

# Restoring Water Quality in Eutrophic Ponds

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## Summary

Eutrophication is the process by which surface water becomes progressively enriched with nutrients like nitrogen (N) and phosphorus (P). When this occurs, unwanted algae and weeds grow, and fish kills can occur. Reducing nutrient runoff is the key to prevention. But, once nutrients accumulate in surface water, additional treatments may be needed before water quality improves. This extension circular is divided into two parts: Prevention and Treatment. Preventing nutrients from entering your pond is a foremost priority and should always be pursued. However, as explained below, once nutrients enter ponds, they often stay in place and cause yearly cycles of algae and weed growth to occur. To reduce the symptoms of eutrophication, N and P need to be removed or made unavailable to plants and algae (Fig. 1). This is where “treatment” options become important and are discussed.



Figure 1. Changes in water quality appearance following a chemical and biological approach to removing nitrogen and phosphorus. Photos show one 20 x 20 ft. floating treatment wetland. Photos were taken at Cooper YMCA, Lincoln, NE

**1**Bold blue font terms are defined in glossary.

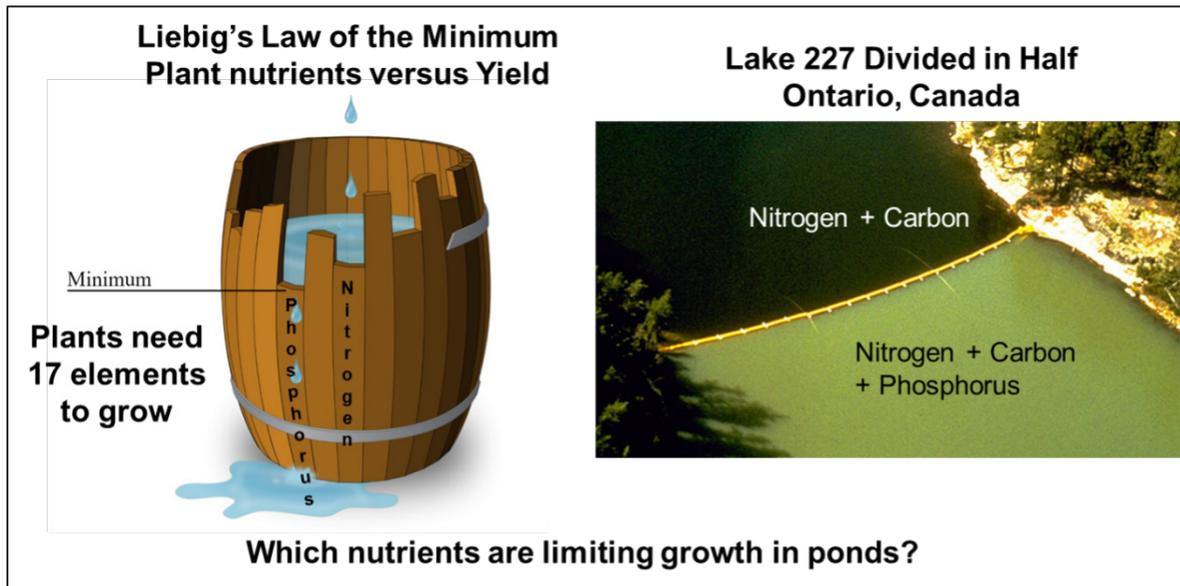


Figure 2. Liebig's barrel showing concept of limiting nutrients and Ontario lake divided in half showing phosphorus spurting algal growth.

## Introduction

Lakes and ponds contribute significantly to “The Good Life” enjoyed in Nebraska by providing outdoor recreation, wildlife habitat, and an aesthetic diversity to landscapes. But ponds in our region are particularly fragile and susceptible to a variety of problems including nuisance and **harmful algae blooms**<sup>1</sup> (HABs), excessive weed growth, **fish kills**, and siltation. While surface waters naturally age, human activities can greatly accelerate this process, and this leads to a high percentage of ponds throughout Nebraska with low water quality. Urban stormwater retention ponds surrounded by fertilized lawn and impervious streets or parking lots, are especially vulnerable to water quality degradation through nutrient runoff.

## Why do so many ponds in Nebraska have algae and weeds?

One basic principle taught in agronomy and plant science courses is “**Liebig's Law of the Minimum**!”<sup>1</sup> Briefly, this principle explains that plants and algae need 17 essential nutrients to grow, and they receive 14 from the soil-water environment. The amount of plant growth (or yield) that occurs is not necessarily determined by the amount of nutrients in excess, but rather by the concentration of elements that are limited. To make this point, Justus Liebig created a diagram of a wooden barrel where the wooden planks (staves) were of different heights (Fig. 2). Liebig explained that the amount of water the barrel could hold (analogy for plant growth) was not controlled by the tallest staves, but the shortest. In other words, plant growth, like weeds, is limited by the scarcest nutrients.

We use Liebig's illustration because lake and ponds are often described as being either “**phosphorus-limited**” or “**nitrogen-limited**.” In other words, ponds have threshold values for phosphorus (P) or nitrogen (N), and once P and N concentrations exceed these threshold concentrations, algae and weeds begin to grow. Conversely, when P and N concentrations are reduced below these thresholds, algae and weeds growth are diminished. An excellent example of this concept was demonstrated in Ontario, Canada, (circa 1975) where researchers divided a lake with a curtain barrier. They added nitrogen and carbon to one side and nitrogen, carbon, and phosphorus to the other side. Results from this experiment showed the added phosphorus caused an algal bloom in the lower portion of the lake (Fig. 2). **If your homeowners association (HOA) pond shows signs of algal growth, there is a good chance your pond has received excess phosphorus, and concentrations have exceeded the threshold needed for algal growth.** This is why the water quality of your pond has deteriorated.

## External inputs versus internal nutrient cycling

**Surface runoff**, also called overland flow, occurs when water from rain or snow melt reaches the soil surface at a rate greater than the rate water can infiltrate into the soil. This causes water to flow over the land surface. Water is considered a universal solvent, meaning it is capable of dissolving and transporting many substances, such as fertilizers and pet wastes. For this reason, surface runoff is responsible for bringing external nutrients into ponds and is the major cause of eutrophication. Changes in watershed management practices that reduce external nutrient loading are required

## External Inputs versus Internal Nutrient Cycling

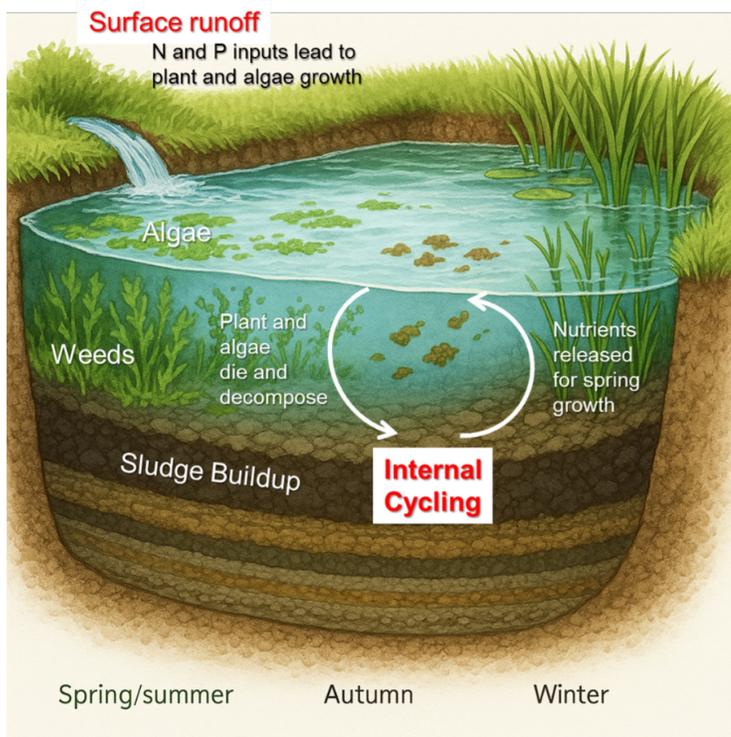


Figure 3. External nutrient inputs and internal nutrient cycling in eutrophic pond. Illustration generated with artificial intelligence (abbreviated as “AI” in other captions below).

for long-term recovery of eutrophic ponds. While reducing nutrient runoff is required for recovery, few signs of improvement in water quality are often observed in the years following external load reduction (Jeppesen et al., 1991). This is because the eutrophic condition is sustained by internal processes that tightly re-cycle nutrients within the pond.

Internal nutrient cycling can be described in a few ways, but an easy explanation is to consider what happens to algae and weeds over a growing season. As external P and N enter the pond, algae and weeds begin to grow (Fig. 3). As the season progresses (spring → fall), the algae and plants die and sink to the bottom of the pond. Bacteria in the pond begin to consume this organic material and release N and P nutrients back into the water, which allows new plants and algae to grow in subsequent years.

## Prevention versus Treatment



Despite efforts to reduce external nutrient loads, internal cycling of nutrients can cause algae and weed blooms to

occur year after year. Thus, it is necessary to have tools that not only reduce external nutrient-loading from surface runoff (**Prevention**) but also treat the cause of eutrophication within the pond (internal nutrients), so that real-time benefits in water quality can be achieved (**Treatments**).

In keeping with the concept of Liebig’s Law of the Minimum (Fig. 2), you can think of “prevention” as a way to keep ponds from accumulating the amount of N and P needed for algae and weeds to grow in excess. Likewise, “treatment” is a way to remove or lower N and P concentrations in the pond water so that these nutrients are again limiting.

## PREVENTION



The adage “an ounce of prevention is worth a pound of cure” certainly applies to the eutrophication of ponds. Best management practices that prevent nutrient runoff should always be pursued and examples of things homeowner associations (HOAs) can do include:

- Establish buffer strips around the periphery of the pond. Tall grasses and plants can slow down runoff water, remove pollutants by filtering and settling, and improve infiltration before water enters the pond. Buffer strips also provide habitat for wildlife.
- Ban the use of phosphorus-containing fertilizers. Common fertilizers have three numbers on the front of the bag indicating the amount of nitrogen, phosphorus, and potassium in the fertilizer. Look for fertilizers that have a “zero” for the middle number (Fig. 4). Turfgrass research has shown that once lawns become established, they rarely need additional P for growth.
- Mulch your lawn instead of bagging the grass. Mulching returns nutrients to the soil, retains soil moisture and reduces the mass of grass clippings that go to landfills.
- Encourage pet owners to pick up their pet’s waste with posted signs or free waste bags and disposal containers.



Figure 4. Example of phosphate-free fertilizer.

- Always apply appropriate amounts of fertilizer by following label instructions.
- Avoid applying fertilizer right before imminent rainfall.
- Manage geese populations around pond by modifying habitat (Fig. 5).

### Geese Populations

A single goose can poop up to 3 lbs. per day, every day. Multiply this by flock size and it is easy to see how a **gaggle** of geese can generate enough nutrient-rich waste to deteriorate water quality. Geese also tend to come back to the same pond, year after year. There are also resident geese that do not migrate. They thrive in areas with readily available food sources, such as lawns, golf courses, and parks. Consequently, preventing geese from inhabiting your pond is an excellent preventive measure. But how? And is this even possible?

The answer is a definitive “yes,” if you properly prepare. Here are a few things HOAs can do to deter geese:

- Geese will stay away from ponds with large buffer strips (10+ feet) because they are afraid of predators (Fig. 5). Putting up a short fence around the pond can keep geese away. This can be a good first step until natural grass/plant buffers become established.
- Geese also do not like the chemical that is in grape Kool-Aid, methyl anthranilate. The strong scent and flavor of grape Kool-Aid irritate geese and cause them to leave. Spraying grape Kool-Aid around the shoreline of your pond can prevent geese from congregating (Fig 6).
- Geese can get aggressive, but you can cause them to leave peacefully by shining a green laser light on their feet (Fig 6).

### What should a heathy HOA pond look like?

Lake HOAs consists of many people, who often have a diversity of opinions on what their association’s ponds should look like. Some members prefer a manicured pond, much like what you might see at a golf course (Fig. 7A). While manicured ponds may look nice to some, they are not natural, provide little ecological value, and require routine chemical maintenance to remain weed- and algae-free. More-



Figure 5. (Left) Illustration (AI generated) and photograph of Canada geese (Right) Photograph of local Lincoln, NE pond with wide buffer strip to deter geese populations.

### Geese Deterrents



Figure 6. Geese deterrents include spraying grape Kool-Aid on banks or shining green laser light near geese.

over, as aquatic-based plants, such as cattails spring up, some HOA members feel these plants should be mowed down or killed. Removing vegetation is counterproductive to the filtration effect aquatic plants can provide to incoming runoff. By contrast, ponds that have established vegetative strips have natural barriers to reduce nutrient and sediment input into your pond, provide wildlife habitat, and can also be aesthetically pleasing (Fig. 7B).

If HOAs collectively decide they want their pond to look like a golf course pond (Fig. 7A), then eutrophication is highly likely, and algae and weeds will become abundant. Chemical control of annual weeds and algae will be an annual event that will require the addition of products such as **fluridone** (commercial products like Airmax Wipeout or Sonar A.S.), a pesticide that acts as a photosynthesis inhibitor in all plants, and **copper sulfate**, which is often used to kill algae. Commercial vendors can be hired to apply these products, but costs can be several hundred to thousands of dollars. Also, remember that excess nutrients in your pond are the root of the problem (i.e., Liebig's Law, Fig. 2), and these annual chemical additions are only treating the symptoms of excess nutrients, **not the source of the problem**. In other words, chemical weed and algae treatments do not remove nutrients from your pond.

Another problem with using fluridone, is that the water can become quite murky and no plants will be able to grow. While this prevents the growth of unwanted weeds, plants in clear water can photosynthesize light and produce oxygen (Fig. 8). Increased oxygen concentrations in your pond can facilitate the decomposition of organic matter, such as fallen leaves (see below). Without oxygen, this organic matter gets degraded under **anaerobic** conditions, and buildup of black, stinky (hydrogen sulfide,  $H_2S$ ) muck (partially decomposed organic matter) can occur at the pond's bottom. Another problem with pesticides is the negative impact they have on the aquatic ecosystem, including fish, frogs, birds, and beneficial insects. Multiple years of fluridone use will facilitate muck buildup. The greater the muck buildup, the longer it will take (i.e., years) for an active treatment (see Treatment section below) to remove nutrients and restore water quality. This is because bottom muck can be viewed as a "storage bin" of undecomposed nutrients that must also be removed if water quality is to improve.

### Why is dissolved oxygen so important to a pond's health?

If you have ever been camping and started a campfire, you probably blew on the fire to get it started. Blowing on a fire adds oxygen and increases the burning of the kindling/wood. This example can be used as an analogy for how dissolved oxygen in pond water helps break down fallen leaves, dead plant material, and muck.

The amount of dissolved oxygen in ponds and lakes determines the type of decomposition that takes place.



Figure 7. Comparison of a well-manicured golf course pond (A) versus a golf course pond with natural buffer strips to minimize nutrient runoff (B).

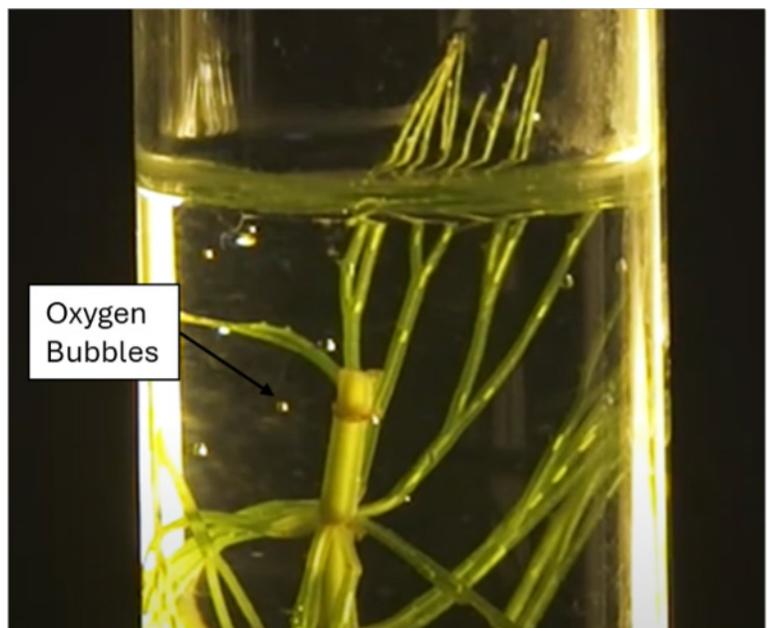


Figure 8. Photograph of Coontail weed producing oxygen bubbles underwater through photosynthesis.

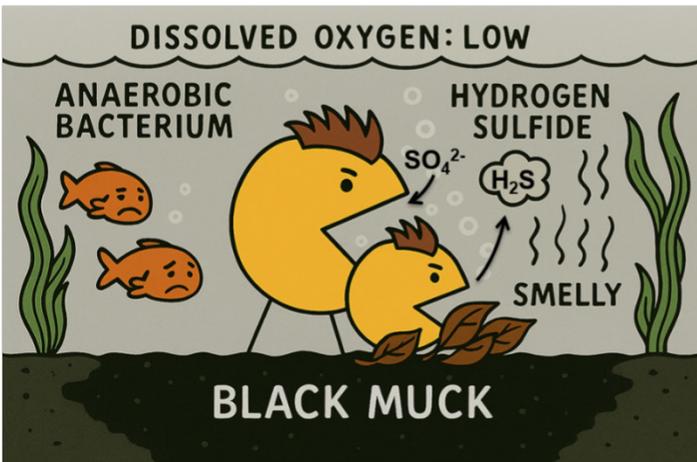
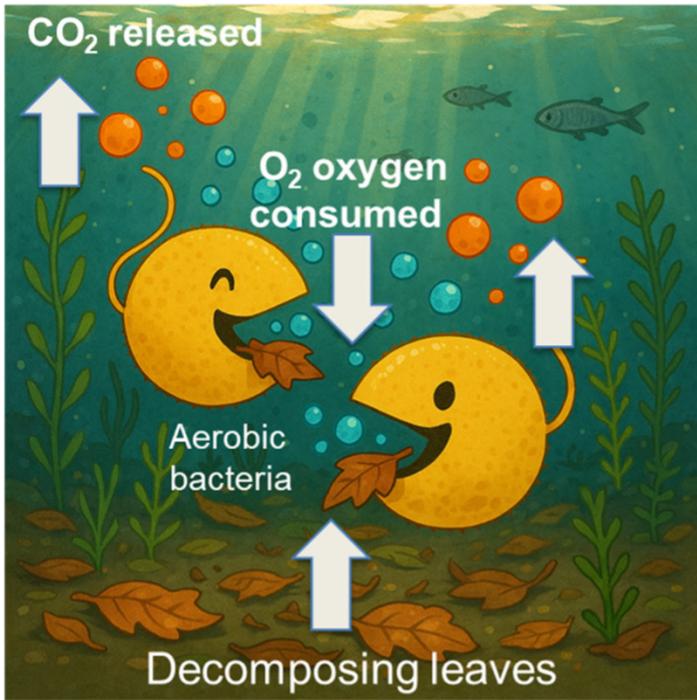


Figure 9. (Top) Aerobic bacteria consuming dead leaves when oxygen is present. (Bottom) Anaerobic bacteria consuming dead leaves under low oxygen conditions and producing hydrogen sulfide gas. Both figures were AI-generated.



Figure 10. Photographs of leaves placed in nylon bags and submerged in low clarity and high clarity water ponds.



Figure 11. Top, Mechanical harvesting bottom muck from lake (Source: Sediment & Muck Removal Services | Bluewave Waterworks) and Bottom, tributary (Source: Aaron Mittelstet)

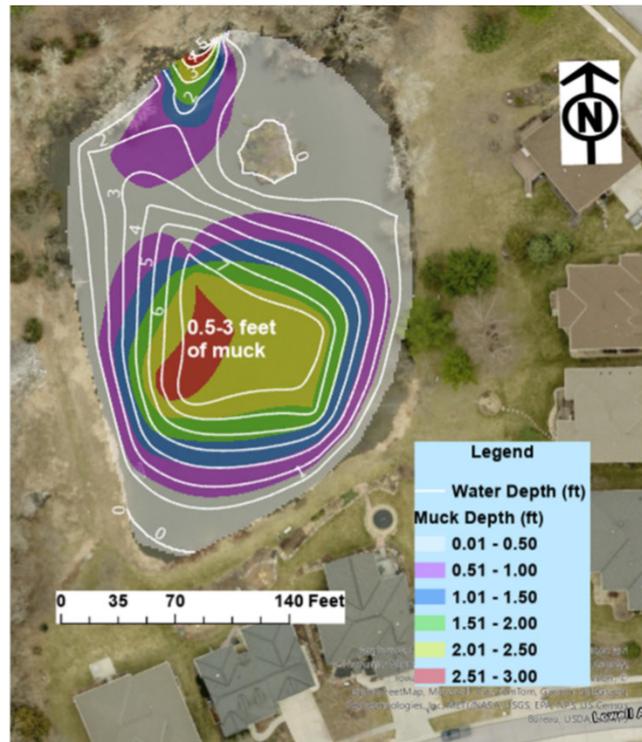
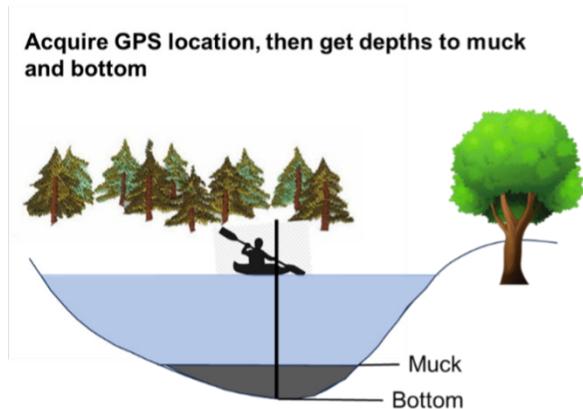


Figure 12. Illustration of determining muck depths in ponds using GPS coordinates and a pole with depth markings.

Bacteria that live in the water are always hungry and want to consume the carbon found in organic materials (Fig. 9). To consume this carbon, they need oxygen, and this type of bacteria are called **aerobic** bacteria (Fig. 9, top). As the aerobic bacteria consume carbon, they produce carbon dioxide, just like a campfire. The problem is that if there is too much organic matter in the pond, the aerobic bacteria can run out of dissolved oxygen. When oxygen gets low, the water environment becomes “**anaerobic**” and anaerobic bacteria take over. Anaerobic bacteria use other chemicals in place of oxygen, like sulfate ( $\text{SO}_4^{2-}$ ). The anaerobic bacteria still consume carbon, but at a much slower rate than aerobic bacteria. They also produce hydrogen sulfide ( $\text{H}_2\text{S}$ ) or methane. This is how black, stinky muck develops (Fig. 9, bottom).

To demonstrate this point, we collected some dead maple leaves and placed them in some nylon mesh bags. We added one bag to a pond that had clear water and high dissolved oxygen. The other bag went into a eutrophic pond that had low water clarity. After four weeks, we retrieved the bags and examined the leaves. Results showed that the leaves in the eutrophic pond were blackened and not decomposed. Leaves in the high clarity pond were mostly degraded and practically see-through, or semi-transparent, meaning most of the carbon had been consumed (Fig. 10). This difference in degradation results show how stinky muck can accumulate in the bottom of ponds that have poor water clarity and low dissolved oxygen.

Several years of low oxygen conditions can lead to muck buildups that may require mechanical dredging or harvesting—a process that is expensive and cost-prohibitive to many HOAs. As illustrated in these photographs, specialized equipment is needed to harvest the muck (Fig. 11). Much of the cost for removal is transportation costs because it can be challenging to find a location that will accept bulk loads of muck.

One way to determine if your pond has muck buildup is to use a pole or rod that has markings for length. Place the pole vertically into the pond and stop when you reach resistance (muck), record depth. Then push the pole further into the pond’s bottom until it stops. That additional depth will indicate the depth of muck. By taking various measurements throughout the pond with **GPS** coordinates, UNL has produced maps of water and muck depths for various ponds (Fig. 12).

Adding aerators to ponds can help prevent anaerobic conditions from developing and increase dissolved oxygen, which helps aerobic bacteria break down muck faster. In addition, when steps are taken to improve water quality, the clarity of water improves. When water is clear, light can penetrate and plants can photosynthesize and produce oxygen, which can also increase dissolved oxygen in your pond.

A final reason for being concerned about the dissolved oxygen in your pond is that it affects how iron, which is naturally found in soils/sediments, holds onto phosphorus. When

dissolved oxygen is available, iron binds with phosphorus and makes it unavailable. However, when oxygen concentrations get low, iron changes form and releases phosphorus back to the water. This is another reason seasonal algae blooms can appear in ponds even if phosphorus inputs (run-off) are controlled (Shaw et al., 2004)

### How do you know if your pond has a nutrient problem?

Once you suspect your pond may have a nutrient problem, the first step is to collect water samples and have them chemically analyzed (Fig. 13). To start, testing pond water for orthophosphate, total phosphorus, nitrate, and total nitrogen are recommended. UNL uses its own analytical instrument for these analyses (Fig. 13), but many commercial laboratories are also available for these analyses. At the end of this extension circular is **Appendix A** that has a table explaining these N and P chemical species in more detail and how to interpret laboratory results.

### Your pond is part of a larger watershed

A watershed is defined as an area of land that collects and funnels rainfall and streams to a common outlet. The outlet may be a pond, stream, or wetland. We all live in multiple watersheds because the watershed of a small stream is nested within the watershed of a larger river downstream. For example, someone who lives in Lincoln, Nebraska, resides in the Salt Creek, Platte River, Missouri River, and Mississippi River watersheds. This means any discharge of a pollutant into Salt Creek could eventually make its way to the Gulf of America via the Platte, Missouri, and Mississippi Rivers.

Another important consideration is that urban ponds are often connected to other ponds and waterways within a watershed (Fig. 14). Consequently, all the preventive measures HOAs take to reduce nutrient runoff will benefit your pond and ponds that are downstream from your pond. **However, surface water that is upstream from your pond could be contributing to the nutrient loads your pond is receiving.** Delineating the extent of the watershed contributing to your HOA pond could be useful in getting other HOAs involved in preventing nutrient runoff.



Figure 13. UNL student, Ashleigh McGreer, performing sample analysis with analytical instrument used to analyze water samples for N and P (SEAL AQ300)

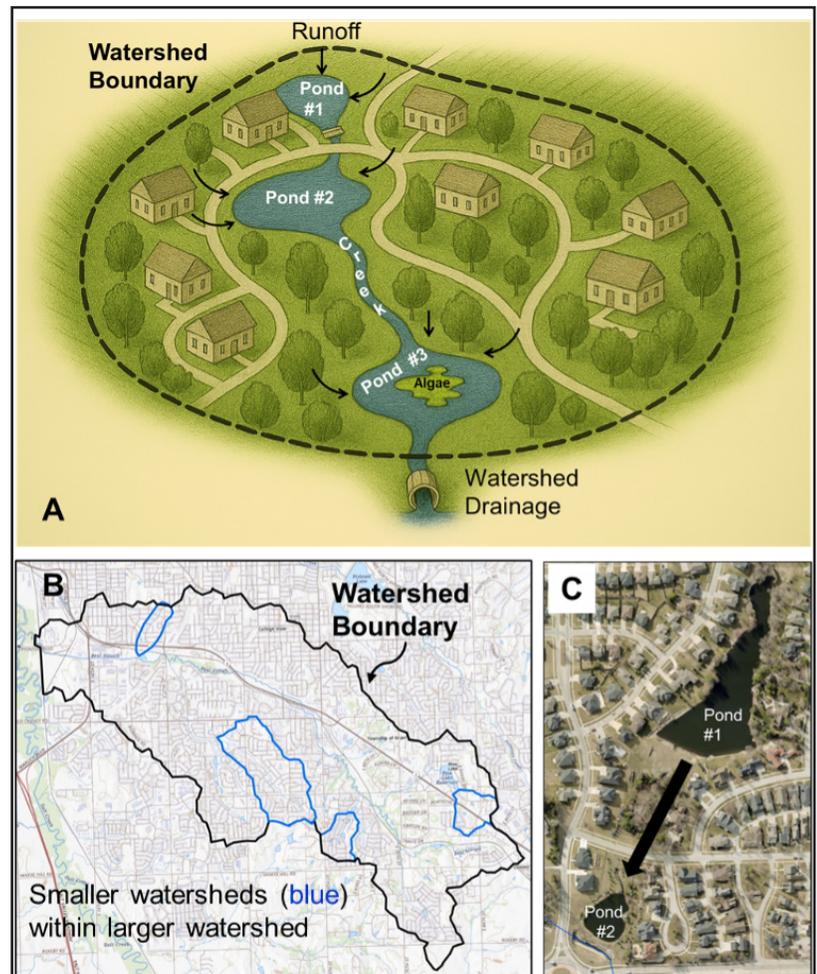


Figure 14. A. AI-generated suburban watershed with three ponds, showing signs of eutrophication. B. Several small watersheds (blue outline) within a larger watershed (black). Each of the subwatersheds will drain into the larger watershed (Beal Slough), which then flows into the Salt Creek watershed. C. Two ponds in Lincoln, NE surrounded by homes and interconnected inside a watershed, with Pond #1 water moving into Pond #2.

## TREATMENT



Once homeowner associations have determined that their pond has an excess nutrient problem either through nutrient analysis (Fig. 13, Appendix A) or physical appearance (i.e., excess weeds or algae, Fig. 15), the number of options available to HOAs is limited and includes:

### Options

1. **Do nothing and hope the situation improves.**
2. **Implement preventative measures to reduce runoff.**
3. **Use herbicides and algacides on an annual basis (i.e., pesticide approach).**
4. **Reduce nutrient concentrations in the pond so that N and P are limiting to algae and weed growth.**

**Option 1.** Doing nothing is often chosen not necessarily by choice, but by not knowing what to do to correct the situation. Eutrophication builds up over time and is unfortunately inevitable. As mentioned in the introduction, once N and P accumulate in a pond, there are no easy removal mechanisms and internal recycling of nutrients occurs. This means annual growth of weeds and algae can be expected each year.

**Option 2.** Reducing nutrient runoff is better than Option 1 and the preventive runoff actions HOA can take have already been discussed. Unfortunately, just like in Option 1, once nutrients have accumulated in a pond, yearly outbreaks of weeds and algae are still likely, even when preventive measures for reducing runoff are pursued.

**Option 3.** Hiring commercial vendors to apply pesticides is commonly used and can be effective by offering a “quick fix”. However, it is important to recognize that a pesticide approach does nothing to reduce N and P from your pond, which is the source of the problem.

**Option 4.** The goal of lowering N and P concentrations in the pond water is so nutrients become limiting to algal and weed growth—as stated in Liebig’s Law of the Minimum. This approach works and can result in improvements in water quality, but

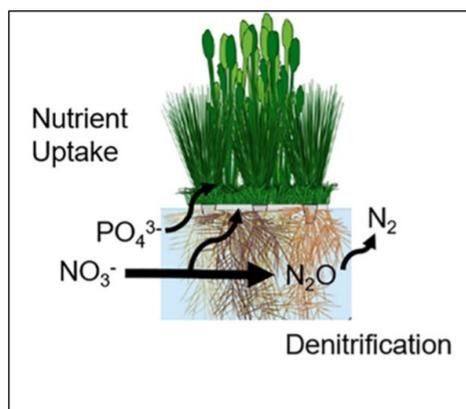


Figure 16. Biological approach to removing N and P from the water using floating treatment wetlands.



Figure 15. Example of HOA pond showing signs of eutrophication.

it takes longer (years) and requires diligence by the HOAs in implementing the treatments. Below are a few treatments HOAs can implement to reduce N and P concentrations in their ponds and minimize algae and weed growth.

### University of Nebraska’s approach

For the last several years, researchers and students at the University of Nebraska-Lincoln (UNL) have been working on a novel approach to remove N and P from the nutrient-rich waters by combining a biological treatment with a chemical treatment.

### Biological Approach

Floating Treatment Wetlands (FTW) are engineered ecological systems that improve water quality. Wetland plants are being employed in floating frameworks, where their exposed roots are suspended in the water. Plant uptake (growth) removes N and P from the water, while microbes on plant roots convert nitrate ( $\text{NO}_3^-$ ) to nitrogen gas ( $\text{N}_2$ ), which safely returns to the atmosphere (Fig. 16). The conversion of nitrate to nitrogen gas is called **denitrification** and is an excellent way to remove N from eutrophic ponds.



How much nitrogen can these floating wetlands remove? Research by UNL put vinyl pool liners beneath FTWs and spiked nitrate into the pools (McCoy et al., 2024). By measuring the loss of nitrate with time, UNL estimated how much nitrate is removed over a growing season. UNL estimated that two 20 x 20 ft FTWs (Fig. 16) could remove between 0.6 kg (1.3 pounds or lbs.) and 3.7 kg (8.2 lbs.) of  $\text{NO}_3\text{-N}$ . This is enough removal to reduce nitrate concentrations in a one-to-two-acre pond. At the Cooper YMCA Pond (Fig. 1), nitrogen concentrations were reduced to the point that the plants in the FTWs started showing signs of nitrogen deficiency (yellowing of leaves).

The floating mats used in the FTWs were purchased from BeeMats and the wetland plants were purchased from PlantNebraska (formerly Nebraska's Statewide Arboretum). The fences around the FTWs were custom made from PVC pipe. These fences keep geese from eating the plants before they became established.

### Chemical Approach

While the biological approach is designed to remove N, the chemical approach is designed to remove P. Lanthanum ( $\text{La}^{3+}$ ) is a rare-earth element that can be used to remove excessive phosphate ( $\text{PO}_4^{3-}$ ) from nutrient-rich waters. It binds to phosphates in the water, creating lanthanum phosphate, which is a form of phosphorus that is not available for plant or algae growth. Lanthanum is slowly released through an airlift pump, which also adds oxygen to the water (Fig. 17).

Lanthanum composites were made from lanthanum chloride, sand and wax and molded into cylinders. These lanthanum composites are then inserted into an airlift pump which generates air bubbles that cause ripples of water to radiate away from the airlift pump (Fig. 17B).

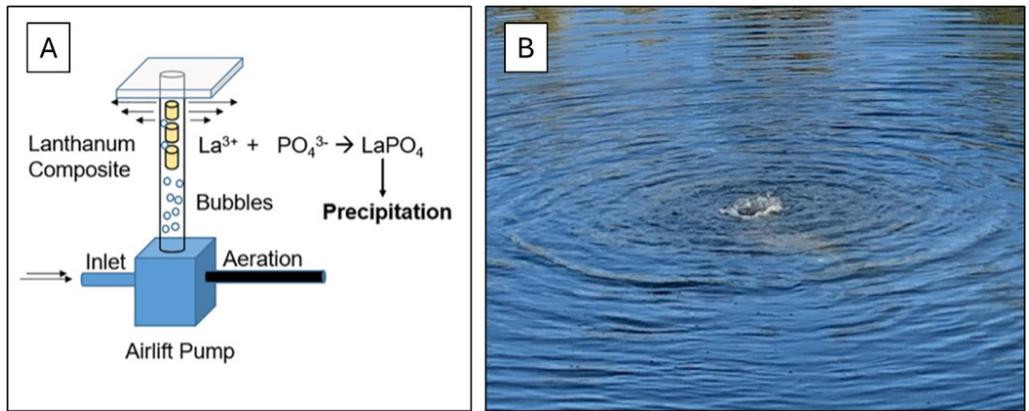


Figure 17. A, Illustration of chemical approach using an airlift pump with lanthanum composites, B, Water ripples generated from airlift pump help distribute lanthanum to pond.

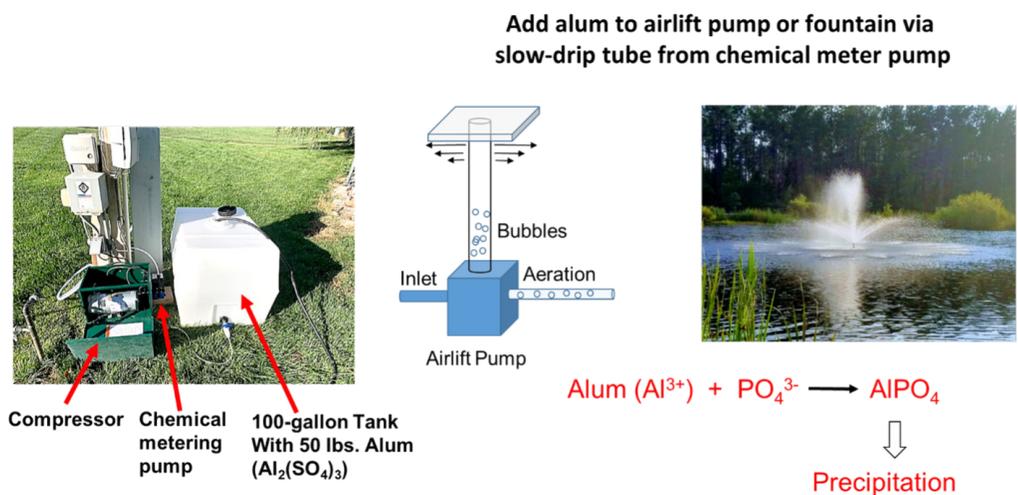


Figure 18. Photographs and illustrations of alum being used in place of lanthanum and its distribution to ponds via an airlift pump (middle) or water fountain (right).

Three barriers to using lanthanum composites by HOAs include:

- lanthanum is an expensive chemical,
- lanthanum composites are not commercially available—they were created at UNL, and
- airlift pumps were also custom built.

To overcome these obstacles, UNL started using aluminum sulfate, (i.e., alum), which is readily available. Alum can be slowly dripped into an airlift pump or fountain (Fig. 18, left and middle). By using a chemical metering pump, we dispersed 100 gallons of an alum solution (50 lb alum mixed in 100 gallons of water) every 30 days. Using a standard pond fountain, which many HOA ponds already have, all that would be needed is a tank, a metering pump, and some tubing (Fig. 18).

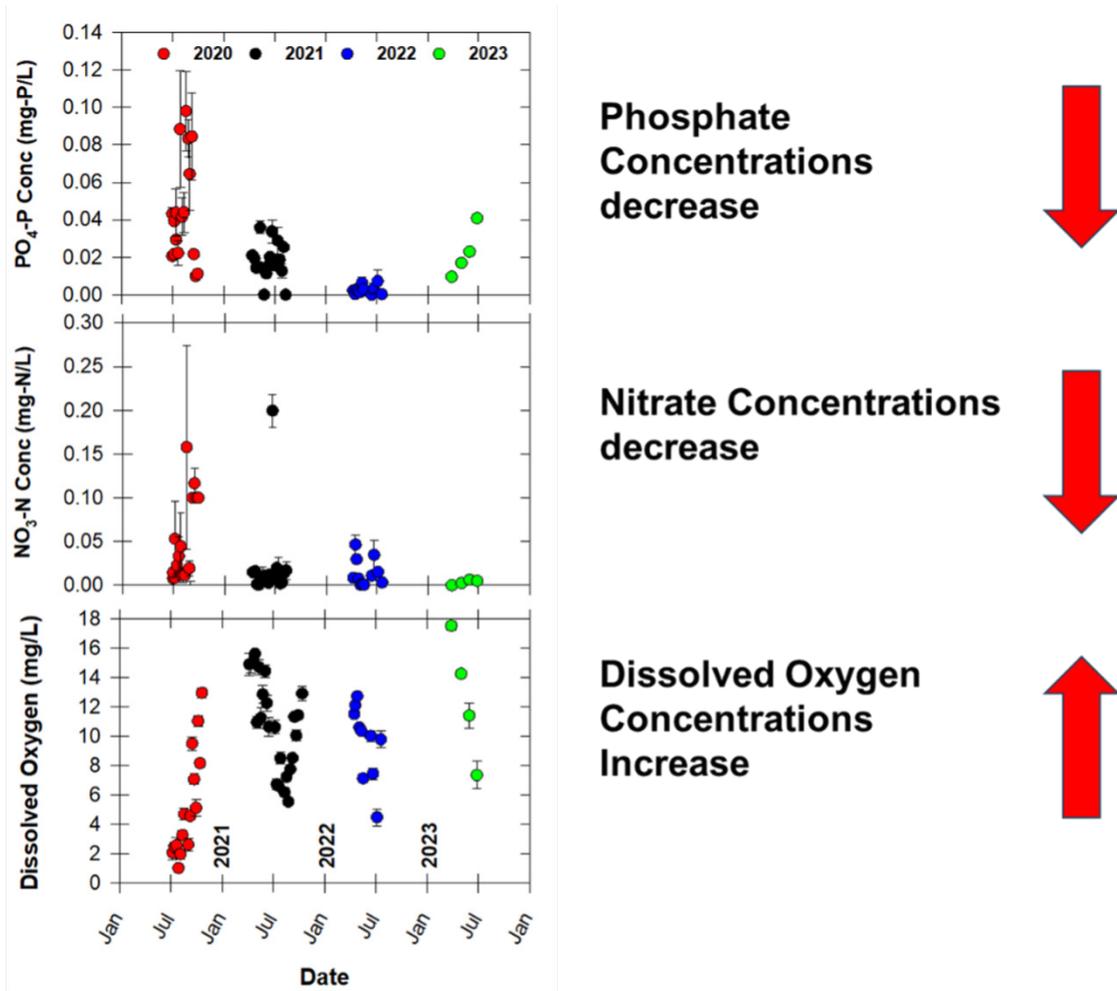


Figure 19. Changes in orthophosphate, nitrate-N and dissolved oxygen concentrations following UNL's biological and chemical approach to treating eutrophic ponds (McCoy et al., 2024).



Figure 20. Photograph of Cooper Pond at the start of treatment (top) and post treatment (bottom)

## University of Nebraska—Results

UNL's first field test of their biological and chemical approach to treating eutrophic ponds occurred at the Cooper YMCA (Lincoln, NE) in 2020. A timelapse camera was installed to photographically record changes in water quality (Fig. 1). This research was performed by UNL graduate students Levi McKercher, Jenna McCoy, and Matthew Chafee with detailed results presented in McKercher et al., 2022 and McCoy et al., 2024 and Chafee et al., 2023. In addition to visual changes observed over the four years, chemical analysis also verified changes in water quality parameters (Fig. 19). Specifically, orthophosphate concentrations decreased, as did nitrate-N concentrations to the point where they became limiting to weed and algae growth (Fig. 20). In addition, the concentration of dissolved oxygen in the pond increased. Increased dissolved oxygen allowed organic materials to be decomposed and resulted in a decrease in pond muck from a few feet to less than a foot.

### Example—Hartland Pond

In 2024, UNL initiated a biological-chemical approach to treating several eutrophic ponds in Lincoln, NE. In this example the pond received two floating treatment wetlands, a compressor, and two airlift pumps. The airlift pumps receive lanthanum composites monthly, and a slow-drip alum solution (100-gallon tank and chemical metering pump, Fig. 18). Water samples were collected and analyzed approximately once every 1.5 months.

Results from this more recent field study again showed that orthophosphate and nitrate-N concentrations decreased like in the Cooper YMCA Pond, but N and P concentrations are not yet below minimal threshold levels (Fig. 21). Aesthetically, water quality has begun to improve. For the Hartland Pond, duckweed (Appendix B) was evident in 2024 but was not present in 2025. The Hartland Pond had not used any pesticide in the past and the sediment/muck layer was minimal.

While the chemistry behind the removal of N and P from the water is sound, there are several environmental factors that can complicate results. First, the mass of sediment/muck in the bottom of the pond is a reservoir of nutrients that needs to decrease, and this will only occur if dissolved oxygen values are increased. Also, spring and fall winds and temperature changes can cause pond waters to mix (see **Turnover** in glossary), bringing organic rich materials to the surface. This can cause N and P concentrations to increase temporarily, especially in the spring. Moreover, nutrient input from upstream sources can re-contaminate your pond with nutrients. Finally, if geese are inhabiting HOA ponds every year, this can be a continuous source of external inputs.

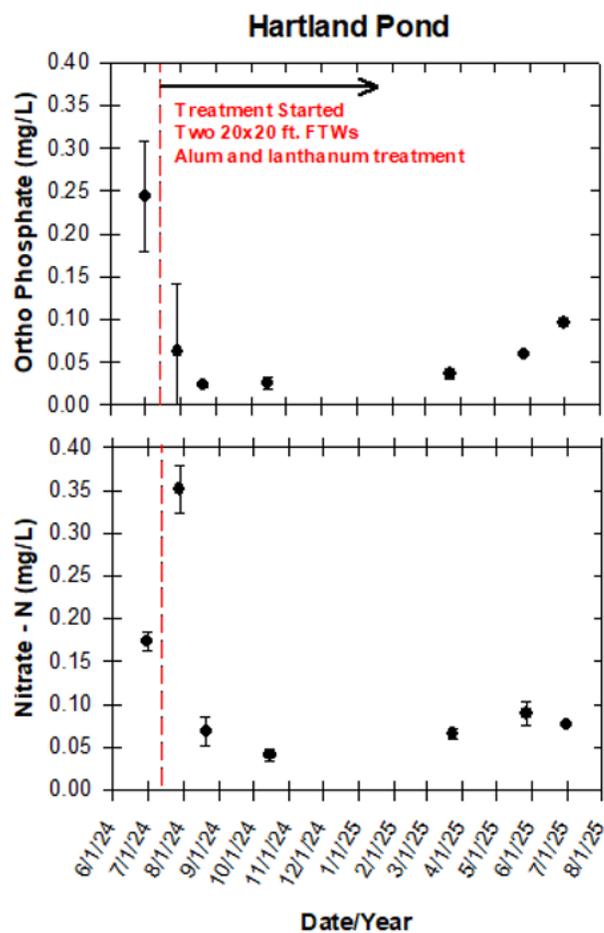


Figure 21. Changes in orthophosphate and nitrate following UNL's biological-chemical treatment.

This is why preventive measures need to be included with active treatments.

### What changes in water quality can be expected?

As alum or lanthanum additions begin to reduce phosphorus concentrations in your pond, water clarity will begin to improve. Increased water clarity will improve light penetration, which could allow weeds to proliferate in the first year. Weeds like curly leaf or coontail could begin to grow (Appendix B). While some may find these unsightly, these plants do photosynthesize and release oxygen (Fig. 8), which is beneficial for degrading the built-up muck (partially decomposed organic matter, like fallen leaves) at the bottom of your pond. With continued alum treatment, the P concentration in your pond can drop to a point where nuisance weeds no longer appear. Finally, improvement of water clarity also makes observing fish much easier. Some HOAs have reported being able to see fish and bluegill nests just off the shoreline (Fig. 22).



Figure 22. Photographs of pond water clarity before and after lanthanum treatment (top) and visibility of bluegill nests following water treatment (bottom)

### In Summary

A clean and sustainable environment, which includes aesthetically attractive ponds and lakes, contributes to “The Good Life” found in Nebraska. When ponds get overrun with excess nutrients, water quality deteriorates. Restoring water quality in eutrophic ponds is possible but it takes time and diligence by nearby residents and homeowners associations. As presented in this publication, both preventive and treatment options are likely needed to improve water quality. Preventive measures reduce the amount of nutrients entering your pond while treatments options lower internal nutrients that have already accumulated. When preventive and treatment options are done together, water quality can improve.

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## Glossary

**Aerobic**—an environment (soil or water) that has free oxygen or presence of air. Aerobic bacteria require oxygen for life.

**Anaerobic**—an environment (soil or water) devoid of free molecular oxygen ( $O_2$ ). Anaerobic bacteria use other species besides oxygen (i.e., sulfate) to degrade organic materials and end up producing undesirable products (hydrogen sulfide or methane gas).

**Algae**—plant species that lacks a stem, root, or leaves. One-celled (phytoplankton) or multicellular plants that are either suspended in water (plankton) or attached to rocks and other substrates (periphyton).

**Blue-green algae**—also known as cyanobacteria, which is a major group of photosynthetic bacteria that are single-celled but form colonies in the form of filaments, sheets, or spheres.

**Cooper sulfate**—An inorganic chemical salt used to kill algae in ponds and lakes.

**Denitrification**—The microbial transformation of nitrate ( $NO_3^-$ ) to molecular nitrogen ( $N_2$ ) through a series of intermediates.

**Eutrophication**—the process by which a body of water becomes enriched in dissolved nutrients that stimulates the growth of aquatic plant life (algae, weeds) often resulting in the depletion of dissolved oxygen.

**Filamentous algae**—Colonies of microscopic plants linked together to form hair-like or thread-like strands. With time, filamentous algae can form large floating mats on top of the pond that are aesthetically unpleasing.

**Fish kills**—Term used to describe occasional occurrences in ponds when dissolved oxygen concentration decrease and cause fish to die. The input or production of dead organic material in ponds can spur aerobic bacteria to decrease oxygen concentrations and cause fish kills.

**Fluridone**—A non-selective aquatic herbicide used to kill plants by disrupting photosynthesis.

**Gaggle**—A flock of geese.

**Harmful Algae Blooms (HABs)**—the rapid growth of blue-green algae or cyanobacterial in water that can produce toxins that are harmful to people, animals, and the environment. HABs may appear in assorted colors, most notably bright John Deere-like green; also, blue-green, red, or brown.

**Kjeldahl Nitrogen**—The sum of nitrogen bound in organic materials (i.e., organic N), plus ammonium ( $NH_4^+$ ) and ammonia ( $NH_3$ ).

**Liebig's law of the minimum**—Growth of a plant (algae) is not dictated by the total resources (nutrients) available, but by the scarcest nutrient (limiting factor).

**Limiting factor**—The nutrient or nutrients that are in scarcest supply and controlling the overall growth of a plant.

**Nitrogen- and phosphorus-limited**—The total nitrogen to total phosphorus ratio (molar) is a traditional baseline for comparing nutrient balance in surface waters. In general, TN:TP ratios well below 16 are indicative of nitrogen-limited, while TN:TP ratios well above 16 are considered phosphorus-limited. From a practical standpoint, both N and P need to be reduced in eutrophic ponds for water quality to improve.

**Photosynthesis**—the process by which green plants and some other organisms (i.e., cyanobacteria) use sunlight to convert carbon dioxide to carbohydrates (sugar) and water.

**Respiration**—The reverse reaction of photosynthesis. Bacteria convert organic material to energy and in the process consumes oxygen and release carbon dioxide.

**Rooted aquatic plants**—multi-celled plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide habitat for fish and aquatic insects. Overabundance of macrophytes can occur in shallow water with high nutrient concentrations.

**Secchi disk**—A black and white and circular disk (8 in) that is used to measure water clarity. The disc is lowered into the water until it disappears. Replicate tests are performed and average Secchi depths are recorded.

**Stratification**—The natural layering of water due to differences in density, which is related to temperature. Water's greatest density is at  $4^\circ C$  or  $39^\circ F$ . As water warms in spring it remains near the surface and colder water sinks. As ice melts in the spring and surface waters cool in the fall, turnover can occur. See Turnover.

**Surface runoff**—Also called overland flow, occurs when water from rain or snow melt reach the soil surface at a rate that is greater than the rate water can infiltrate into the soil and flows over the ground surface.

**Turnover**—a natural process that causes the mixing of top layer of lake waters to mix with deeper water layers. This usually occurs in spring and fall when temperatures change. In the spring, melting ice can

cause cold water to sink to the bottom and bring bottom water to the top. In the fall, cooler temperatures can cause top water layers to cool and sink, again causing a mix of bottom and top waters layers.

**Watershed**—Area of land that collects and funnels rainfall and streams to a common outlet.

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## Appendix A—Sampling and analysis of N and P in eutrophic ponds

This appendix provides additional information on sampling your pond for nutrient analysis.

The first step to sampling is to collect water samples. When collecting samples, it is customary to use a clean vial (plastic or glass), rinse three times with pond water then retrieve the sample. Keep sample cool or on ice while transporting to the analytical laboratory. Chemical analyses typically need to be performed within 48 hours of collection, so it is best to contact the commercial laboratory first and plan accordingly.

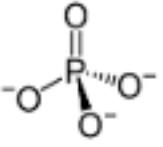
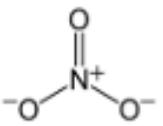
Analytical laboratories may have their own water quality bundle packages available, where a suite of chemical analy-

ses and water quality measurements (e.g., pH, conductivity) are performed. HOAs can decide which packages meet their needs. Alternatively, you can ask that your water samples simply be analyzed for nitrogen and phosphorus, which include the four chemical species listed in Table 1.

It is important to note that analytical testing facilities may report results either as *micrograms per liter* ( $\mu\text{g/L}$ , also equivalent to “parts per billion” ppb) or *milligrams per liter* ( $\text{mg/L}$ , parts per million, ppm). These values differ by a factor of one thousand (1000):  $1 \text{ mg/L} = 1000 \mu\text{g/L}$ . Therefore, it is important to look at the units ( $\mu\text{g/L}$  or  $\text{mg/L}$ ) in the laboratory report and compare results to the threshold values listed in Table 1.

Individual costs for these recommended analyses can vary among laboratories, but for reference, the 2025 costs

**Table 1. Information of chemical nutrients typically analyzed for in ponds and lakes.**

Chemical Species	Structure	Description	Threshold concentration
Orthophosphate		<b>Orthophosphate (OP)</b> , also called soluble phosphate, or soluble reactive phosphorus is the simplest form of phosphate. Orthophosphate (OP) is the form that is readily available for biological uptake by plants and algae. OP is usually measured directly on an analytical instrument in water samples following filtration and needs to be completed within 48 hours of collection. When collecting samples, it is customary to use a clean vial (plastic or glass), rinse three times with pond water then retrieve the sample. Keep sample cool or on ice while transporting to the analytical laboratory.	Concentrations of OP $30 \mu\text{g/L}$ (or $0.03 \text{ mg/L}$ ) or more can cause algae blooms in ponds. Orthophosphate below $10 \mu\text{g/L}$ ( $0.01 \text{ mg/L}$ ) is needed to make P limiting.
Total Phosphorus	Multiple structures of orthophosphate combinations plus organic-bound phosphorus	<b>Total Phosphorus (TP)</b> . TP is used to represent orthophosphate, as well as other analogs or combinations of the orthophosphate structure, plus organic phosphate (phosphate incorporated into biomass, like leaves). Analysis of total phosphorus involves a digestion procedure of the water sample, where more complex forms of phosphorus are broken down and converted to orthophosphate. Think of total phosphorus as the amount of phosphorus in the “reserve tank” (TP will eventually be broken down naturally and become orthophosphate)	Total phosphorus below $20 \mu\text{g/L}$ ( $0.02 \text{ mg/L}$ ) is needed to make phosphorus limiting for algae and weeds (Shaw et al., 2004).
Nitrate		<b>Nitrate</b> is a molecule composed of one nitrogen atom combined with three oxygen atoms. Nitrate is vital for the growth and survival of plants and animals. Nitrate is naturally produced during the decomposition of organic matter as bacteria can convert organic nitrogen into ammonium and then eventually, nitrate, if oxygen is present. One confusing aspect of chemical analysis of water samples is that laboratories may report results for nitrate as either “nitrate” ( $\text{NO}_3^-$ ) or “nitrate-N” ( $\text{NO}_3^- \text{N}$ ). What is the difference? Nitrate is the concentration of the whole nitrate ion. Nitrate-N is the concentration of nitrogen in the nitrate molecule. Given nitrate is one part nitrogen and three parts oxygen, nitrogen only makes up 22.6 percent of the nitrate ion. Conversion from nitrate to nitrate-N and vice versa can be performed by: Nitrate ( $\text{NO}_3^-$ ) = $\text{NO}_3^- \text{N} \times 4.43$ Nitrate-N ( $\text{NO}_3^- \text{N}$ ) = $\text{NO}_3^- \times 0.226$ For example, EPA’s Maximum Concentration Limit (MCL) for nitrate-N in drinking water is $10 \text{ mg NO}_3^- \text{N/L}$ . This would be equivalent to $44.3 \text{ mg NO}_3^- \text{/L}$ ( $10 \text{ mg/L NO}_3^- \text{N} \times 4.43 = 44.3 \text{ mg NO}_3^- \text{/L}$ ).	Given that all inorganic forms of nitrogen (nitrate, nitrite, ammonium) can be taken up by aquatic plants and algae, it is advisable to have these inorganic forms of nitrogen below $30 \mu\text{g N/L}$ ( $0.3 \text{ mg N/L}$ ) to prevent summer algae blooms.
Total Nitrogen	Multiple structures of inorganic nitrogen plus organic nitrogen	Like total phosphorus, <b>total nitrogen</b> represents inorganic forms of nitrogen like nitrate, nitrite, ammonium and ammonia, plus organic N. As with total phosphorus, the organic N in total nitrogen will eventually be broken down and released as ammonium, which will convert to nitrate, if oxygen is available.	<b>Not applicable</b>

Analysis	Costs
Ortho Phosphate—Dissolved Orthophosphate	\$23.65
Total Phosphorus	\$32.67
Nitrate—Nitrate/Nitrite Nitrogen	\$16.50
Total Nitrogen—Total Nitrogen (TKN + Nitrate)	\$46.75
<b>Total Costs</b>	<b>\$119.57</b>

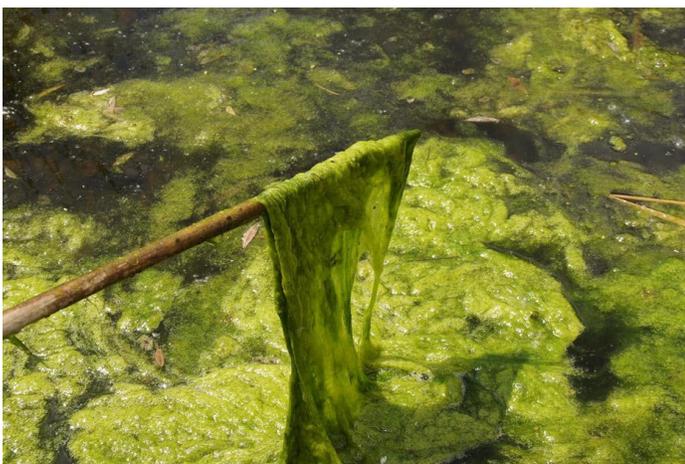
<sup>1</sup>Costs are from Midwest Laboratories, Omaha, NE. Midwest laboratories recommend collecting a ~500 mL (~16 oz) sample in a rinsed glass or plastic bottle. Keep sample on ice and transport to laboratory.

for Midwest Laboratories are listed above (Table 2). The University of Nebraska Water Science Laboratory can also provide these analyses.

One argument for getting a water sample analysis done is that it allows HOAs to know just how much N and P is in their pond and how much nutrient removal is going to be needed before changes in water quality appearance occurs. Keep in mind that the mass of muck at the bottom of the pond also needs to be considered because this partially decomposed organic material is a reservoir of nutrients that will also need to degrade. This is why treatments can take a few years to complete.

## Appendix B—Commonly Observed Algae and Weeds

**Filamentous Algae**—When UNL first started treating Cooper YMCA Pond (Fig. 1), it was covered with a green carpet of algae. This stringy, floating mat of algae is **filamentous algae**. If this type of algae is on your HOA pond, you can be assured that your pond has excess phosphorus.



Source: Control Filamentous Algae | How to Remove Pond, Lake Weeds

**Planktonic Algae**—microscopic algae that live in the water and can cause water to have a green, brown, or reddish color. This type of algae grows quickly when nutrient concentrations are high and environmental conditions are

optimal (warm, sunlight) causing an algal bloom. Blooms usually die off quickly when temperatures drop (first frost).



Source: <https://extension.psu.edu/planktonic-algae>

**Curly leaf pondweed (*Potamogeton crispus*)**—Curly leaf pondweed is a species that has serrated, curly leaves, somewhat like lasagna. During treatment of eutrophic ponds (Fig. 1) we noticed that once the water clarity improved in Year 2, curly leaf began to flourish. Thus, the plant needs sunlight because it is rooted in the pond bottom. Curly leaf did not grow in the third and fourth years after N and P decrease from the biological-chemical treatment was implemented (Figs. 16–17).



Source: S.D. Comfort

**Coontail (*Ceratophyllum demersum*)**, also commonly known as Hornwort gets its name from its “raccoon tail” cluster of leaves at the end of its main stem.



Source: Pond Grass: The Perfect Addition to Your Water Garden Ecosystem

**American pondweed** (*Potamogeton nodosus*)—

American pondweed begins to show up in ponds after treating for a year or two (once water clarity improves) and is considered a good plant. Some benefits of American pondweed include: the plant is beneficial to many types of wildlife as well as aquatic insects, and frogs. The floating canopy provides shade for gamefish. Also pondweed occupies areas right off the shoreline where algae typically grow.



Source: <https://magnoliafisheries.com/> and S.D. Comfort

**Duckweed** is often prevalent in nutrient-rich ponds that have a buildup of leaves and organic matter. Duckweed prefers slow or stagnant water, which allows it to spread more easily. There have been lots of complaints about this weed from HOAs. Reducing duckweed requires diligence in keeping pond N and P concentrations low. Topical herbicides are available to spray on duckweed, and it is best to use during early signs of growth to reduce the prolific spreading that can occur.



Source: <https://www.thepondguy.com/duckweed/>



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