Module 9 Surface Water Quality Indicators (including Chemistry)

Introduction

Why is it important to measure the level of organisms, nutrients, or other indicators of water quality? And what are important measurements of these indicators? The purpose of this module is to identify the important indicators of surface water quality, identify the standard for each, and examine how they are measured.

Water monitoring programs can test for a wide range of water quality indicators. Selection of the indicators to test should be based on a number of factors. These factors include how the collected data will contribute to understanding of water quality and watershed health, the concerns and issues in a particular watershed community, and the ease with which tests can be performed and afforded.

In this module participants will examine nine indicators of water quality: *Temperature, Dissolved Oxygen, pH, BOD, Fecal Bacteria, Phosphates, Nitrates, Turbidity, and Total Solids.*

Surface Water Issues

Whether you live on a lake, by a stream, in a city, or out in the surrounding countryside some of your daily activities may be adversely affecting the water quality of your region. A delicate balance exists between our lakes, ponds, and streams and their surrounding watersheds. Our water is affected by all our land-based activities. There are dozens of surface water issues individuals or communities might be concerned about. Soil erosion, pesticide use, septic systems, heavy metals, animal waste, urban development, or road building in rural areas are examples of issues that impact water quality. Individuals and communities can monitor surface water using indicators that can address these issues. Four key indicators of surface water quality are sediment, nutrients, toxic substances, and organic wastes.

Sediment

One of the biggest sources of water pollution is sediment. Sediment is defined as small particles of "dirt" that are carried along by water as it runs off the land. Most sediment comes from the erosion of agricultural and surface-mined land and construction sites. Waters that are heavily polluted with sediments are very obvious because of their muddy appearance. This is especially evident in rivers, where the force of moving water keeps the sediment suspended rather than allowing it to settle on the bottom.

However, when the river reaches a lake or reservoir, the water loses speed and the sediment drops to the bottom, a process called **siltation**. Therefore, the lake water looks clear after you move some distance from the point where the river enters. But this does not mean that sediment is not a pollution problem in lakes.

As sediment settles, it covers the lake bottom, smothering the organisms that live there and changing the lake bottom's nature. What was once a sandy or clay bottom now becomes a "muck" bottom, which few organisms can live in. An abundance of sediment in the water can affect fish by clogging their gills, covering their breeding areas, and smothering their eggs. If heavy sediment loads are carried into a lake or reservoir over a period of years, they can actually fill the basin and eventually turn it into a wetland or even dry land.

All lakes are naturally destined to fill up with sediment over time, but human activity speeds up the sedimentation process.

Nutrients

Like land plants, the flora (i.e., algae, mosses, and aquatic plants) of streams, lakes, and rivers require phosphorus and nitrogen to survive. However, excessive amounts of these nutrients from fertilizer in rainfall runoff can lead to an over abundance of the flora. Large quantities of algae, called **blooms**, are a serious problem in many polluted streams.

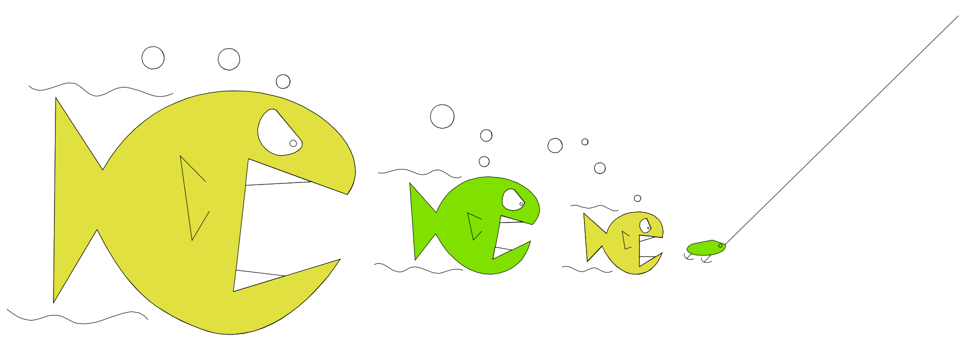
Toxic Substances

Toxic substances act as poisons. They reach the waters through industrial and municipal wastewater discharges, and in runoff from cities, farms, and mining operations. Toxic substances affect aquatic life and people in four ways.

First, the substance can cause immediate danger or death. This is called **acute toxicity**. Second, if the effect is more subtle, the substance can produce long-term effects that alter appetite, growth, metabolism, or reproduction. Such action, known as **chronic toxicity**, can eventually lead to mutation, serious illness, and death.

The third effect concerns toxic substances that enter the water in very low concentrations, so low in fact that they pose no apparent risk at that level. However, these toxins can **bioaccumulate**. Bioaccumulation is a process whereby a substance becomes concentrated by the biological organisms that consume it.

As an example, a particular toxin might be absorbed by microscopic plants and animals, known as plankton, in levels that do not poison them. A minnow, however, eats thousands of these plankton, each with its own small amount of the toxin. A bass or trout eats hundreds of minnows, each with its amount of toxic substance gained from the thousands of pieces of plankton. Obviously, the higher up this "food chain" goes, the more toxins are accumulated with each bite. By the time a bass or trout is eaten, significant quantities of the toxin have been consumed.



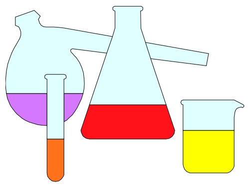
The fourth possible effect of toxic substances is on animal behavior. In this case, the organism is not killed, but its behavior is changed. This includes cases where fish or animals become disoriented, show increased or decreased aggression, or develop unsuccessful reproductive behavior.

Organic wastes

Oxygen is as essential to aquatic life as it is to life on land. The amount of oxygen in water is called the **dissolved oxygen** (DO) **concentration** and is dependent on the water temperature (the colder the water the more oxygen it can hold). Oxygen is added to water in two ways: it is taken directly from the air, a process that is enhanced in areas of turbulent water (i.e. water falls), and it is produced as the result of photosynthesis by aquatic plants and algae. Oxygen is removed from water by the respiration of aquatic organisms and the decomposition of wastes and dead plants and animals. The addition and removal of oxygen are generally balanced in normal, healthy streams, and the DO remains high.

Organic material, such as that found in wastewater, uses oxygen for decomposition. The amount of oxygen required to decompose waste is called **biochemical oxygen demand** (BOD). When the BOD of the waste exceeds that available oxygen, the DO in the stream is reduced or depleted and is unavailable for fish and invertebrates. Very low DO can cause fish kills.

Sluggish streams are particularly low in DO since DO levels are normally lower in slower, less turbulent streams. In streams with extremely low DO, organisms such as “bloodworms” (midge larvae), worms, and air-breathing snails may be the only invertebrates present.



Measuring indicators of surface water quality

Surface water indicators can be measured using a variety of methods and equipment. There are three common methods of measurement used in water quality monitoring: titrimetric, colorimetric, and electronic meters. The type and scale of indicator measurement is often called a **parameter.** Each of the three methods uses a parameter that is compared to a known scientific scale. When parameters are compared by water monitors meaningful comparisons can be made on a stream, pond, or lake's water quality.

1. **Titrimetric**

   Titrimetric analyses are based on adding a solution of a known strength (i.e. the titrant) to a specific volume of a treated sample in the presence of an indicator. The indicator produces a color change indicating the reaction is complete. Titrants are generally added using a tritrator (graduated dropper) or a precise glass pipet. The Winkler method for measuring dissolved oxygen is an example of a tritrimetric analysis.

2. **Colorimetric**

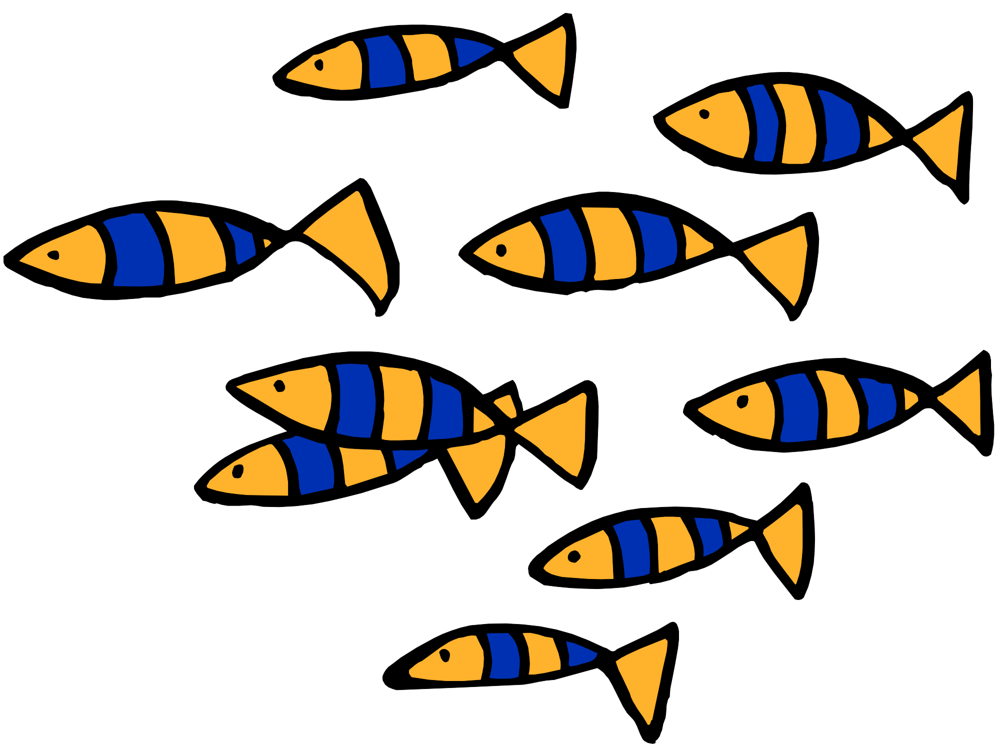
   Colorimetric tests measure the concentrations of various substances by gauging the reaction of an indicator with a known sample amount, and comparing the resulting color with a known range of values. For example, pH is a measure of the concentration of hydrogen ions (i.e. the acidity of the solution) determined by the reaction of an indicator that varies in color depending on the hydrogen ion levels in the sample water. The sample's color is then visually compared to a known range of pH values using an Octet Comparator.

3. Electrometric Meters

Specific electronic meters are manufactured for field and laboratory tests of various water quality factors. At fresh water sites, Keeper uses a Hanna Meter which tests for pH, conductivity oxidation-reduction potential, and temperature. Electrometric meters must be calibrated periodically to ensure accurate test results.

4. Test Strips

Several companies are now manufacturing test strips for field and laboratory tests that are quick to use. Single or multiple test patches on strips display different color scales that measure water quality parameters. Test strips are pre-calibrated to ensure accuracy.



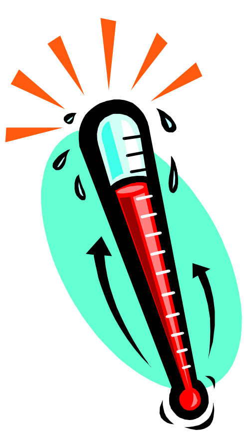
Nine Indicators Used in Surface Water Quality

Temperature

Temperature

Temperature ranges approximately required for growth of certain organisms:

Temperature		*Examples of life*
greater than 68°F (warm water)		most plant life; most bass, crappie, bluegill, carp, catfish, caddis fly
less than 68°F stonefly, (cold water)	upper range 55-68°F	some plant life; salmon, trout, mayfly, caddis fly, water beetle, spider
	lower range less than 55°F	trout, caddis fly, stonefly, mayfly



Why is temperature important?

The rates of biological and chemical processes depend on temperature. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Optimal temperatures for fish depend on the species: some survive best in colder water, whereas others prefer warmer water. Benthic macroinvertebrates are also sensitive to temperature and will move in the stream to find their optimal temperature. If temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die. Temperature is measured in degrees Fahrenheit (F) or degrees Celsius (C).

For fish, there are two kinds of limiting temperatures: the maximum temperature for short exposures and a weekly average temperature that varies according to the time of year and the life cycle stage of the fish species. Reproductive stages (spawning and embryo development) are the most sensitive stages. The following table provides temperature criteria for some species.

Maximum average temperatures for growth and short-term maximum temperatures for selected fish (°C and °F).

Species	Max. weekly average temp. for growth (juveniles)	Max. temp for survival of short exposure (juveniles)	Max. weekly average temp. for spawning[a]	Max. temp for embryo spawning[b]
Sockeye salmon	18°C (64°F)	22°C (72°F)	10°C (50°F)	13°C (55°F)
Bluegill	32°C (90°F)	35°C (95°F)	25°C (77°F)	34°C (93°F)
Brook trout	19°C (66°F)	24°C (75°F)	9°C (48°F)	13°C (55°F)
Common carp	-----	-----	21°C (70°F)	33°C (91°F)
Channel catfish	32°C (90°F)	35°C (95°F)	27°C (81°F)	29°C (84°F)
Largemouth bass	32°C (90°F)	34°C (93°F)	21°C (70°F)	27°C (81°F)
Rainbow trout	19°C (66°F)	24°C (75°F)	9°C (48°F)	13°C (55°F)
Smallmouth bass	29°C (84°F)	—	17 °C (63 °F)	23°C (73°F)
Atlantic salmon	20°C (68°F)	23°C (73°F)	5°C (41°F)	11°C (52°F)

a - Optimum or mean of the range of spawning temperatures reported for the species.
b - Upper temperature for successful incubation and hatching reported for the species.

Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Solubility of dissolved oxygen in water.

Temp. °F	*Temp. °C*	*Solubility mg/L (ppm)**
32	0	14.6
33.8	1	14.2
35.6	2	13.8
37.4	3	13.5
39.2	4	13.1
41	5	12.8
42.8	6	12.5
44.6	7	12.2
46.4	8	11.9
48.2	9	11.6
50	10	11.3
51.8	11	11.1
53.6	12	10.9
55.4	13	10.6
57.2	14	10.4
59	15	10.2
60.8	16	10.0
62.6	17	9.8
64.4	18	9.6
66.2	19	9.4
68	20	9.2
69.8	21	9.0
71.6	22	8.9
73.4	23	8.7
75.2	24	8.6
77	25	8.4
78.8	26	8.2
80.6	27	8.1
82.4	28	7.9
84.2	29	7.8
86	30	7.7

Causes of temperature change include weather, removal of shading streambank vegetation, **impoundments** (a body of water confined by a barrier, such as a dam), discharge of cooling water, urban storm water, and groundwater inflows to the stream.

Dissolved oxygen

Dissolved oxygen (DO) is one of the most important indicators of water quality for aquatic life. It is essential for all plants and animals. When oxygen levels in the water fall below about *3 parts per million* (ppm), fish and many other aquatic organisms may not survive. Oxygen is a particularly sensitive factor because chemicals, biological processes, and temperatures often determine its availability at different times during the year.

A DO test (using a kit or meter) tells how much oxygen is dissolved in the water. But it does not tell how much dissolved oxygen the water is capable of holding at the temperature at which it is tested. When water holds all the DO it can hold at a given temperature, it is said to be 100 percent saturated with oxygen. The warmer the water is, the less the DO, and the colder the water, the more DO it can hold. The table in the margin shows this relationship at various temperatures.

Oxygen is transferred from the atmosphere into the surface waters by the aerating of the wind. It is also added at or near the surface as a by-product of plant photosynthesis. As a result, floating and rooted aquatic plants increase DO levels.

Since the existence of plants also depends on the availability of light, the oxygen-producing processes occur only near the surface or in shallow waters where sunlight can penetrate. Oxygen levels may be reduced because the water is too warm (such as near a power plant) or because there are too many bacteria or aquatic organisms using the oxygen in a given area.

When algae growth is excessive, as in a “bloom,” the upper levels of algae can shade the light to lower depths and cause death to the algae there. Decay of these dead algae uses up oxygen leading to very low DO levels, fish kills, death of other organisms, and bad smells. Also, at night all photosynthesis stops and the algae respire (breathe) and use up available oxygen supplies, then suffocate, die, and decay.

As expressed in the previous table, amounts of DO in the water can vary greatly, depending upon temperature, photosynthesis, wind, light, algae blooms, etc. DO varies by time of day also and should always be measured at the same time. Very low readings (under 4 ppm) should be rechecked. Supersaturated levels above the maximums listed in the table for a given temperature can occur, but should also be rechecked (for example, below riffle sections or waterfalls). High wind or bright sunshine combined with large amounts of live plant material can create supersaturated conditions; these should be looked for if very high levels are confirmed by a second reading.

Dissolved oxygen requirements for native fish and other aquatic life

Cold-water organisms
(including salmon and trout) (below 68°F)
spawning .... 7 ppm DO and above
growth and well-being .... 6 ppm DO and above

Warm-water organisms
(including game fish such as bass, crappie) (above 68°F)
growth and well-being .... 5 ppm DO and above

pH

pH is a measure of how acidic or basic (alkaline) a solution is. At a pH of 7.0, water is said to be *neutral*. Pure water has a pH of 7.0. When the pH is less than 7.0, the water is said to be *acidic*. When the pH is greater than 7.0, the water is said to be *basic* or *alkaline*. pH is measured on a scale of 1.0 to 14.0.

pH is defined as the negative logarithm of the hydrogen concentration, which means that the concentration of hydrogen ions does not increase or decrease in a linear fashion; that is, a pH of 3 is not twice as acidic as a pH of 6.0. Increases are in powers of 10. A pH change of one whole number is therefore quite a large change.

Water dissolves mineral substances it comes in contact with, picks up aerosols and dust from the air, receives man-made wastes, and supports photosynthetic organisms, all of which affect pH. The buffering capacity of water, or its ability to resist pH change, is critical to aquatic life as it determines the pH range. Generally, the ability of aquatic organisms to complete a life cycle greatly diminishes as pH becomes greater than 9.0 or less than 5.0. Tables in this pH section describe the effects of decreasing pH levels for some organisms.

pH ranges that support aquatic life

most acid *neutral* *most alkaline*

1 2 3 4 5 6 7 8 9 10 11 12 13 14

bacteria
1.0 .... 13.0

plants (algae, rooted, etc.)
6.5 .... 12.0

carp, suckers, catfish, some insects
6.0 .... 9.0

bass, crappie
6.5 .... 8.5

snails, clam, mussels
7.0 .... 9.0

largest variety (trout, mayfly, stonefly, caddis fly)
6.5 .. 7.5

Summary of damages to aquatic ecosystems with decreasing pH

pH Range	***Effects***
8.0 - 6.0	Long-term changes of less than 0.5 pH units are likely to alter the living composition of freshwater to some degree. However, the significance of these slight changes is not great. A decrease of 0.5 to 1.0 pH units in this range may cause detectable alterations in community composition. Productivity of competing organisms will vary. Some species (including snails) will be eliminated.
6.0 - 5.5	Decreasing pH will cause a reduction in species numbers and, among remaining species, cause significant alterations in ability to withstand stress. Reproduction of some salamander species will be impaired. Bacterial decomposers will begin to die, and the number of planktonic animals will decline sharply.
5.5 - 5.0	Many species will be eliminated, and species numbers and diversity will be reduced. Crustacea, plankton, mollusks, amphipods, most mayfly species, and some stonefly species will begin to drop out. Acidophilus mosses, fungi, and filamentous algae will choke out most of the normal aquatic vegetation. Northern pike, perch, and suckers will die.
5.0 - 4.5	Decomposition of organic debris will be severely impaired. Sphagnum will become an aquatic plant. Lake herring and rock bass will die.
4.5	All of the above changes will be more severe, and most fish will be eliminated.

Median minimum pH tolerances of aquatic taxonomic groups

Taxonomic Group	*Median pH Tolerance*
algae	
Bacillariophyceae (diatoms)	6.0
Desmidiaceae (desmids)	5.3
Chlorophyta (green algae)	4.6
Chrysophyta (yellow algae)	4.6
Cyanophyta (blue-green algae)	4.5
Euglenophyta (flagellates)	3.1
insects	
Odonta (dragonflies)	6.4
Trichoptera (caddisflies)	6.3
Ephemeroptera (mayflies)	6.0
Hemiptera (bugs)	6.0
Diptera (true flies)	5.6
Coleoptera (beetles)	5.5
Plecoptera (stoneflies)	5.2
miscellaneous	
Pelecypoda (bivalves)	6.7
Gastropoda (snails)	6.6
Hirundinea (leeches)	6.5
Porifera (sponges)	5.2
Crustacea (crustaceans)	4.9
Anura (frogs)	4.1

Photosynthesis by aquatic plants removes carbon dioxide (CO_2) from the water, which can significantly increase pH. Therefore, in waters with abundant plant life (including planktonic algae), an increase in pH can be expected during a sunny afternoon, especially in low-velocity or still waters.

Other events in the watershed that may also affect pH include increased leaching of soils or minerals during snowmelt or heavy precipitation, accidental spills, field burning, agricultural runoff (pesticides, fertilizers, soil leachates), and sewage overflows.

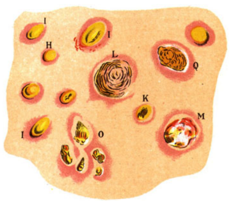
BOD

What is biochemical oxygen demand and why is it important?

Biochemical oxygen demand, or BOD, measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. BOD also measures the chemical oxidation of inorganic matter (i.e., the extraction of oxygen from water via chemical reaction). A test is used to measure the amount of oxygen consumed by these organisms during a specified period of time (usually 5 days at 20°C). The rate of oxygen consumption in a stream is affected by a number of variables: temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and inorganic material in the water.

BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die.

Sources of BOD include leaves and plant debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban stormwater runoff.



Fecal Bacteria

What are fecal bacteria and why are they important?

Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff.

In addition to the possible health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand. (Refer to the section on dissolved oxygen.)

Indicator bacteria types and what they can tell you

The most commonly tested fecal bacteria indicators are total coliforms, fecal coliforms, *Escherichia coli*, fecal streptococci, and enterococci. All but *E. coli* are composed of a number of species of bacteria that share common characteristics such as shape, habitat, or behavior; *E. coli* is a single species in the fecal coliform group.

Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood and in other places outside the human body. Thus, the usefulness of total coliforms as an indicator of fecal contamination depends on the extent to which the bacteria species found are fecal and human in origin. For recreational waters, total coliforms are no longer recommended as an indicator. For drinking water, total coliforms are still the standard test because their presence indicates contamination of a water supply by an outside source.

Fecal coliforms, a subset of total coliform bacteria, are more fecal-specific in origin. However, even this group contains a genus, *Klebsiella*, with species that are not necessarily fecal in origin. *Klebsiella* are commonly associated with textile and pulp and paper mill wastes. Therefore, if these sources discharge to your stream, you might wish to consider monitoring more fecal and human-specific bacteria. For recreational waters, this group was the primary bacteria indicator until relatively recently, when EPA began recommending *E. coli* and enterococci as better indicators of health risk from water contact. Fecal coliforms are still being used in many states as the indicator bacteria.

E. coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA recommends *E. coli* as the best indicator of health risk from water contact in recreational waters; some states have changed their water quality standards and are monitoring accordingly.

Nutrients

Nutrients play an important role in modern agricultural production as well as the green industry in urban areas. The use of fertilizers to grow crops, lawns, yards, and gardens increasingly is a concern for water quality in the Pacific Northwest. In addition, nutrients are lost in the production of livestock in rural areas and by other domesticated animals in rural areas and by other domesticated animals in urban areas as manure or runoff. Animal waste when unmanaged often degrades waterbodies and watersheds. Wildlife can even contribute nutrients to streams when population cycles reach a peak or when they are fed at feeding stations during the winter. Finally, humans add significant quantities of nutrients to their environments through yard waste, solid waste, sewage, septic, and storm water runoff systems.

Excess nutrients of all kinds are a major pollutant in water. Nitrates and phosphates are the primary nutrients that are of concern in most waterbodies because of their association with the growth and development of aquatic plants. However other nutrients can be of concern. For example, high levels of potassium, copper, iron, lead, or sulfur have all been found to affect water quality in the region. In this module we will only discuss nitrates and phosphates because they are the most common nutrient contaminants in water across the region, however, locally other nutrients may be just as important to study.

Nitrates

What are nitrates and why are they important?

Nitrates are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. These forms of nitrogen include ammonia (NH_3), nitrate (NO_3), and nitrite (NO_2). Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L.

Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.

Phosphates

Phosphates, chemical compounds that are made from the element phosphorus, are sometimes used in detergents and fertilizers. A stream at its headwaters would probably contain very little natural phosphorus, but by the time it reached a river, the level of phosphorus could sharply rise to a point and nonpoint source pollution. The heaviest concentration of phosphorus in a water system is usually in **estuaries**, where rivers meet the ocean. Urban activities such as washing cars and applying fertilizers can greatly increase phosphate levels.

Phosphates in our wastewater are often not removed by sewage treatment facilities. The type of sewage treatment that removes phosphates is becoming more common, but is not universal. Therefore, high levels of phosphates can be found in the water below many sewage treatment plants.

Phosphates are also plant nutrients, and they are found in most complete fertilizers used for agriculture, golf courses, parks and recreation fields, yards, lawns, and gardens. Most plants need a much greater amount of nitrate than they do phosphates, but both are considered “limiting nutrients.” The major concern with excess nutrients is the growth of aquatic plants that severely impacts the balance of hydrologic systems. This means, if there is an appropriate balance of phosphate and nitrate in the water, the aquatic plants will grow and reproduce at an ideal rate. But if there is more of one nutrient than the other, than the scarcer nutrient is said to be the “limiting nutrient.” The aquatic plants will grow and reproduce only as much as the amount of the limiting nutrient will allow.

Nutrients from urban runoff can form an important type of water pollution because, when they are available in favorable quantity and proportion, they contribute to an overabundance of plant growth. Waterways can become choked with plants such as algae and duckweed, and when these plants die and decay, they lower the oxygen supply in the water.

A test for the presence of phosphates in a stream can give some information about urban activity in the watershed. Tests at several locations along the stream can help pinpoint areas of greatest phosphate runoff. Generally, a level of 0.1-0.2 milligrams per liter (mg/l) of phosphate is sufficient for plant growth. Depending on the levels of the nitrate, phosphate levels below 0.1 mg/l may be associated with few plants; phosphate levels above 0.2 mg/l may be associated with a greater number of plants.

Turbidity (Water clarity)

Material that becomes mixed and suspended in water reduces water clarity and increases water turbidity. Factors contributing to this turbidity are varied. In the summer, an important contributor is plankton. Plankton organisms grow and multiply very rapidly in the warm, sunlit, nutrient-rich water. During periods of heavy runoff, silt is also a factor.

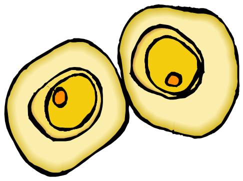
Turbidity affects fish and aquatic life in the following ways:

1. Cloudy waters interfere with the penetration of sunlight. Submerged aquatic vegetation needs light for photosynthesis. If suspended particles block out light, photosynthesis and the production of oxygen for fish and aquatic life are reduced. If light levels get too low, photosynthesis may stop altogether and plant life will die. Conditions that reduce photosynthesis in plants also increase respiration, oxygen use, and the amount of carbon dioxide produced. (Respiration is the consumption of oxygen and photosynthesis in the production of oxygen, both of which occur during daylight hours).

2. Large amounts of suspended matter clog the gills of fish and shellfish and kill them directly.

3. Suspended particles may provide a place for harmful microorganisms to lodge.

4. Fish can't see very well in turbid water and so may have difficulty finding food. (High turbidity also makes it easier for small fish to hide from larger predators).



Cartilage cells

Total Solids

What are total solids and why are they important?

Total solids are dissolved solids plus suspended and settleable solids in water. In stream water, dissolved solids consist of calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other ion particles that will pass through a filter with pores of around 2 microns (0.002 cm) in size. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, and other particulate matter. These are particles that will not pass through a 2-micron filter.

The concentration of total dissolved solids affects the water balance in the cells of aquatic organisms. An organism placed in water with a very low level of solids, such as distilled water, will swell up because water will tend to move into its cells, which have a higher concentration of solids. An organism placed in water with a high concentration of solids will shrink somewhat because the water in its cells will tend to move out. This will in turn affect the organism's ability to maintain the proper cell density, making it difficult to keep its position in the water column. It might float up or sink down to a depth to which it is not adapted, and it might not survive.

Higher concentrations of suspended solids can serve as carriers of toxics, which readily cling to suspended particles. This is particularly a concern where pesticides are being used on irrigated crops. Where solids are high, pesticide concentrations may increase well beyond those of the original application as the irrigation water travels down irrigation ditches. Higher levels of solids can also clog irrigation devices and might become so high that irrigated plant roots will lose water rather than gain it.

A high concentration of total solids will make drinking water unpalatable and might have an adverse effect on people who are not used to drinking such water. Levels of total solids that are too high or too low can also reduce the efficiency of wastewater treatment plants, as well as the operation of industrial processes that use raw water.

Total solids also affect water clarity. Higher solids decrease the passage of light through water, thereby slowing photosynthesis by aquatic plants. Water will heat up more rapidly and hold more heat; this, in turn, might adversely affect aquatic life that has adapted to a lower temperature regime.

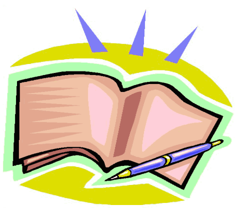
Sources of total solids include industrial discharges, sewage, fertilizers, road runoff, and soil erosion. Total solids are measured in milligrams per liter (mg/L).

Discussion Points

- Of the four key indicators which one is of greatest concern in your community? How do you know this?
- Which of these chemical water quality indicators were you most familiar with? Why?
- What measurement methods have you used to examine water quality?
- Relate these 9 indicators to your own, or your community's drinking water quality.

Major Points to Remember

- Four key indicators of surface water quality are sediment, nutrients, toxic substances, and organic wastes.
- There are four common methods of measurement used in water quality monitoring: titrimetric, colorimetric, electronic meters, and test strips.
- Nine key indicators of surface water quality are: *temperature, dissolved oxygen, pH, BOD, fecal bacteria, phosphates, nitrates, turbidity, and total solids.*



Journal and Evaluation

Record and describe three actual water quality issues you might investigate in your journal. For each issue, indicate which of the nine surface water quality indicators would best help examine your concern and why you would use them.

Short-course Presenters

Part Three is a basic overview to field water quality assessment and monitoring components. It is important to recognize that individual participants, communities, and organizations will have differing experiences in monitoring or assessment. Meeting the participants learning needs where they are at and increasing understanding and awareness is a key outcome to this section of the short-course. There are many different protocols for water quality monitoring. Local, state, regional, tribal, or national agency guidelines have been established across the region. It is most important that participants learn what a protocol is, not which protocol to use. Providing a foundation for understanding the physical, biological, and chemical monitoring components and their associated standards will best help meet the underlying objective. This understanding builds upon the watershed concept and the why and how of monitoring programs. Part three concepts set the stage to integrate the ideas into action during the field portion of the short-course.

PART 3, Day 3 of the PNW Water Quality & Monitoring Short-course takes 2.5 hours and should include 0.5 hr of breaks. Use a diversity of hands-on, activity, demonstration, and lecture/discussion methods in presenting these modules. Each module is designed to last for 35 minutes, about 15 minutes of instruction and a ten minute reinforcement activity followed by questions will work best.

Two activities support Module 9, the first is to demonstrate the four types of equipment that can be used to measure water quality, the second is to share the results of total coliform bacteria tests begun the first day of the short-course.

Activity one: Demonstrate how to use the four types of equipment that can be employed to measure specific indicators of surface water quality. For example, how to use a LaMotte pH (titrimetric) kit, a Hach (color wheel) pH kit, an electronic pH meter, and a pH test strip to measure the pH of the same water sample has worked well (pages 200-201).

Activity two: The second activity is to share in the results of the coliform tests (presence/absence) that were begun the first day of the short-course using locally collected water samples from streams, lakes, or ponds. By sharing the protocol used to collect and incubate the samples (date, time, technique, and incubation process) this concept can be introduced. For example, during the pilot, five individual samples (LaMotte, Code 5850) were collected at a selected site the first day of the short-course. They were collected at the end of storm water drains that came on to the beach in Newport, Oregon; from a stream running behind a residential area in Gold Beach, Oregon; from an irrigation canal near Selah, Washington; downstream from a retired dump near Waterville, Washington; and from the surface of the St. Maries River in Idaho. All samples were incubated in the dark in a covered box on top of a hot water tank, or in a heated closed for 36+ hours. All samples indicated the presence of coliform bacteria. A more sophisticated system developed by Micrology Laboratories, LLC (http://www.micrologylabs.com) was also used. These samples were then displayed during the presentation of Module 9. In turn, some participants took total coliform samples during the field portion of the program and incubated their samples using the same protocol. During the presentation of this module, samples were distributed with LaMotte interpretation cards (Code 5850-CC and 5850-FC) and each learner determined positive or negative results of the 5 samples presented. This prompted discussion on where the samples were taken, about personal hygiene, safety, swimming, walking on the beach, kids playing in neighborhood streams, playing in the park, walking the dog, and general exposure to these organisms.