Controlling Water Quality and Algae Blooms In Valley Lake

By

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Abstract

Literature on phosphorus and experiments on lakes with the addition of phosphorus is extensive. Also common is writing on algal blooms. However, there is a lack of literature on the effects of chemical treatments of lakes, specifically residential lakes, that experience algal blooms. A professional consultant administered bi-weekly treatments for algal blooms in Valley Lake, a small residential lake located in northeastern Illinois during the summer of 2005. Water sampling was done to follows the affects the treatments had on turbidity, % transmittance (another measure of clarity), and phosphorus. No significant statistical difference was observed in lake conditions when treated or left to rest for a week, with a minor exception to the % transmittance at the 1-meter depth. The overall changes in the variables, a treated vs. nontreated, and an individual treatment approach are taken to explore the dynamics of Valley Lake. The clarity of the lake was at its highest before spring turnover and steadily declined throughout the summer. Phosphorus levels varied slightly but did not appear to be greatly impacted by the treatments, possibly due to internal nutrient cycling. To improve water quality the dredging of bottom sediments may be required.

Literature Review

Water Quality

Good water quality is essential to support a diverse abundance of organisms. When a lake is subjected to an influx of nutrients stimulation of plant growth occurs and biodiversity suffers due to a decrease in water quality. This nutrient enrichment is called eutrophication; eutrophic environments undergo succession rapidly. In a eutrophic lake excesses of nutrients can lead to algal blooms, which take away from the aesthetics of the lake and can hamper recreational use of the lake. Typically, increased phosphorus leads to increased algal blooms, which leads to accelerated plant growth. Reversing the negative impacts of algae is extremely challenging.

Generally a healthy lake has low levels of phosphorus. Excesses levels of phosphorus leads to a eutrophic lake and water quality commonly referred to as "pea soup." Phosphorus can come from fertilizer runoff, nutrients from soil erosion, storm water, agricultural runoff, sewage, or pollution that occurs within a watershed. All extra nutrients applied to a watershed eventually reach lakes, streams, and ponds.

A nutrient increase can adversely affect aquatic systems since algae are able to quickly take up excess phosphorus and leave other plants in need. Algae also can out compete other plants for sunlight. The algae life cycle experiences drastic fluctuations.

With an influx of excess nutrients algal numbers increase rapidl, and as the life cycles end massive numbers of algae die. As these dead algae decompose they use up a lot of oxygen, which can cause a fish kill.

Abrupt changes in algae numbers do not always occur. A bloom is able to maintain itself by surplus nutrients, or more specifically, by an influx of the limiting nutrient (Emsley 1976). Excess plant growth adversely affects ecosystems by disrupting normal functions and changing competition dynamics. Algal blooms are a natural part of succession, but succession usually takes hundreds or thousands of years. Humans accelerate this process by adding to the nutrients of a system in a process called cultural eutrophication. If a bloom is sustained then the results are disastrous for other species that share the same environment. Humans are adversely affected by decreased recreation and aesthetic enjoyment. Eutrophication is more than just nuisance plant growth; it is considered a form of nonpoint pollution and is a relatively recent environmental problem. It is usually impossible to pinpoint the exact source of extra nutrients contributing to eutrophication, so it is therefore difficult to stop the influx and slow the process.

Water Chemistry

Balance of an ecosystem is complex. An average cycle for a lake includes a low spring biomass that builds up to a maximum in June or July, and then a decline in total biomass in late summer. Biomass includes all living matter within the lake. Two major processes govern biomass: photosynthesis and respiration, which dictate the oxygen available in both the atmosphere and water (Emsley 1976). Dissolved oxygen is just one water chemistry component that needs to be understood when managing a lake.

The ultimate goals in aquatic restoration projects are stability and self-maintenance (Dohner 1995). To achieve restoration one has to use existing knowledge about the complexities of a lake. Phosphorus and nitrogen cycles play vital roles in the development of aquatic plant life. According to Liebig's Law of the Minimum (1855) plants growth can be "limited by the nutrient that is present in the environment in the least quantity relative to plant demands for growth" (Smith 1999). To grow plants need both phosphorus and nitrogen, and a lack of one may inhibit growth of an organism, because it limits the other. In eutrophic or oligiotrophic lakes, lakes extremely high or low in nutrients, nitrogen is usually the limiting factor since phosphorus is often abundant. It does not matter how much nitrogen is present if phosphorus is in short supply since both nutrients are needed for growth; phosphorus limits nitrogen and may not allow an organism to grow. Without nitrogen the excess of phosphorus may not be useful in plant development.

Nitrogen

Nitrogen is readily found in the air as nitrogen gas, but this form is not readily available to plants. Instead, nitrogen from the air, N_2, must be converted into the ammonia form of nitrogen (NH^+_4) by algae and bacteria before it can be use by other organisms. Through decay, excretion, bacterial denitrification and bacterial nitrification nitrogen changes forms between NO^-_3, NO^-_2, NH^+_4 and N_2 gas.

In addition to its gaseous form, nitrogen may be found in soil and water in the forms of nitrate, nitrite or ammonia. "The availability of various nitrogen compounds influences the variety, abundance, and nutritional value of aquatic animals and plants" (Goldman 1983). Since nitrogen is easily lost and is often short in supply, it often acts as a limitation to growth.

Phosphorus

In eutrophic systems phosphorus is high and nitrogen will be the limiting factor. Aquatic plants need phosphorus in small amounts, though phytoplanktons are only able to use phosphorus in the phosphate form (PO_4) for growth. Some algae are successful at creating algae blooms at phosphate concentrations as low as .02mg phosphate/liter (Emsley 1976). However, it is more typical for algal blooms to occur at levels of .05mg of phosphate/liter. After this bloom occurs the inorganic phosphate concentration may be reduced to .005mg of phosphate/liter.

Sources of phosphorus are vast. In the spring, ice from winter melts, temperature gradients in a lake invert, and spring turn over occurs, mixing nutrients in the water column. After spring turn over, algae grow exponentially and can exploit all available phosphorus. After this initial growth algae use the phosphorus from animal excretions, sediments, and eroded soil. Agricultural, domestic, and industrial wastes are major sources of phosphate that are readably used by algae, and therefore contribute to lake eutrophication. Phosphorus can be taken up in a matter of minutes (Schindler 1974).

Algae grow exponentially with excess phosphorus, but are also able to overcome circumstances where phosphorus may not be available. When phosphorus concentrations are low algae rely on luxury consumption. Luxury consumption is when algal cells store more phosphorus than is needed for cell growth and use their own phosphorus when an outside source cannot be found (Goldman 1983). Algae recycle phosphates quickly, so when levels are low more cell divisions can occur. According to Emsley (1976), after the death of plankton up to 90% of all the organism's phosphorus is released within one day. Another technique algae have to survive phosphorus deficits is alkaline phosphatase production (Goldman 1983). This enzyme is able to separate phosphate from larger organic molecules in the water and sediment, making it available for algal growth.

Lake Sediment

Because there is more phosphorus in the sediment than in the lake water, sediment samples can be used to determine the relative fertility of a lake (Goldman 1982). Lake sediment is "made up of precipitated solids, settled mud and other inorganic and organic debris" (Emsley 1976). Lakes with higher percentages of clay as part of the bottom sediment may be able to hold more phosphorus due to the properties of clay. Mixing of sediments has an adverse effect on water clarity and contributes to algal blooms. Lake sediments can be mixed by organisms, such as carp, and are an important interface for chemical processes. The most important chemical process is the transfer of phosphorus from a solid to a soluble phosphate, which can then be used by algae.

Case Studies

Processes of phosphorus transfer and the importance of phosphorus are still debated within the scientific community. Scientists have taken a hands-on approach and have used experimental manipulations to try to understand natural processes.

These past experiments, such as those on the Experimental Lakes in northwestern Ontario, have helped illustrate the complexities of water pollution, such as eutrophication. In 1965 the Canadian government set aside 56 lakes for research after the Canadian and United States governments started questioning transboundary pollution from Canada into the Great Lakes. Each lake is numbered and records are kept of the experimental history of each.

Schindler 1974 studied the relationship between carbon, nitrogen, and phosphorus in Lake 226. A sea curtain divided the lake and each side was nutrient loaded with nitrogen and carbon. One side was also loaded with excess phosphorus. The authors (Schindler 1974) found obvious differences between the two sides: the side with the extra phosphorus looked like pea soup and algal blooms covered the entire surface, while the other side remained clear.

Before Schindler performed his experiments on Lakes 226 and 227 it was commonly thought that carbon controlled eutrophication. However, carbon dioxide in air can offer a supply carbon and keep up with phosphorus concentrations (Schindler 1977). Schindler found that despite varying ratios of phosphorus to nitrogen (14:1 or 5:1) algae were still able to dominate. Phosphorus does not have a gaseous form like carbon, but depending on the type of algae different nutrients are the limiting factors and algae can still dominate an aquatic system.

In addition to looking at the input of phosphorus, Schindler carried out a similar experiment in Lake 227 and observed that the lake recovered quickly when phosphorus additions were stopped. Despite the relationship of growth of algae with increased phosphorus Schindler (1974) maintains that phosphorus cannot be used to indicate whether or not a lake will develop algal blooms. Lakes are complex systems and to use just one variable as a predictor is not completely accurate; nitrogen levels should also be considered.

Changing phosphorus levels will not necessarily result in a decreased algal mass, as was found with Gull Lake between 1974 and 1978. Despite voluntary efforts to reduce phosphorus loading in Gull Lake, MI, eutrophication rates did not slow (Moss 1980). Residents changed fertilizer practices and eliminated a pile of woodchips that was decomposing into the lake. The lack of change may be due to a lag between decreasing phosphorus levels and decreased algal mass. With the reductions in phosphorus the lake did not experience positive improvement, but it did not deteriorate further either.

In April 1992 English people from the north and south basins of Windermere, Cumbria took a more forceful approach; they used tertiary chemical stripping of the phosphates at sewage treatment plants to solve their nutrient problem. The site had been experiencing an influx of nutrients since 1945 and the basins had an overabundance of

Cladophora (a green filamentous macroalga). Through chemical stripping using ferric salts a remarkable and quick response was noted. Success in this case was dependent on the removal of nutrients from the water (Parker 2000).

Restoration Options

Trying to understand the complex relationships between nutrients, natural processes and organisms in aquatic ecosystems is difficult yet vital if restoration goals are to be met. If trying to change an ecosystem it may be helpful to distinguish between *restoration* and *rehabilitation*. The idea of restoration denotes wanting "the system to return to its former condition," while rehabilitation is the "process of renewing and maintaining ecosystem health" (Dohner 1995). Restoration of natural habitats includes both biological and chemical components.

Biological Control

Biological control is when one species is introduced to control another. An example of this is the addition of farm animals to a field with a weed problem in order to control weed growth. The farm animals eat the weeds, weed growth is controlled, and little human effort is needed.

In aquatic systems, introducing triploid, sterile carp is common to help combat unwanted aquatic weeds. However, the addition of carp, or any biological control, should be considered carefully since it could worsen the problem. Carp provide a cheaper alternative than routinely applying aquatic herbicides, but they may provide new challenges. Carp either eat everything or nothing (IDNR 2004). Additionally, "carp can be a significant internal nutrient source and can physically disturb the lake bottom, thereby contributing to problems of high lake turbidity and productivity" (Dohner 1995).

Carp add to an algae problem by stirring up muck on the bottom while feeding. In addition to releasing the phosphorus that is not tied up in plants and encouraging algal blooms, this increased turbidity hinders the ability of other plants to grow due to lack of sunlight. Even if other plants were to grow, the carp would eat them. Increased turbidity, or decreased clarity, also impairs the ability of other fish to feed, especially those such as bass that depend on their sight to catch prey. The addition of carp to a lake may result in muddy water with algae blooms and a lack of other aquatic vegetation to add stability to bottom sediments.

Riparian Zones

A more stable way of improving water quality than biological introductions is the use of riparian zones, or the addition of plants to create a buffer zone. These zones offer natural ways to add beauty, decrease erosion, absorb extra nutrients stabilize shoreline, prevent flooding, and inhibiting erosion. Riparian zones are commonly used to decrease runoff from agricultural and homeowner's lawn fertilizers. Water quality is improved since there are fewer nutrients in the water that can add to an algal bloom.

Using riparian zones as a restoration option is one of the best solutions to consider. After the initial cost of implementation and once the plants are established (after a few growing seasons) there is very little effort needed from a landowner for this option. Mowing once a year will maintain a riparian zone.

In addition to being easy to use, the added plants also filter and absorb nutrients while physically stopping sediment from entering the water. Buffer strips can trap 70-95% of sediments and 25-60% of nutrients and pollutants from runoff (Colwell 2001). These zones can be made up of native terrestrial plants, submerged plants, and even trees, such as willow trees, which have a high affinity for water. In addition to improving water quality, the plants also create a habitat for small fish and insects, which helps increase the biological diversity of the area and the plants themselves add to biological richness. These two processes make riparian zones extremely important.

If creating a whole shoreline of native plants is not possible, there are other organic control options available. Placing yellow barley straw or yellow wheat straw in lakes may help improve water quality. Bacteria, oxygen and warm water trigger the decomposition of the straw. The straw is broken down into lignin; the lignin then oxidizes into homic acids, and when homic acids are combined with sunlight and oxygen they can destroy algae with no effect on higher plant and aquatic life (Illinois Department of Natural Resources 2005).

In water deeper than one meter, dyes can be used to reduce the amount of sunlight in the water column (IDNR 2005). Since plants depend on sunlight for photosynthesis, cutting this resource off to them would result in death, but plants that are wanted may also be killed. Organic dyes could be used that would not harm fish; however, the lake would have an artificial appearance and this is a temporary solution. Again, this would only be effective at depths greater than one meter, and would not be effective at preventing algal mats on the surface of a body of water.

Oxygenation

Limiting the energy sources available for algal growth is another restoration tactic. When dissolved oxygen is less than 2mg/L at the sediment-water interface phosphorus is released from its solid ferric (hydr)oxide form; if oxygen levels remain above 2mg/L then the phosphorus should remain fixed (Gächter 1998). Based on this it was thought that lakes internal phosphorus cycling could be limited by maintaining an aerobic hypolimnion (the bottom and most dense area of water) and an aerobic sediment surface.

In 1983 oxygenation was considered one of the safest and cheapest methods of dealing with eutrophication problems (Goldman 1983). However, Gächter (1998) studied the effect of oxygenation in Lake Sempach and Lake Baldegg, two eutrophic lakes, for the Swiss Federal Institute of Environmental Science and Technology (EAWAG). Her ten-year study shows that added oxygen does not affect internal phosphorus cycling and therefore is not an effective way to treat algal blooms. The only effective cure was decreasing phosphorus loadings after new regulations for detergent phosphorus content and effluent treatments were put into effect; success was not related to aerators (Gächter 1998). Oxygen was found to not affect phosphorus in sediments, so it does not have a lasting effect on the trophic state of the water (Gächter 1998).

Using aerators, as a way to influence algal blooms, is still not completely accepted. Though oxygenation is not self-maintaining and they do not permanently lower phosphorus content, they may help fish and fauna by proving them with more oxygen for life functions.

Chemical Treatments

A pond or lake completely void of plant life should not be the goal; plants are needed in healthy water environments to increase biodiversity, complete nutrient cycles, and provide stability. However, to defend against overly aggressive plants aquatic herbicides are often used. This option can be expensive and more than one application is usually needed.

Aquatic herbicides are a common tool in lake management but due to complexities in water chemistry it is still difficult to "control" lakes. Permits are required to handle certain chemicals, and if these chemicals are applied incorrectly, adverse effects can occur. It is possible to kill fish or plant life that is desirable.

Many herbicides work by making phosphorus precipitate out or by inactivating it. Some options include buffered aluminum sulfate (alum), ferric alum, calcium salts, and copper sulfate. The treatments can come in powder, granular, liquid, or pellet form. Alum works by binding with water borne phosphorus and forms a flocculent layer that settles on the bottom sediments. This flocculent layer doubles as a boundary that helps limit the addition of sediment-bound phosphorus to the water column. However, this option is expensive, requires that external inputs of phosphorus stop, and results vary widely, from one to twenty years (Colwell 2001).

Algaecides kill algae specifically and come at low cost. If applied properly vascular plants and wildlife are not affected. With algaecides health risks from algae can be decreased while clarity, aesthetics, property value, and recreation can all improve. However, adding chemicals to a lake may cause buildup of elements such as copper that could cause future problems; special disposal of sediments in the future may be necessary (Colwell 2001).

Many different brands of chemicals are available, and care should be taken to ensure that application is done correctly. Treatments can be toxic to people or pets if done improperly and killing everything or nothing results in a waste of money. Often a bathymetric map is needed to know how much water is in a lake so accurate amounts can be applied.

Homeowners can use some general herbicides if they own the land, but licenses are required if more than two individuals own waters or when the chemical is of a higher grade (IDNR 2004). Some popular brands include Cutrine Plus, Reward, Cutrine Ultra, and Cleargate. However, these chemicals are not always cheap. The algicide Cutrine Plus (a chelated copper product) costs $35/gallon, and a lake the size of the study lake requires between 29 and 86 gallons for a treatment (Colwell 2001).

It is difficult to accurately treat a lake for unwanted vegetation because the chemistry of each lake is different. The Illinois Department of Natural Resources (2005) suggests doing treatments before July 1st, since at this time most plants are still young and have not reached the seedling stage. The best applications are completed early in the day when conditions are sunny and the water temperature is above 60 degrees Fahrenheit. Treatments also require care since too strong of an application may kill not only algae or seaweed, but also fish. The goal is not to completely eliminate algal blooms, but instead to return them to their natural cycle.

Despite the abundance of aquatic herbicides and algaecides, there is not much literature on the affects they have on lakes. High levels of phosphorus and nitrogen typically lead to increases in algae production in aquatic ecosystems. In turn, this excess of nutrients and resulting algal blooms can cause a chain reaction of deterioration in water quality. Specifically, this results in high turbidity, low transmittance of light, and can hinder recreational use of the location. Valley Lake, a small manmade lake in north eastern Illinois was treated bi-weekly for algae blooms using a combination of the aforementioned chemicals. If these treatments were effective I expected to see low, stable levels of phosphorus and turbidity, with high light transmittance because algal blooms will be controlled.

To see if the chemical treatments significantly improve the water quality in Valley Lake I will test the following:

Turbidity:

Pretreatment vs. Treated

H_O= Mean Turbidity Pretreatment = Mean Turbidity Treated
H_A= Mean Turbidity Pretreatment > Mean Turbidity Treated
Pretreatment vs. Nontreated
H_O= Mean Turbidity Pretreatment = Mean Turbidity Nontreated
H_A= Mean Turbidity Pretreatment > Mean Turbidity Nontreated
Treated vs. Nontreated
H_O= Mean Turbidity Treated = Mean Turbidity Nontreated
H_A= Mean Turbidity Treated > Mean Turbidity Nontreated

% Transmittance- Surface:

Pretreatment vs. Treated
H_O= Mean % Transmittance Pretreatment = Mean % Transmittance Treated

H_A= Mean % Transmittance Pretreatment > Mean % Transmittance Treated
Pretreatment vs. Nontreated
H_O= Mean % Transmittance Pretreatment = Mean % Transmittance Nontreated
H_A= Mean % Transmittance Pretreatment > Mean % Transmittance Nontreated
Treated vs. Nontreated
H_O= Mean % Transmittance Treated = Mean % Transmittance Nontreated
H_A= Mean % Transmittance Treated > Mean % Transmittance Nontreated

% Transmittance- 1-Meter:

Pretreatment vs. Treated
H_O= Mean % Transmittance Pretreatment = Mean % Transmittance Treated
H_A= Mean % Transmittance Pretreatment > Mean % Transmittance Treated
Pretreatment vs. Nontreated
H_O= Mean % Transmittance Pretreatment = Mean % Transmittance Nontreated
H_A= Mean % Transmittance Pretreatment > Mean % Transmittance Nontreated
Treated vs. Nontreated
H_O= Mean % Transmittance Treated = Mean % Transmittance Nontreated
H_A= Mean % Transmittance Treated > Mean % Transmittance Nontreated

Phosphorus- Surface:

Pretreatment vs. Treated
H_O= Mean Phosphorus Pretreatment = Mean Phosphorus Treated
H_A= Mean Phosphorus Pretreatment > Mean Phosphorus Treated
Pretreatment vs. Nontreated
H_O= Mean Phosphorus Pretreatment = Mean Phosphorus Nontreated
H_A= Mean Phosphorus Pretreatment > Mean Phosphorus Nontreated
Treated vs. Nontreated
H_O= Mean Phosphorus Treated = Mean Phosphorus Nontreated
H_A= Mean Phosphorus Treated < Mean Phosphorus Nontreated

Phosphorus- 1-Meter:

Pretreatment vs. Treated
H_O= Mean Phosphorus Pretreatment = Mean Phosphorus Treated
H_A= Mean Phosphorus Pretreatment > Mean Phosphorus Treated
Pretreatment vs. Nontreated
H_O= Mean Phosphorus Pretreatment = Mean Phosphorus Nontreated
H_A= Mean Phosphorus Pretreatment > Mean Phosphorus Nontreated
Treated vs. Nontreated
H_O= Mean Phosphorus Treated = Mean Phosphorus Nontreated
H_A= Mean Phosphorus Treated < Mean Phosphorus Nontreated

Methods

Study Area

Valley Lake is a twelve-acre, man-made lake located in the Des Plaines River watershed in Lake County, IL. It was constructed in 1952 and has since been managed by the Wildwood Park District. The majority of the shoreline consists of residential lots, with the exception of two park district parks, one at the north end and one at the south. There are also three storm water inlets to the lake.

Valley Lake has an average depth of 1.44 meters and a maximum depth of 2.89 meters. It holds an estimated 18.6 million gallons of water and the shoreline length is 1.14 kilometers (Colwell 2001). Seventy percent of the shoreline consists of mowed turf grass, and sixty-one percent of the shoreline is slightly or moderately eroding (Colwell 2001). There is a high amount of waterfowl, and their feces contribute to high levels of phosphorus, along with runoff from lawn fertilizers.

An additional problem of low clarity is attributed to wind, wave, and carp action. The lake is shallow, and has no plants to stabilize sediments; therefore sediment is easily stirred into the water column. Road salt from winter months also contributes to dissolved solids in the water column. The average clarity of Valley Lake in 2000 was .97 meters, while the Lake County average was 1.52 meters (Colwell 2001).

Nitrogen concentrations are equal to or slightly lower than the Lake County average, but phosphorus levels were four times higher than other Lake County lakes (Colwell 2000). This extremely high level of phosphorus has actually lead the IDNR to label Valley Lake hypereutrophic (due to high levels of storm water, runoff, and waterfowl). A hypereutrophic lake has overabundant levels of nutrients experiences high levels of biological productivity, mostly from algal blooms. At Valley Lake, high phosphorus from fertilizers and internal cycling of nutrients are increasing algae production, which is a growing concern for local citizens.

Algal problems primarily started in 1988 when the Wildwood Park District added 225 sterile grass eating carp to help control elodea, a waterweed, growth. Later, in 2000, the Illinois Department of Natural Resources wrote that elodea was not at nuisance levels, but regardless the fish were still stocked. The fish ate everything in the lake, even creating a browsing line by eating overhanging plants, and this left the lake with high levels of turbidity, sediments easily resuspended, and algal blooms. The same day the carp were added, the DNR reduced the stocking ratio, but it was too late. Numerous attempts to capture the grass eating carp have been made, but results have been minimal. The life expectancy of the sterile fish is 15-20 years, so their life cycle should be coming to an end, since they, at least theoretically, cannot have any offspring.

While waiting for the carp to die, much effort has gone into trying to keep water quality levels high, but with varied results. Historically, the park district has struggled with plant and algae control treatments. Before the carp were added, a partial treatment targeting weeds and costing $125 was done in 1985 (Ellison 2005). Since the carp addition in 1988, the lake has been treated with copper sulfate to control algae growth. The IDNR has restocked other fish, including bass and bluegill, almost yearly. The amount of copper sulfate that has been used to control algal blooms at least doubled between 1988 and 2000.

Copper sulfate is just a quick remedy, a contact killer, and long-term restoration needed to be implemented. To "fix" the lake the park district considered alum treatment, revegetation, and limiting external sources of nutrients. In their 2000 study, the IDNR created a potential management plan, which is as follows:

"I. Created a Bathymetric Map
II. Remove Grass Carp from the Lake
III. Reestablish Native Aquatic Vegetation
IV. Nuisance Algae Management Options
V. Mitigate Shoreline Erosion
VI. Remove Invasive Shoreline Plant Species
VII. Water Quality Protection with Watershed Controls
VIII. Maintain or Enhance Areas for Wildlife
IX. Alleviate Excessive Numbers of Waterfowl"

In 2005 the Valley Lake Conservation Committee was formed to help the park district make decisions regarding the lake. Aerators that had been running since 1981 were turned off to see if any effect was felt. New professional management was hired and my research was done to test out the effectiveness of the new treatments. Restoring a lake takes years, and the more information on hand about a lake the more informed decision-making could be. It is important to know about a lake, but this knowledge needs to be *applied* to make a difference.

Water sampling

Thirty sampling locations were chosen randomly by placing a grid over a map of the lake and choosing 30 of the sections. There were 52 grids and each was assigned a card from a standard deck of cards, the cards were shuffled and the first 30 cards pulled were the grids chosen. The middle of each square became the location for sampling and this location was revisited each time samples were taken. While in the field visual markers were used to relocate an x and y coordinate from the shore, which was sufficient for the small size of the lake.

Samples were taken every weekend between 10 AM and noon, starting May 24, 2005 and ending August 13, 2005. Two samples of 10ml were taken from each location at both the surface and either 1-meter down or as deep as possible without acquiring bottom sediments. The surface sample was taken by simply leaning over the side of the canoe. To collect the water from below the surface a one-liter water collector was used. The collector had a clear acrylic body so it was obvious to see if bottom sediments had been taken. The collector came with a nylon rope that was already calibrated. Samples were stored in 10ml glass bottles with rubber stoppers.

Lake Conditions

If wind was strong, an anchor was used to stabilize the canoe to ensure samples of the surface and below surface were at the same location. Paddles were used to gently maneuver the canoe without stirring bottom sediment.

Water temperature of both the surface and one meter below were recorded. Seven temperatures at each depth were taken (Lifeguard Little Time or Temp digital thermometer) and averaged to create an average temperature of the water at the time of sampling. Any other observations were also recorded, including if people were swimming, important weather conditions for the week, and general observations of water quality.

A secchi disk was used to measure turbidity at each location. The line of the secchi disk was calibrated in inches by the Illinois Health Department. Measurements were converted to meters during data recording.

Water Chemistry

All samples were tested directly after collection. Percent Transmittance was tested for each location and depth using a Spectrometer set at green, or 565nm. To zero the spectrometer, a sample of distilled water was used and then the equipment was calibrated. The spectrometer can transmit several colors, but green (wavelength 565nm) was chosen because it is in the middle of the spectrum and would be good at singling out sediment and algae in the sample.

Phosphorus was measured using a simple Seachem phosphorus test. The resolution for this test was 0.01mg/liter, but it was impossible to decipher between the 0.01 increments, so 0.05 increments were used instead.

Nitrogen was measured using a Seachem nitrogen test. The resolution for this test was 0.02 mg/liter. It was impossible to accurately decipher between shades of blue on the test results strip, so an interval of 0.05 mg/liter was chosen instead.

All plates and test tubes were cleaned after each test with distilled water and dried with paper towel to ensure that the last test done with the same equipment did not affect the following test.

<u>Results</u>

To assess the effectiveness of the treatments on the lake over the course of the summer the overall Turbidity (Figure 1), % Transmittance (Figure 2), and Phosphorus (Figure 3) results were compiled and an average for each sample day was calculated. Tests done on nitrogen continually showed 0.00mg (results not shown). Raw data for each variable at each depth throughout the sampling dates can be found in Appendix A.

The beginning of the testing had the highest clarity, and as the summer progressed clarity decreased. Although treatments were done throughout the summer, the quality of the clarity and % transmittance never returned to pretreatment levels. Turbidity steadily increased throughout the summer, with the exception of June 25th, where the treatment seems to have had an effect. The turbidity decreased (transparency increased) and the secchi disk could still be seen at 1.34m, an improvement from the 0.9m of the week before. Overall, turbidity decreased from 1.64m to 0.24m by the end of the summer. While there may have been fluctuations throughout, the water quality slowly deteriorated, at a rate of approximately .1m/week. Figure 1 shows the average turbidity for each sampling date throughout the summer.

Figure 1. Average Turbidity

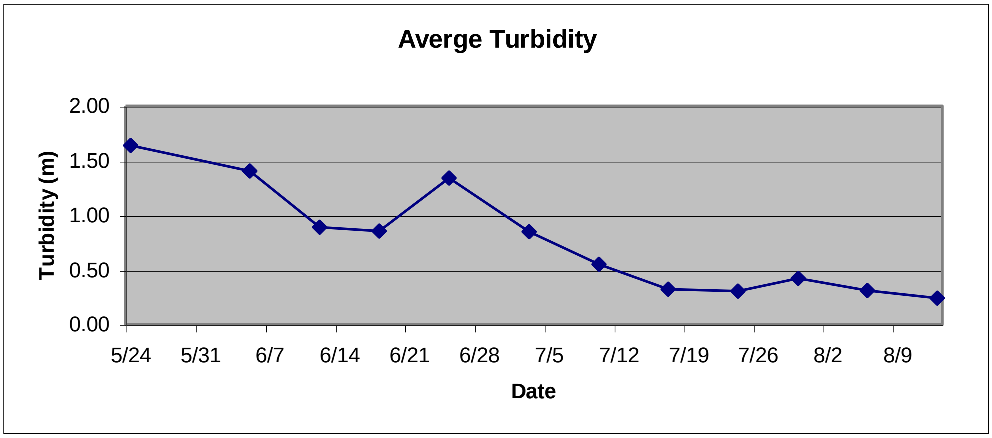


Figure 2 illustrates the average % transmittance of both the one-meter and surface; this is another measure of sediments in the water. % Transmittance quantifies the amount of light available to algae and provides further information of the clarity of the water. As expected, the % transmittance follows the same trend as the turbidity. The highest clarity was at the beginning of the summer and a steady decrease in the quality of the water occurred throughout the summer. The 1-meter samples generally had more light pass through them than did the surface samples. % Transmittance averages stayed between 79 and 96% throughout the summer. Values started in the 90's, fluctuated between 80's and 90's and ended by fluctuating in the low 80's.

Figure 2. Average % Transmittance

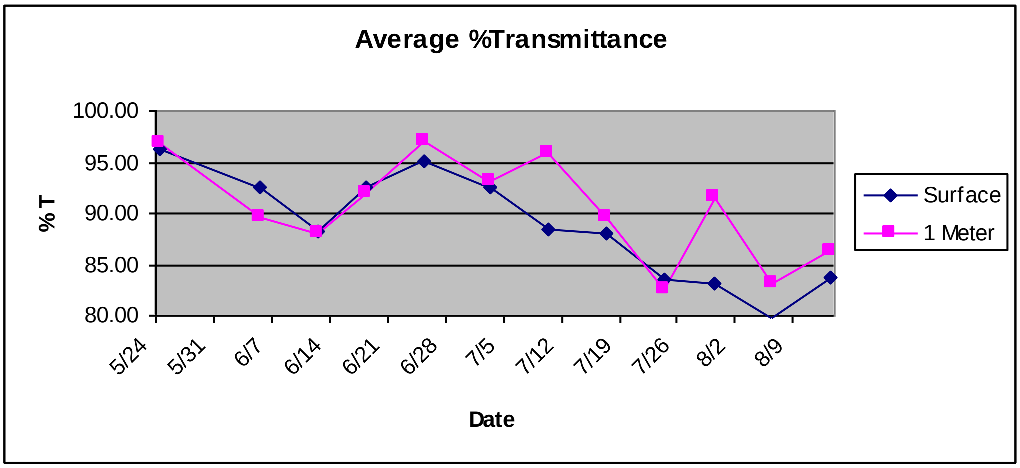
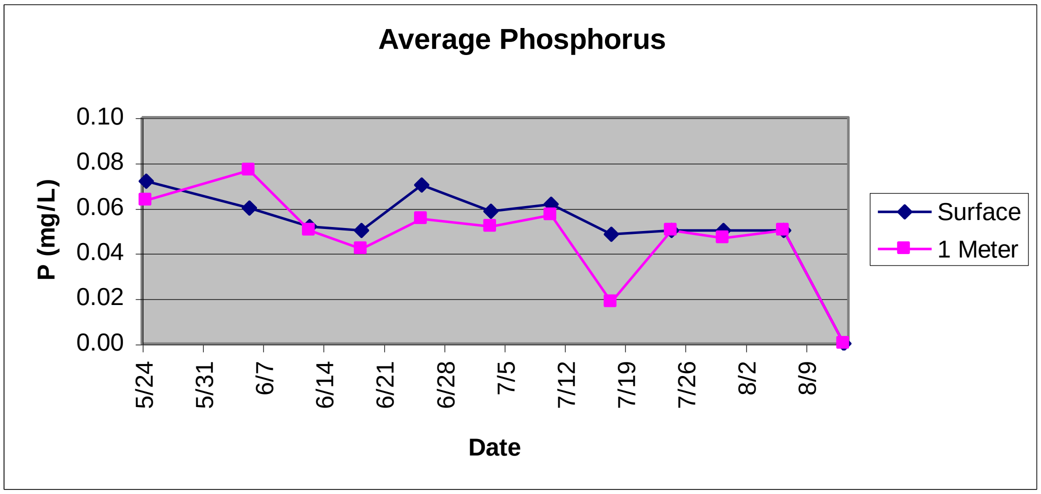


Figure 3 shows the average available phosphorus at each of the sample dates. The beginning of sampling revealed the highest amount of available phosphorus with averages of .07 mg/l at the surface and .06 mg/l at 1-meter. Phosphorus levels remained relatively stable, despite bi-weekly treatments to inactivate, or decrease phosphorus. The test used to quantify phosphorus used a color gradient. Since 0.05 incriments were used there may have been trace amounts of phosphorus during the last sample date, but the color of the tests were closer to 0.00 mg/l than 0.05 mg/l.

Figure 3. Average Phosphorus



Looking at the results for overall summer patterns was one way to analyze the data collected. It is also helpful to divide the weeks of sampling between treated and nontreated, to measure the impact of the treatments. A treated sample day is one that follows right after a professional treatment. A nontreated sample day is one that does not have a treatment during the same week, but is usually a week and a half after a treatment. Table 1 classifies the dates as pretreatment, treated, or nontreated and includes the dates of treatments.

Table 1. Date Classifications

Date	**Activity**	**Sample Classification**
24-May	Sampled	Pretreatment
5-Jun	Sampled	Pretreatment
1. June 6	*Treated*	
12-Jun	Sampled	Treated
18-Jun	Sampled	Nontreated
2. June 20	*Treated*	
25-Jun	Sampled	Treated
3-Jul	Sampled	Nontreated
10-Jul	Sampled	Not considered
3. July 11	*Treated*	
17-Jul	Sampled	Treated
24-Jul	Sampled	Nontreated
4. July 25	*Treated*	
30-Jul	Sampled	Treated
6-Aug	Sampled	Nontreated
5. August 8	*Treated*	
13-Aug	Sampled	Treated

Once the dates for treated and nontreated were established, the data for the corresponding groups were then compiled and the resulting averages and standard deviations for each of the variables turbidity, % transmittance and phosphorus could be calculated. The differences between the treated and nontreated days for the variables are small. The pretreatment for turbidity averaged 1.52 meters. Treated weeks averaged 0.64 meters, with a standard deviation of 0.42 meters, while nontreated weeks had an only slightly higher average of 0.58 meters, but a smaller standard deviation with 0.28 meters.

Turbidity is slightly lower (clearer) when treated, but phosphorus and % transmittance are very similar with or without treatments. The % transmittance pretreatment values start off the season for both the surface and 1-meter at approximately the same value (94.43 surface/94.75 1-meter). At the surface, % transmittance remained at 87% (87.67% treated, 87.15% nontreated) when treated or nontreated, and was improved from 87.67% to 90.49% at 1-meter when treated. The baselines of each variable differ considerably from the treated and nontreated variables, with much clearer water (lower turbidity), higher light transmittance, and more phosphorus.

Table 2. Results Summary

	mean (std dev)	
Turbidity (m)	Surface	
Pretreatment	1.52 (.29)	
Treated	0.64 (.42)	
Nontreated	0.58 (.28)	
% Transmittance Average	*mean (std dev)*	
	Surface	1 meter
Pretreatment	94.43 (5.10)	94.75 (2.62)
Treated	87.67 (10.80)	90.49 (4.15)
Nontreated	87.15 (6.73)	87.67 (5.25)
	mean (std dev)	
Phosphorus (mg)	Surface	1 meter
Pretreatment	0.07 (.02)	0.07 (.03)
Treated	0.04 (.03)	0.03 (.03)
Nontreated	0.05 (.01)	0.05 (.01)

To determine whether or not the values obtained for each variable were statistically significant, z-tests were performed. The tests and hypothesizes for each were listed previously. The results for these tests are found in Table 3. For each variable there was a significant difference for pretreatment vs. surface and the pretreatment vs. 1-meter. When considering treated vs. nontreated for each variable there was no significant difference fount at the 0.05 or 0.01 levels, except for the 1-meter % transmittance which did show a statistical difference.

Table 3. Significant Differences: Pretreatment, Treated, and Nontreated Samples

Turbidity	**Significance Level**	
	0.05	0.01
Pretreatment vs. Treated	Yes	Yes
Pretreatment vs. Nontreated	Yes	Yes
Treated vs. Nontreated	No	No

% Transmittance- Surface	**Significance Level**		**% Transmittance- 1-Meter**	**Significance Level**	
	0.05	0.01		0.05	0.01
Pretreatment vs. Treated	Yes	Yes	Pretreatment vs. Treated	Yes	Yes
Pretreatment vs. Nontreated	Yes	Yes	Pretreatment vs. Nontreated	Yes	Yes
Treated vs. Nontreated	No	No	Treated vs. Nontreated	Yes	No

Phosphorous- Surface	**Significance Level**		**Phosphorous- 1-Meter**	**Significance Level**	
	0.05	0.01		0.05	0.01
Pretreatment vs. Treated	No	No	Pretreatment vs. Treated	No	No
Pretreatment vs. Nontreated	No	No	Pretreatment vs. Nontreated	No	No
Treated vs. Nontreated	No	No	Treated vs. Nontreated	No	No

To further explain the collected data, each individual treatment will be looked at. Table 4 gives a summary of the averages for turbidity, % transmittance, and phosphorus for each of the individual five treatments. The chemicals used each time were different. Pretreatment values show the greatest water quality and with time quality decreases. When considering treated versus nontreated, it was expected that phosphorus would be lower, that turbidiy would be lower (higher value), and that % transmittance would be higher, however this was not always the case. For example, after the June 6th treatment, the % transmittance at both the surface and 1-meter was actually higher when not treated than right after the treatment.

Table 4. Treatment Summaries

Date	**Analyzed**	**Chemicals**	**Turbidity**	**% T (Surface)**	**% T (1-Meter)**	**Phos. (Surface)**	**Phos. (1-Meter)**
24-May	Pretreatment		1.64	96	96	0.07	0.06
5-Jun	Pretreatment		1.4	92	89	0.06	0.08
6-Jun	*Treated*	2.5 gal Cutrine Ultra					
		1 gal Reward					
12-Jun	Treated		0.89	88	88	0.05	0.05
18-Jun	Nontreated		0.9	92	91	0.05	0.04
20-Jun	*Treated*	3.5 gal Cutrine Ultra					
		.5 gal Reward					
25-Jun	Treated		1.34	95	96	0.07	0.06
3-Jul	Nontreated		0.85	92	93	0.06	0.05
11-Jul	*Treated*	2 gal Cutrine					
		1.5 gal Cleargate					
		.5 gal Reward					
17-Jul	Treated		0.32	88	89	0.05	0.05
24-Jul	Nontreated		0.3	83	82	0.05	0.05
25-Jul	*Treated*	5 gal Cutrine Ultra					
		5 gal Cleargate					
		24 oz. Reward					
30-Jul	Treated		0.42	83	91	0.05	0.05
6-Aug	Nontreated		0.31	79	83	0.05	0.05
8-Aug	*Treated*	5 gal Cutrine					

		.5 gal Reward									
13-Aug	Treated		0.24		83		86		0		0

Discussion

Overall Trends

According to Parker (2000), lakes recover slowly from nutrient enrichment when external inputs are reduced. Deep lakes are able to recover relatively quickly since internal cycling is low. Shallow lakes are especially slow to recover since the internal cycling of phosphorus from the sediments delay the reduction of total phosphorus. Valley Lake is a very shallow lake, and the difficulty of treating it was reflected in the results obtained.

The overall patterns for turbidity and % transmittance follow the standard biomass cycles for a lake. The average lake has a low spring biomass and a maximum biomass in June or July. This pattern is reflected in the clarity of Valley Lake, which is high in the beginning of the summer when algal growth is low and there are high levels of phosphorus available. Towards the end of the summer, clarity and % transmittance are low due to sediment mixing and algae dominating the system. Eutrophication of the lake is reflected in the decrease in light transmittance and increase in turbidity. Algal growth is stable until spring turnover, when nutrients are then mixed due to inversing temperature gradients in the water. Once these nutrients become available algal blooms grow and decrease turbidity and light transmittance. The first two weeks of sampling show high clarity for the lake and represent time before spring turn over (see Figure 1).

To further study the clarity a spectrometer was used. By using a spectrometer the values for the surface and 1-meter could be distinguished from each other, which would not be possible if the measurements were made with a secchi disk that is lowered from the surface. Both are measurements of clarity and sediments. For the majority of the sample dates the light transmittance was greater for the water samples from 1-meter than from the surface (see Figure 2). Lower transmittance for surface waters are most likely due to the algae on the surface of the lake, which is caused by the high amount of sunlight available. Sediment in the water column, along with algae, help explain the variations in the % transmittance at 1-meter. The variations between individual samples at 1-meter depth were less than variations at the surface, where results were less stable.

Surface results of % transmittance follow closely the same pattern as the turbidity. The 1-meter results are sometimes above and sometimes below the surface results, and this may be due to sediment in the water column or differences in amount of algae. There may be more algae on the surface than below the surface, or vice versa. If an algal bloom is growing it may take up surface area to absorb sunlight, or if it is dying then phytoplankton may be sinking to the bottom, leaving the surface a little clearer.

Trying to predict clarity from phosphorus levels is quite difficult with the data obtained; phosphorus follows a different pattern than turbidity and % transmittance. The average phosphorus levels appear to remain relatively steady, but after the last treatment, in August, levels drop below measurable quantities (see Figure 3). Phosphorus levels started off highest in the beginning of the summer at 0.08mg/l at the surface and 0.07mg/l 1-meter down. As algae use phosphorus, levels decrease, and once the algae die nutrients are released.

The average transparency for the surface was lower than 1-meter, and it appears that the average phosphorus levels for the surface are higher; both of these indicate a stronger presence of algae at the surface. After spring turn over the available phosphorus at both depths wavers around the 0.05 level, until at the middle of August levels drop to untraceable levels. Phosphorus is difficult to explain since external inputs are impossible to monitor. The fertilizers people put on their lawns around Valley Lake and the excessive numbers of waterfowl that habitat the lake both contribute to phosphorus levels. It is likely that there is so much phosphorus in the lake water, sediments, and surrounding land (that happens to be partially eroding in several areas of the lake) that it will be extremely difficult to control phosphorus inputs. Yet phosphorus is very important to control, since it is the most influential nutrient when considering algal blooms.

Additionally, there are an unknown number of carp in the lake that stir up the bottom while feeding, which releases more nutrients that were trapped in the sediment. In 1988, 225 sterile grass eating carp were added to the lake and the number still surviving is unknown.

Treated vs. Nontreated

The results for the treated vs. nontreated sampling dates were somewhat disappointing. The research done proves what was already known: it is impossible to "fix" a lake in one summer. Despite the treatments, the quality of the lake still declined throughout the summer. There was not a significant statistical difference between the treated and nontreated samples for all of the variables except for the % transmittance at 1-meter.

After the spring turnover, the clarity of the lake decreased significantly. The treatments may have offered some help to the clarity problem of the lake, but the treatments did not offer stability. There was a statistically significant difference between pretreatment samples and both treated and nontreated samples, due to spring turnover effects. If the treatments had been effective, the data would support a statistical difference between the treated and nontreated samples, but this was not achieved.

After algal blooms and a season of growing and treating, the average treated surface value remained at 87.67 and the 1-meter remained at 90.49. The average values remained relatively high while treated; however, the nontreated weeks did also. Large standard deviations for the treated samples at the surface are most likely due to a storm water inlet located in the northeast end of the lake. This area showed an obvious increase in the amount of algae, most likely due to an influx of excess nutrients from the inlet.

Phosphorus started the season off at 0.07 mg/l at both depths, with slightly more variation at the 1-meter level. There may have been more variation below the surface since spring turnover was occurring and the water column experienced mixing. When treated, both depths had a standard deviation of 0.03 mg/l, but there was slightly more phosphorus when treated. Compared to the 1-meter there was more phosphorus when treated. This is surprising since the treatments work to inactivate phosphorus by using copper, which then sinks to the bottom. Perhaps there is an influx of phosphorus from outside sources.

When not treated, the water contained the same amount of phosphorus at both the surface and at 1-meter, 0.05 mg/l, with 0.01 as the standard deviation. Differences in phosphorus levels between treated and nontreated samples were small and not statistically significant. However, according to Emsley (1976), some algae can create blooms with only 0.02mg/l of phosphorus available, so the few hundreds of a milligram difference may be important, and even these small changes may be positive progress. The 1-meter levels of phosphorus did show a 0.02mg/l drop when treated.

Individual Treatment- Possible Complications

Each treatment done to the lake was unique. Each time the outside variables of the physical lake condition were different and different chemical combinations were used to treat each time. The chemicals used for each treatment can be found in Table 4.

During the June 12th sampling, following the June 6th treatment, many ducks were present, so that may account for the minimal decrease in phosphorus levels. There were also numerous people at the beach, which may have increased the turbidity and decreased the % transmittance for the south end samples.

Sampling following the June 25th treatment showed an improvement in the turbidity readings, this may be due to minimal wind that week and lack of rain. Without rain, nutrients are not washed off people's lawns and into the lake, which means less "food" for algal blooms. However, phosphorus levels may have been able to maintain due to carp stirring up sediment and minimal erosion of the edge of lawns.

Results for post July 11th treatment show a dramatic increase in turbidity, and also a decrease in the % transmittance. Phosphorus levels decreased slightly, probably due to algal blooms using it. These weeks were extremely hot, windy, a microburst, or mini tornado ripped through the area, and heavy but short rain occurred. Debris was knocked into the lake, water levels were low, large trees around the perimeter were lost, and erosion occurred. It is surprising that the phosphorus levels did not increase, as external inputs were undoubtedly high during this time. It is possible that algal blooms used the new phosphorus and this explains the dramatic increase of turbidity, a high amount of suspended particles.

The July 25th treatment had the most chemicals applied. While the treated samples showed a slight improvement, the next week the quality of the water declined again. Algal chunks appeared and lots of debris from the microburst remained in the water. The entire east side of the lake had algae on the surface, presumably from wind. Using more chemical did not appear to have a lasting effect, as the nontreated samples reflected. More debris was removed from the lake during the latter week, but new nutrients would have already entered the water, which further complicated the work of "fixing" the lake.

The final treatment studied occurred on August 13th. The amount of chemicals applied decreased, and there was still no major improvement in the quality of the lake. The overall water level of the lake remained low, although it had improved from all the rain in the previous month. Instead of appearing in chunks, all the algae was in small suspended particles. Temperatures were cooler this week, but algal blooms were not affected.

Future Directions

Valley Lake will undergo another summer of treatments by the professional chosen by the Wildwood Park District. How the lake will be treated the summer of 2007 has yet to be determined. The Valley Lake Conservation Committee (VLCC), a committee of the Wildwood Park District will continue to seek solutions to reducing the eutrophication of the lake. VLCC is currently considering dredging as a possible permanent solution to internal nutrient cycling. By removing sediments there will be less nutrients available to algae. This option is a financial strain on the park district, so implementation of this will not be in the very near future, but it is an option to strive for.

Additionally, the VLCC is fundraising to introduce aquatic plants back into the lake. These plants will have to be fenced to prevent the carp from eating them. Benefits of the vegetation include: increase biodiversity, filtration of nutrients, beauty, and stability of sediments.

It is extremely difficult to attempt to control a lake, as there are so many variables that are out of human control. As it normally takes years for degradation to occur, it also takes years for improvement. With local interest, professional consultation, and time the VLCC and local residents hope to restore the water quality of Valley Lake for the sake of both homeowners and the organisms that call the lake home.

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