Interpreting and Using Water Quality Results

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Introduction

Most lakes have some water quality results. And many lake stewards and others have difficulty interpreting that information to find what it means in terms of ecological processes in the lake.

Some lakes have results for: all major nutrients, all trace nutrients, and all metals. These full spectrum analyses are uncommon due to their cost but the Ontario Ministry of the Environment (MOE) has done them on some lakes and rivers.

The most common measurement by lake associations is total phosphorus and water clarity (by Secchi disk). The Lake Partners Program of MOE provides total phosphorus analysis at no cost and maintains records for lake associations of their phosphorous and Secchi results over the years. Phosphorus is often measured also because many have heard of a model that uses total phosphorus to predict “lake development capacity” (how many cottages and homes can the lake tolerate).

Many lakes, especially those with lake trout, have measured temperature versus depth and have measured oxygen at specific depths.

The goal of this document is to help understand and interpret such water quality information. It is not a recipe; it is a discussion. In ecology, simplifications seldom hold true.

Why do we measure indicators of water quality?

We need early warnings that predict important changes in the lake’s ecological processes. Responses to warning signs will vary according to the values and priorities of lake users but will be some form of management intervention. Direct interventions should be guided and approved by professionals from Provincial Ministries and/or Conservation Authorities. Measurements of water quality variables will guide the nature of any such interventions.

What Do We Need to Know?

Major topics for many lake users and associations are:

1. What are the nutrient inflows to and levels in the lake and what are the consequences for the nature of the lake ecosystem?
2. What fish and other aquatic species are present and in what relative numbers?
3. Are there sources of unnatural pollution?
4. Are there any human health concerns?

What Do We Want from the Measurements?

Beyond getting baseline measurements and monitoring those water qualities over time, we want to watch for changes and trends in those changes.

To be sure about a trend requires a series of measurements all taken under comparable conditions. To detect a trend in total phosphorus in a lake on the shield using only one Lake Partners result per year, could take five years. Samples for Lake Partners are comparable because they are all taken following the same protocol, they are all taken in early May, at the start of the growing season when total phosphorus (TP) in the water should be near its maximum. If the second data point is either up or down, that does not establish a trend. If the second and the third data points are consistently different from the first, you might be alerted. The last 3 years of data may give a 'baseline' value for the lake but are not enough to establish a trend. But three points are unlikely to establish a trend because there is variability in measurements.

Variability comes from: how the water sample was taken, how it was stored and treated before it was analysed, and how it was analysed. For example, a single zooplankter not removed by filtering your water sample from a lake with 10 ug/L total phosphorus, can raise that reading to an erroneous 35 ug/L. Other variability can be added by sampling at incomparable times in the growing season and spatial variability comes from sampling different areas in a lake that are not ecologically comparable.

It is not uncommon for total phosphorus measurements to vary by 10% or even as much as 50% in samples from an unchanging lake situation. From 2% to 5% of TP data points can be "outliers". That is: points that do not match the majority of the data because they are erroneous. So don't make severe predictions based on any short series of data.

If you are using measurements to establish trends for the lake, you must choose the sampling locations so that they represent the whole lake. To do this is likely to require sampling at more than one location on most lakes.

Many lakes, especially those with lake trout, have measured temperature versus depth and have measured oxygen at depths. It is best to have a fisheries biologist interpret these measurements.

Lake Turnover

Lake turnover needs to be discussed in order to understand the seasonal supply and movement of nutrients and gases in the lake. All except very shallow lakes turn over each spring and each autumn. Water from the upper layers mixes completely with water from the deeper parts of the lake.

During summer, the surface layer of water (up to 6 or 7 metres) depending on the summer temperatures) heats up. That changes both the temperature and the density of the surface water. The difference in density between the surface layer and the water below it, keeps the two layers of water from mixing. They slide over each other like two plastic bags of milk. The greater the heating of the surface layer, the more difficult it is to mix them.

Heavy particles of dead algae and animal plankton settle down through the surface layer into the deep layer and eventually become part of the sediment in the lake bottom. Oxygen, which is dissolved in the water, enters at the water's surface and from the growth of green plants and algae. Since the water from the surface can't mix into the deep water, no additional oxygen gets into the deep water all summer.

In autumn, the surface water cools and reaches the same temperature and density as the deep water. With a little wind, the surface water gets mixed down into the deep water and the deep water mixes up to the surface. This "turnover" mixes oxygen, dissolved in the water, down into the deeper water to supply the fish, crayfish, insects and frogs over winter.

When winter's ice seals off most of the water in the lake from the air, the oxygen mixed into the water by autumn turnover is the only supply for both the active animals in the lake and for decomposition of dead organic matter that has built up over the growing season. If too much plant or algal matter has sunk to the bottom, decomposition could use too much oxygen and cause a "winter-kill" of sensitive fish species.

In spring, when the ice cover is removed, all the water in the lake is at the same temperature and therefore the same density and it is easy for the winds to mix the water from top to bottom. This "spring turnover" mixes nutrients such as phosphorus up from the sediments into the surface water where sunlight will allow algae and other green plants to use those nutrients in photosynthesis. It is common at this time to see a gradual growth of algae as a response to that fertilization

In summer, when water temperatures have maximized and conditions become stagnant, severe 'blooms' may develop. In some lakes, in shallow, stagnant water, blooms of blue-green algae may make the water look like bluish-green pea soup. Fresh blooms may smell like mowed grass, but soon they smell like rotting garbage. Although many species of blue-green algae are relatively harmless, it is good to be cautious. When the cells of some species are broken open, they release toxins (commonly *microcystins*) that can affect human health, either by contact or by ingestion. Most cottage water treatment systems will break open the algal cells and increase the risk. Prevention is the only reliable cure and simply requires reducing the inflow of nutrients into the lake, consistently, before any signs of blue-greens. For information on health risks of blue-greens, contact 1-800-268-1154, the Ministry of Health INFOline.

The Lake is your Garden

Understanding water quality results will be easier if you think of your lake as a garden (and your river as a flowing garden). The main focus will be nutrients. Water won't be scarce.

The major nutrients in garden fertilizer are: nitrogen, potassium and phosphorus. The major nutrients limiting, or promoting, plant growth in a lake are: carbon, nitrogen and phosphorus. The air supplies carbon as carbon dioxide which readily dissolves in water. Human activities affect the nitrogen and phosphorus supplied to lakes.

Just as your garden needs nutrients for plant growth, so do lake plants need nutrients but too much nutrient in a lake will cause too much plant growth and that will change the ecological processes, the responses of wild species and the human response to the results.

Interpreting Commonly Measured Water Quality Information

Nitrogen

Nitrogen can certainly promote algal growth but it is seldom measured because its supply into a lake is difficult for us to control. Compounds containing nitrogen dissolve readily in water and move freely. Some forms of nitrogen even move as gases from car exhausts and farm fertilizers.

Nitrogen does have one potential use in water quality issues. In one of its chemical forms, each nitrogen atom has two oxygens attached (NO_2) and is called "nitrite". Nitrite is common in freshly escaped septic waste. In oxygenated water, nitrite gains another oxygen and changes to "nitrate" quite rapidly. The presence of nitrite can be used to pinpoint the source of the escaping waste because it quickly turns to nitrate within a few metres of the escape point. Nitrite is not a common test but can be done by volunteers with the aid of a commercial 'kit'.

Phosphorus

Phosphorus may be carried into water attached to particles of soil or organic matter. This phosphorus moves in surface wash or in flows of particulate matter. Runoff from lawns, from erosion of organic matter on construction sites and along municipal ditches, and from farm manure are examples.

Some phosphorus enters lakes dissolved in water. Some bedrocks do contain phosphorus, but it dissolves out of the rock only slowly. Some phosphorus from the rocks gets into the air as dust and can be an important source for lakes downwind of quarries.

The main flow of phosphorus into lakes in our region is from septic wastes of humans in both dissolved and particulate forms. That means we have most of the phosphorus that can enter our lake in our pipes and tanks, and thus within our control. By restricting the flow of phosphorus from our infrastructure into our lakes, we can make phosphorus the nutrient that limits the growth of plants, including algae. The one nutrient that is in shortest supply relative to the needs for plant (algal) growth can control that growth. Phosphorus is vital to energy transfer in all living cells but only small amounts are needed. To control plant growth in the lake, we must hold the phosphorus concentration below that low concentration.

However, phosphorus that has entered the lake in past times may still be available in the lakebed. Historic inflows of phosphorus would be removed only by outflow in a river or by incorporation into living tissue that is then removed from the lake. For most lakes, neither of these will have removed much of the historic load of phosphorus from the lake. That phosphorus will be in the sediments. Some will be buried but sediments nearer the top, under low oxygen conditions, will release phosphorus back into the water. Lake turnover can then move the phosphorus back up into the top-water where algae and plants can access it. Thus, even if you stop today's inflow of phosphorus into your lake, you may still get an annual input of phosphorus from the historic store in the lake bottom.

Lakes can also receive large inflows of phosphorus when beaver dams upstream of the lake are breached and especially when they are completely removed so that the sediment in the bottom of the beaver pond also is flushed out and into the lake. Unthinking work with a backhoe can instantly eutrophy whole arms or bays of lakes.

Very little phosphorus will enter lakes from the granitic rocks of the Canadian Shield underlying many of our lakes. More phosphorus will be available for plant growth in lakes on the limestone plain which do not have enough calcium to form marl. (Marl forming lakes precipitate the phosphorus in a form that does not dissolve easily into the water.)

Previously, 20 milligram/litre of total phosphorus has been interpreted as the threshold above which serious eutrophication, or over-feeding, of a lake can occur. More recently 15 mg/L is suggested as a dangerous zone for total phosphorus, possibly too close to the point where the lake could tip over into serious malfunction.

Most lakes will measure total phosphorus according to the methods prescribed by the Lake Partners Program of MOE who provide minimal analyses without charge. The results are available on their website.

Major Nutrients and Buffer Strips

Nitrogen and phosphorus enter your lake in ground water and surface runoff. Buffer strips – vegetation borders along shorelines – can help prevent that entry. Many municipalities require 15 metres of undisturbed vegetation along any shoreline. Recent research shows that in many circumstances, 30 metres is needed – 15 is not enough. The requirement for undisturbed vegetation should be supplemented to say "… and undisturbed leaf litter". The fungal tissue – the white mat below the partially rotted leaves – is a major means of absorbing nutrients from water flowing under the leaf litter.

Most phosphorus enters lakes by flowing in such surface runoff. The roots of the living vegetation also are needed in the buffer strip to intercepts and absorb soluble nitrogen flowing in the shallow groundwater.

All parts of the buffer strip also impede water flow, cause soil and organic particles to drop out of the flow, and hold soil particles in place preventing erosion. Erosion of soil particles into a lake can carry enough nutrients to cause local over-feeding (eutrophication) of the lake's ecological system.

Oxygen

All fish need oxygen to live. They must get their supply from the oxygen that is dissolved in water. More oxygen, and all other gases, will dissolve in cold water than in warm. Oxygen, the only gas likely to be worth your attention can be critical to the ecological processes of a lake.

In winter, when the ice seals off most water from the air, the only available oxygen is what was dissolved in the water when the ice was formed. If too much organic matter such as dead plants and algae, have settled to the bottom, their decomposition will use up some of that oxygen.

In eutrophic lakes, there is too much plant material and it uses too much oxygen in its decomposition. Consequently, fish and other animals, that must breath oxygen, will die. In areas of very shallow water with a lot of organic matter in the water, the lack of oxygen can become so extreme that hydrogen sulfide or rotten egg gas will form and breaking the ice will release a bad smell and possibly some yellow coloration. This is common in beaver ponds.

A similar condition can develop in summer if the plant growth is really excessive. During daylight the plants' photosynthesis produces and releases oxygen. After dark this oxygen release stops but respiration by live plants and decomposition of dead organic matter continue to use oxygen. And with extreme amounts of plants, dead or alive, fish will die overnight for lack of oxygen.

Lake trout raise a special concern about oxygen and are the most common reason to measure the oxygen concentration in your lake. In late summer the lake trout seek out deep holes where the water is cold and tends to hold more oxygen. If there is not enough oxygen in the water in these deep holes, the lake trout will not survive the summer. Survival of lake trout depends on the volume of cold, well-oxygenated water available in the deep holes in the lake. Underwater spring- fed lakes tend to be less prone to low oxygen issues.

To measure dissolved oxygen you will want an instrument that measures both oxygen concentration and water temperature and you will need to measure depth with each reading. The critical time will be late summer when the surface water temperature has neared its maximum. Instruments for these measurements may be available at MNR. MOE, and Conservation Authority offices and normally will require a trained technician to operate the instrument.

Metals

Heavy metals such as mercury or lead may reach pollutant levels if lakes become markedly acid, releasing the metals from the bedrock and soil, or if there is an industrial source of these metals. Neither is common in our region so measuring heavy metals is seldom warranted except possibly for baseline measurement to establish the background, or natural, level.

Heavy metals require water samples to be specially treated at the time of collection. Either MOE or a commercial laboratory should be consulted before taking samples for this purpose.

Measurement of one of the metals, calcium, does have predictive value. Unless your lake has over 20 miiligrams/litre of calcium, it is highly unlikely that zebra mussels (*Dreissena spp*.) will be able to establish a population even if the larvae are introduced into the lake. Without at least 20mg/L of calcium, the mussels can't successfully build their shells. Many lakes on the Shield will be below this minimum. However, a few do have calcium-bearing rock ridges exposed in the lakebed. These sources can raise the calcium level in the water above the minimum and let the mussels establish populations, sometimes only in particular areas of the lake. Most lakes on the limestone plain have more than the minimum concentration of calcium and must prevent introduction of the mussel larvae or they will have massive populations of mussels. They will filter out much of the particulate organic matter from the water column. Removal of this organic matter deprives food chains of their food source with effects reaching as far as the fish at the top of the food chain. The increased water clarity also can increase sunlight available to plants, increasing plant growth.

Bacteria and Viruses.

If septic systems are leaking into the lake, they are a possible source of pollution by microbes. But what are these polluting microbes? Probably the most dangerous are viruses because they are able to exist in various forms in a wide range of environments including freshwater.

It is reasonably well established that most strains of *E. coli* do not cause problems for humans. They are not the usual cause of common ailments such as swimmers' ear-aches.

E. coli is often mentioned as a measure of water quality. *E. coli* is a large number of bacterial strains with very different qualities. The vast majority are harmless to humans. One group, the toxin-producers (Shiga toxin) are the strains most responsible for human illnesses. One of these, 0157:H7 caused the Walkerton disaster when it was carried from the guts of cows into the human water supply. This event, caused by one specific strain of a toxin-producing *E. coli* does not mean that all *E.coli* degrade water quality. The analysis commonly used for *E.coli* does not distinguish which strain was found or which vertebrate the bacteria came from. They could be from frogs, great blue herons, cows or dogs.

The second reason for the interest in *E. coli* is that this bacterium is used as an *indicator* of polluted swimming beaches. Starting back in the 1960's newspapers published pollution indices for urban beaches and gave the levels as numbers of *E. coli. E. coli* was being used as an indicator of the possible presence of hepatitis virus. If the bacterium was present, it indicated that pollutants from the intestinal tract of vertebrates were getting into the water and therefore, hepatitis could be present. But the fact that *E. coli* was just a handy *indicator* was soon forgotten by the media and by the public. The indicator became confused with the actual cause of danger.

Measuring *E. coli* can be useful in some circumstances. In cases where these measurements have been made in a standardized way at the same locations for several years, trends in the counts or significant peaks in the counts can signal the need to find the cause of change. At sandy beaches with no likelihood of contamination from wildlife, a high *E. coli* count may signal a human-related source of contamination. In situations where cows are entering a lake or feeder stream, *E. coli counts* at that location can be compared with another similar location such as another bay to detect whether the cows are adding to the bacterial count. Some very toxic *E. coli* live in cows. However, Canada Geese also deposit toxin-producing *E. coli* and this is becoming a widespread source of microbial pollution. *E. coli* counts that do not distinguish toxin-producing strains will not be the best expenditure of your water quality resources.

Water Clarity

The Lake Partners Program advocates Secchi disk measurement of water clarity but does not use these measurements to infer nutrient levels, although it is clear that increasing nutrients can promote algal growth that decreases water clarity. Secchi disk readings taken across the province provide a broad view of trends in water clarity. Sudden increases in water clarity, detected by Secchi readings, may indicate population explosions by zebra mussels.

The depth at which you can no longer see the sharp-edged black and white pattern on the disk simply indexes the transparency of the water. The deeper the reading, the clearer the water. The shallower, the lower the transparency. What determines transparency? Many things can. The assumption in Secchi disk measurements is that the main determiner of transparency is the amount of algae. Certainly, algal cells can impede light and reduce transparency but so can the amount of organic matter particles from non-algal sources and so can the degree of “tea colour” in the water. The tea colour is caused by humic and fulvic acids from decaying litter of conifer or mixed forest.

If Secchi readings are good measures of algal growth, they should match more direct and exact measures of alga growth. A very direct measure of algal photosynthesis can be made by measuring the amount of chlorophyll extracted from the algae in water samples. This indicates very accurately the amount of plant growth carried on by the algae. When compared, these measurements often don’t match secchi readings very well.

Secchi data are easy to get from volunteers and Secchi results from lakes all across the province certainly do give a broad-brush trend of changing eutrophication, or over-fertilization of the lakes in various parts of the province.

But Secchi readings may not help manage your lake. Decreasing transparency, measured at the same time in the growing season, over several years could indicate a trend in algal growth. If water colour and sediments in the water are not varying, this could indicate increasing nutrient inflow. However, detecting such a trend early enough to control (manage) the cause will be difficult.

An Approach to Water Quality Management

Manage the entire watershed that feeds water into your lake or river. Unless you do, there will always be the possibility that a lake, or a hamlet, or a highway project upstream will send a burst or a steady stream of unacceptable water down to you. This means that your management plan must be a cooperative, landscape-scale plan involving all lakes, wetlands, municipalities, and agencies upstream of you in your subwatershed. Often, this means a small group of lakes forming a coalition to formulate a common lake management plan.

It is always a good idea to establish a baseline of measurements for as many variables as possible for your lake and to search the records of MNR, MOE and the Conservation Authority for such records. At intervals of several years, the baseline data should be remeasured to detect long-term trends.

Detecting shorter-term changes by annual measurements is your best chance of predicting serious changes before they develop past irreversible thresholds. At this time, your best measurements for this purpose are total phosphorus and secchi disk transparency (Lake Partners Program). However, for lakes on the Shield with only one annual measure of total phosphorus, detecting a real trend may take several years of such measurements because variability in those limited samples and measurements can sometimes give false alarms. Sampling from several parts of a lake can help guard against false results especially when compared to the record over a few years.

Standard water quality measurements should be used to monitor for changes that may need more detailed work to demonstrate their reality and their causes.

Water quality should be monitored for all time but it should not be seen as the only measure of the capacity of a lake or of lake users to tolerate human activities. Phosphorus-based capacity models will lose their utility if technology of treating septic wastes becomes more effective at keeping phosphorus out of the lakes. Many other variables: light, noise, boat traffic, auto traffic, reduction of aesthetic qualities, loss of wildlife, and many other variables need to be incorporated into any estimation of lake development capacity.

Every few years, even when all appears to be normal, lake associations should enter into partnerships with MNR to do extensive fisheries sampling. Investigate possibilities for support under programs such as the Community Fisheries and Wildlife Involvement Program. It could be especially important to do this for stocked lakes and heavily fished lakes.

Finally, take all possible proactive steps to avoid the well-known causes of lowered water quality. Facilitate setting high standards for new septic systems and re-inspection of all existing systems through Municipal Planning policies.