Testing the Waters

The Basics of Water Quality

Introduction

Water quality is a relative term—not a clearly defined, single set of guidelines applicable in all circumstances. Water that is of acceptable quality for irrigating a field of soybeans is not necessarily safe, or palatable for drinking. Before water quality can be assessed the intended use must be known and an acceptable range of standards must be set. In a sense, water *quality* can be thought of as water *suitability*.

Once the intended use is known and an appropriate set of standards selected, the process of water monitoring begins. A wide array of factors can be tested, ranging from temperature, color, and turbidity to bacterial counts, dissolved gases, and hardness. Typically, some subset of factors will be monitored—again depending on intended use. As an example, if a lake were being assessed relative to the habitat requirements of a particular fish, relevant factors might include: dissolved oxygen, temperature, salinity, pH, and turbidity. The goal being a reasonable and relevant
characterization of the water.

The state of the art of water quality testing permits nearly anyone, regardless of experience, to conduct basic tests at minimal expense. Water quality monitoring is an ideal pursuit for students at all levels as it opens up enormous opportunities for learning about their natural environment and how to protect it. Let's discuss some basic water quality factors, what they can tell us, and how to test for them.

pH

pH is a measure of the hydrogen (H^+) ion content of a substance. The pH scale ranges from 0 to 14 units, with a pH of 7 being neutral—that is, neither acidic nor basic. A pH less than 7 indicates an acidic solution, a pH greater than 7 indicates a basic solution. Each single unit changes in pH represents an order of magnitude change in the hydrogen ion concentration. Therefore a pH of 3 is ten times more acidic than a pH of 4 and a pH of 9 is ten times more basic than a pH of 8.

Table 1 lends some perspective to the pH scale relative to common aquatic organisms. Juvenile forms are typically much less tolerant than adults and are the first to be impacted by deviations. It may take several years before the impact on adult population numbers is noticed. This is significant because it may delay recognition of potential problems and makes more apparent the value of regular, long-term monitoring.

Table 1.

pH	Noted Effects
4.0	No fish below this level.
4.5	Lower limit for most fish, amphibians, and insects.
5.0	Decomposition processes inhibited, organic debris accumulates.
6.0–7.5	Optimal range for most fish eggs and larvae.
8.5	Upper limit for most algae
9.0	Upper limit for most fish.

pH is best measured in the field as samples may be altered by the containers in which they are held and some change can occur on standing. Test papers of various ranges and portable electronic meters are most commonly used to measure pH. When selecting test papers, choose the narrowest range paper possible. Test initially with a wide-range paper to determine which narrow range paper is most suitable. pH meters have become much more affordable in recent years and the selection of battery-powered, hand-held meters is wide enough in performance and features to suit anyone's budget and needs. pH meters have the advantages of speed and accuracy and are not prone to interference from highly turbid and darkly colored water—properties which can make color comparisons with test papers difficult.

Alkalinity

Not to be confused with pH, alkalinity is a measure of buffering capacity—that is, the degree to which water can resist changes in pH. Most commonly this capacity is the result of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions present in the water. It is these ions that react with, or buffer, incoming hydrogen (H^+) ions that would otherwise lower the pH of the water. Alkalinity is indicative of the types of soils and underlying rock in the area. Regions rich in limestone ($CaCO_3$) will have lakes, ponds, and streams of moderate to high alkalinity. Regions with bedrock primarily of granite will have water of low alkalinity.

Freshwater alkalinity levels range from 10 to over 200 parts per million (ppm). Test kits will give results either in ppm or in grain per gallon (gpg). The two units can easily be converted by the ratio of 1 gpg = 17 ppm. A well buffered stream or lake will have an alkalinity of between 100 and 150 ppm.

Testing alkalinity is fairly simple and is usually done by titrating the water sample against a weak acid. Alkalinity is directly proportional to the amount of acid necessary to reach a specific endpoint—usually shown by an indicator color change. Alkalinity measurements can be made in the field or samples can be brought back to the lab or classroom.

Hardness

Closely related to alkalinity, water hardness is a more familiar property. Hardness is due to the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions and is the reason many of us have home water softeners. Hard water makes soap difficult to lather and causes the often problematic buildup of mineral scale in home and industrial hot water systems. In lakes and streams, hardness is also indicative of the types of underlying rocks—hence its link to alkalinity.

Hardness is usually measured as ppm, or gpg, of calcium carbonate ($CaCO_3$). Values range from soft (<20 ppm) to very hard (>180 ppm). Magnesium and calcium are essential nutrients for most aquatic organisms and moderate hardness levels (ranging from 20 to 120 ppm) are preferred. Water that is very soft, near or below 20 ppm, in addition to being nutrient poor, exacerbates the toxicity of any metal ions present.

Hardness tests can either be conducted with special test papers or with kits containing reagents necessary for a drop-count titration. Test paper results are determined by comparison to color standards; the titration is interpreted by measuring the amount of titrant required to reach a color-change endpoint. As with alkalinity, harness can be measured either in the field or from samples returned to the lab.

Dissolved Oxygen

Perhaps the key water quality test is that for dissolved oxygen. Important because of the amount of information it can provide, and because of the vital role oxygen plays in the lives of virtually all aquatic organisms. Most of the oxygen dissolved in water comes from the air by diffusion at the air–water interface. Aquatic plants and algae provide a secondary source. The amount of oxygen that can be dissolved in water is a function of numerous factors, the most important of which is temperature.

Oxygen solubility is inversely proportional to water temperature. This is significant because of the compounding factors involved. Metabolic rates in cold-blooded organisms are largely determined by ambient temperatures. As temperature rises, metabolic rates rise and oxygen requirements increase. Concurrently, less oxygen is available because the solubility is declining. It becomes apparent that thermal stressors (extremely hot weather, cooing water discharged by power plants) can have tremendous impacts on aquatic organisms.

In addition to thermal pollution, low oxygen levels may result from several other causes—the most common of which are elevated rates of decomposition and high levels or organic pollution. Artificially enhanced nutrient levels may lead to blooms of aquatic plants and algae—the eventual decomposition of which can profoundly deplete oxygen levels. Poorly treated or untreated sewage effluent can accumulate and in turn place a high demand on oxygen levels as the materials decompose and microorganisms population explode.

What level of dissolved oxygen is necessary? Since oxygen requirements vary among fish and other aquatic organisms, that is a hard question to answer. Table 2 gives a rough outline of basic oxygen requirements. Dissolved oxygen (DO) level is given in ppm (equivalent to mg/L).

Table 2.

DO	Observation
<3	Few or no fish survive.
4–6	Minimum to support reasonable fish population.
8	Minimum for trout and related species.
9–10	Diverse, healthy fish population.

Three primary means exist for measuring dissolved oxygen. Electronic meters provide the greatest speed, accuracy, and reproducibility, but they are also very expensive. Test kits exist in two basic formats: the traditional Winkler titration method and the slightly less accurate color comparison type. Test kits typically "microscale" the Winkler method which provides portability, greater safety, and lower costs. Color comparison kits are the quickest and simplest but are roughly half as accurate as the Winkler method (±1 ppm vs. ±0.5 ppm). The desire for accuracy is weighed against the desire for expediency. Measurements must be taken in the field, regardless of technique.

Phosphates

Phosphorus is an essential nutrient for plants and animals. In most freshwater systems, phosphorus is the *limiting nutrient*. All other essential elements for growth are usually present in relative abundance and by adding only phosphorus a rapid increase in growth can be stimulated. This sudden increase in productivity leads to a rapid buildup of organic material, accelerated rates of decomposition, and a drop in dissolved oxygen levels. This series of events is referred to as cultural, or non-natural, eutrophication. In addition to being unsightly and offensively aromatic, the result can be die-offs of oxygen dependent organisms, devastating reduction in diversity, and premature death of lakes.

Phosphate pollution comes mainly from wastewater (from phosphates in detergents) and from agricultural runoff carrying excess fertilizers—one of the primary components of which is phosphorus. Phosphate levels are usually measured in ppm and acceptable levels vary between lakes and streams. Lakes and slow moving streams are much more susceptible to the accumulation of choking algal mats than are fast moving streams. The recommended maximum level in faster streams is on the order of 0.1 ppm. Most uncontaminated lakes have levels between 0.01 and 0.03 ppm. Levels over 0.03 ppm in lakes are sufficient to accelerate natural eutrophication rates.

Phosphate testing is usually carried out by chemically treating the water sample to convert phosphate into a colored compound. The color is compared to a set of standards from which the phosphate concentration is determined. Tests may be conducted in the field or in the lab after a short holding period.

Sampling Guidelines

Specific sampling protocols will depend on what factor is being tested and the requirements of the method being used. A few things to keep in mind:

- Record when and where the sample was taken. Record local weather conditions, nearby vegetation, and relevant characteristics and observations (marsh, open water, nearby stream inflow or outflow, recent heavy rains, etc.).
- Determine if test must be done immediately (always preferred) or if samples will be held. Holding containers should be rinsed several times before the final sample is collected. Leave little or no airspace in the container.
- Streams and lakes are extremely heterogeneous environments and care should be taken to ensure representative samples. Stream samples should be taken at 50 to 60% of maximum stream depth in an area of moderate to high turbulence. Lake samples will be dependent on the purpose of the study and on available equipment. In deeper lakes (>5 m), many factors show pronounced stratification (variation with depth). Especially variable are temperature, dissolved oxygen, and organism distribution. Sampling depth should be appropriate to the study.

Water quality project are more feasible and more topical than ever. Worthwhile projects that generate real data and permit real conclusions are within your reach. Keep an eye out for safety and keep environmental disturbance to a minimum. Bring along a trash bag or two—you will almost certainly find things to put in them in addition to any waste generated by your group. Happy sampling!