the lake "turns over" or mixes from the bottom to the top. Like the 'lava' in a lava lamp, the phosphate-rich bottom water is boosted back up to the surface and becomes available for uptake by algae. This also happens in the spring, but it is the slightly warmer-than-ice water that sinks, initiating spring turnover and the upwelling of the phosphate-rich bottom waters. This lava lamp-like circulation is called internal loading and creates an almost never-ending, though seasonal, source of phosphorus and may cause fall and spring algal blooms.

This scenario is mostly played out in deeper lakes that stratify into layers of different temperature and oxygen levels in the summer. Shallow lakes may never stratify in the summer, and may mix continuously throughout the ice-free season. In these lakes, phosphorus is even more available and is part of the reason that high algal levels often plague shallow lakes. Carp and other organisms that root around in and stir up sediments are also responsible for phosphorus circulation year round.

Cutting off the external load of phosphorus from point and non-point sources may not lead to an immediate decrease in algae levels. There will always be some phosphorus resuspension, at least seasonally. However, the lake's phosphorus "memory" will slowly fade if the phosphorus inputs decline. If this external load is diminished, a lake over-endowed with nutrients may eventually see a return to a more natural phosphorus cycling regime.

still be available for plants to take up via their root system. Phosphorus may also become resuspended in the water by wind or boats and become available for plankton or plants again. What makes the reaction of phosphorus so complex is that there are many forms of phosphorus and this phosphorus binds to other materials with varying degrees of “bioavailability”, depending on the calcium content of the water and the pH of the lake. Lower pH, soft water systems tend to have less tightly bound phosphorus than hard water, high pH systems so the phosphorus may be more available to plants in those soft water systems. Phosphorus does not dissolve easily in water. It forms insoluble precipitates (particles) with calcium, iron, and aluminum. In hard water areas of Wisconsin, where limestone is dissolved in the water, marl (calcium carbonate) precipitates and falls to the bottom. Marl formations absorb phosphorus, reducing its overall concentration as well as algae growth. Aquatic plants with roots in the marl bottom still get phosphorus from sediments. Hard water lakes often have clear water, but may be filled with aquatic plants (Shaw et. al. 2000).

Iron also forms sediment particles that store phosphorus - but only if oxygen is present. When lakes lose oxygen in winter or when the hypolimnion loses oxygen in summer, iron and phosphorus again dissolve in water. Strong summer winds or spring and fall turnover may mix iron and phosphorus with surface water. For this reason, algal blooms may still appear in lakes for many years even if phosphorus inputs are controlled (Shaw et. al. 2000).

Lakes with low iron and insufficient calcium to form marl are most likely to retain phosphorus in solution once it is released from sediments or brought in from external sources. These lakes are the most vulnerable to naturally occurring phosphorus or to phosphorus loading from human activities because the phosphorus remains dissolved in the water - not pulled down into the sediments. Such lakes often respond with greater algae problems (Shaw et. al. 2000).

The water samples that you collect will help answer important questions like, “How phosphorus enriched is my lake (or what is the trophic

state of my lake)?” The results will help predict if your lake is susceptible to nuisance algal blooms.

Chlorophyll is the pigment found in all green plants, including phytoplankton. Phytoplankton are very small free-floating aquatic plants such as algae. Their abundance, as measured by the amount of chlorophyll *a* in a water sample is commonly used to classify the trophic status of a lake.

Temperature and Dissolved Oxygen

A temperature profile will help to explain the physical, biological, and chemical aspects of your lake. Lake temperature affects the rate of decomposition, nutrient recycling, lake stratification, and dissolved oxygen concentrations near the lake bottom. Changes in water temperature can also affect the distribution of fish in a lake. Some fish (e.g., trout and Cisco) prefer colder water. It is important to these fish species that the deeper water stays cold to ensure their survival. Water temperature can also influence the mixing and stratification patterns in your lake. When a lake becomes stratified (forms distinct temperature layers), circulation of nutrients and other chemicals is restricted within those layers. When a lake mixes, the cold bottom water is brought to the surface and the warm surface water is mixed downward. Nutrients that were at one time restricted to the bottom of the lake are brought upward into the water column. During mixing there is very little temperature variation between the top and bottom waters. Shallow lakes can be mixed all year round from top to bottom due to wind and wave action. Deep lakes (generally greater than 20 feet deep) usually mix in the spring and fall. You will be able to determine whether your lake mixes or stratifies when you perform a temperature profile of your lake.

Those volunteers who use an integrated sampler to collect water samples, will collect water temperature using an electronic digital meter. A cable with a stainless steel probe is attached to the meter. The cable is marked in one foot increments and is dropped into the water. Those volunteers who use a Van Dorn sample bottle to collect water samples, will use the thermometer inside the Van Dorn to record water temperature.



RESPIRATION • *The complex process that occurs in the cells of plants and animals in which nutrient organic molecules, such as glucose, combine with oxygen to produce carbon dioxide, water, and energy. It is the reverse reaction of photosynthesis, as respiration consumes oxygen and releases carbon dioxide. This process also takes place during decomposition as bacterial respiration increases.*

Oxygen is needed by most aquatic organisms to survive. The solubility of oxygen depends on water temperature (the colder the water, the more oxygen it can hold). Dissolved oxygen levels range from 0 to 18 parts per million (ppm). A chart showing the minimum oxygen requirements for some common fish species can be found on page 84.

Oxygen enters the water by direct absorption from the atmosphere or by plant photosynthesis. Oxygen is produced whenever green plants grow. Plants, using sunlight as the energy source, use carbon dioxide and water to produce simple sugars and oxygen. Photosynthesis occurs only during daylight hours and only to the depths where sunlight penetrates. The amount of photosynthesis depends on the quantity of plants, nutrient availability, and water temperature. Higher temperatures speed up the process.

Plants and animals constantly use oxygen to break down sugar to obtain energy by a process called **respiration**. Respiration is basically the reverse of photosynthesis. The combination of these two reactions largely determines the amount of oxygen and carbon dioxide present in lakes at different times of the day and at different depths. It is common to find high daytime surface water oxygen values. These levels may be much lower at night or in the early morning hours. At lake depths below the reach of sunlight, the only reaction that occurs is oxygen-consuming respiration. The deep hypolimnetic waters of productive lakes often experience oxygen depletion. Lakes with high biological activity undergo greater fluctuations than lakes with few plants and animals.

Winter oxygen depletion (winterkill) is a common problem in many shallow Wisconsin lakes. It happens in years when at least four inches of snow covers the lake, preventing sunlight from reaching the water. All photosynthesis stops and plants begin to die and decompose. The extent of oxygen loss depends on the total amount of plant, algae, and animal matter that decays. Drought increases the chance of winterkill by reducing the volume of water in the lake (Shaw et al. 2000).

The oxygen concentration at representative lake depths can be measured using a chemical test (Winkler titration) or an electronic meter. CLMN uses the Winkler titration test due to the relatively low cost and high accuracy of the test. Note on your data sheet which method, titration or meter, you used to determine dissolved oxygen levels.