INVESTIGATION

12

Water Quality Index

Lab

PURPOSE

- Perform tests to determine the Water Quality Index (WQI) of a local body of water
- Perform follow-up WQI tests to establish an ongoing record and basis for possible water remediation

INTRODUCTION

The Water Quality Index (WQI) was developed in the early 1970s in an effort to compare the quality of water from all parts of the country. Over one hundred water-quality experts were called together to create this standard means of using one number to represent nine criteria for calculating the degree of water quality for a given body of water. The results are used to decide whether the water may be considered healthy, to monitor it over time, and to assess it relative it to any other body of water on Earth.

This investigation prepares you to perform all nine tests to determine the WQI for a body of water of your choosing. (If you cannot do all nine tests, a way of approximating the WQI will be explained in a later section of the lab.) Usually these tests are repeated several times to get a full picture of how an ecosystem may change over a period of time.

Below are outlined the bases for these tests and what the tests measure.

Dissolved Oxygen (DO) Oxygen is not very soluble in water. What little gets into solution is vital to aquatic life and water quality. Most oxygen dissolved in streams, rivers, and lakes gets there by contact with the atmosphere. In streams and rivers, water splashing over rocks and waterfalls traps oxygen in the water. Waves on rivers and lakes also increase the oxygen level in solution. Photosynthetic plants in the water also contribute a significant amount of oxygen to the water column.

This test measures the amount of oxygen that is dissolved in the water and is available to the aquatic life that lives there. If the DO levels are too low, fish can drown. A DO that is too low is often an indicator of possible water pollution. It also shows a potential for further pollution downstream because the ability of the stream to self-cleanse will be reduced.

pH Pure water contains an equal amount of H^+ and OH^- ions. Hydrogen ions are acidic and the OH^- ions are basic, or alkaline. pH measures the −log of the H^+ concentration. A pH of 7 is neutral; it is equally acidic and alkaline. pH values below 7 become more acidic and they approach zero as the hydrogen ions increasingly outnumber the OH^- ions. As the values climb above 7, the water is said to be basic. The water becomes more alkaline as the values approach 14 and the OH^- ions outnumber the H^+ ions.

Many aquatic life forms are very sensitive to acid levels in the water. Pollution tends to make water acidic. Most bodies of water have the highest biological diversity when the pH is near 7.

Temperature Change (ΔT) Water temperature is a very important parameter for a body of water. Most physical and biological processes are affected by the temperature. Most aquatic life requires an optimum temperature range to thrive and, like terrestrial life, finds survival difficult at extreme temperatures. Higher water temperatures lower the amount of dissolved oxygen for two reasons. First, all gases are less soluble in warmer water. Second, warmer water increases the metabolic rate of aquatic organisms, which increases the consumption of food and dissolved oxygen.

The increase of water temperatures is called **thermal pollution**, and it is a significant problem on some bodies of water. Most thermal pollution comes from the industrialization of rivers and waterways. Industries, especially large power plants, use large amounts of water to cool their machinery and equipment. Along smaller bodies of water, cutting trees takes away the shade and allows water temperatures to rise. Another cause, large-scale logging, increases soil erosion and water turbidity, which, in turn, raises the water temperature to the detriment of aquatic life.

Fecal Coliform Coliforms are a form of bacteria that are found in the intestines of warm-blooded animals; their presence in lakes, streams, and rivers is a sign of untreated sewage in the water. Fecal coliforms can get into the water from untreated human sewage or from farms and runoff from animal feed lots. While fecal coliforms themselves are not harmful to humans, their measures indicate the presence of harmful pathogens.

Biological Oxygen Demand (BOD) Aerobic bacteria in water eat organic matter and at the same time remove oxygen. When the organic material in dead aquatic plants is decomposed, it releases the nutrients nitrogen and phosphorus. These nutrients trigger more plant growth and more nutrients, which further lower oxygen levels. If there is too large an amount of organic material in the water, the oxygen levels can drop below what is necessary for other aquatic life forms.

The BOD test gives an approximation of the level of biodegradable waste there is in the water. This biodegradable waste can be leaves and grass clippings from human activities, animal waste and manure from food production, wood pulp from paper mills, or many other carbon-based wastes. Water with a high BOD usually has a high bacteria count as well.

Nitrates Nitrates are a crucial nutrient in aquatic environments for synthesis of amino acids and proteins, but serious problems can result from **eutrophication**, or excessive nutrient levels. Excess nitrates get into waterways as nonpoint source fertilizers and from defective septic and sewage treatment systems. Nitrates can also get into the water from natural processes related to the **Nitrogen Cycle**. Most excessive amounts of nitrates come from human-based activities such as runoff from fertilized land, animal wastes from feedlots, and treated municipal waste effluent. Nitrate pollution effects both surface and ground water. It has been implicated as the primary cause of the dead zones in the Gulf of Mexico, the Chesapeake Bay and Long Island Sound. Nitrates also get reduced to nitrites, which can be harmful to humans and fish.

Total Phosphates (PO_4 — P) Phosphates are another essential nutrient for aquatic plants, but only in very low concentrations. Excessive amounts of phosphorus build up easily, and small amounts can contaminate large volumes of water. Phosphorus gets into water from many sources, such as fertilizers, sewage and detergents. Phosphorus exists in water in both organic and inorganic forms. The many forms of phosphorus can be measured separately, but this test will measure the combined phosphorus concentration, giving a better total estimate.

Total Dissolved Solids (TDS) Solids can be found in water in two forms, dissolved or suspended. Dissolved substances will pass through any filter commonly used in a lab. Suspended solids will be stopped by a filter because they are larger than individual atoms, ions, and molecules. This test measures the many solids found dissolved in water, usually in the form of such ions as sodium (Na^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), chloride (Cl^-), hydrogen carbonate (HCO_3^{2-}), and sulfate (SO_4^{2-}).

Solids soluble in water can also be organic, though they are usually salts. A steady concentration of dissolved minerals is necessary for aquatic life—both as essential nutrients and to maintain the osmotic balance with the cells of organisms. Changes in concentration can lead to a weakening of the organism or even death. High levels of TDS can affect water clarity and photosynthesis and lead to a decline in the quality and taste of drinking water. Some sources of dissolved solids are road salts in winter, urban runoff through storm sewers, farm chemicals, sewage treatment effluent, and factors that increase soil erosion such as road building and clear-cut logging.

Turbidity or Total Suspended Solids (TSS) This is a measure of how light is scattered in the water column due to solids that do not dissolve but are small enough to be suspended in the water. The higher the turbidity, the murkier the water. Turbidity keeps light from penetrating into the water and interferes with plant photosynthetic oxygen production and primary productivity. Darkened water holds more heat, increasing the water temperature which in turn lowers the DO. Suspended solids can clog fish gills and, in the case of silt and clay settling to the bottom, also smother larvae and fill in nesting sites. These solids may come from soil erosion or channelization from dredging. Increased water flow rates erode stream banks and allow the water to carry a heavier load of particles, storm and sanitary sewage effluent, and increased algae growth.

PERFORMING THE TESTS

Calculating the WQI first requires the results of nine test measurements. These test values are then converted into Q-values by using graphs. The Q-values are multiplied by a weighting factor and then added up to determine the final WQI number that measures the overall water quality.

Materials

- thermometer
- water collecting bottles (clear)
- water collecting bottles (black)
- eye protection gear
- 0.1 M HCL
- 100-mL beaker
- 250-mL beaker
- long pole
- tape
- nonstretching rope or twine
- rubber gloves

Note: Several of the WQI test measurements may be obtained by two or more methods. Discuss with your teacher which of the methods is to be followed for each test, then obtain the procedures and any additional materials required.

Test Procedures

The following directions describe how to get the results of each test and locate its Q-factor. After the tests are performed and recorded you will find instructions for using a worksheet (see **Fig. 12-11**) to establish the WQI for your body of water.

Dissolved Oxygen Test

Temperature drastically affects the solubility of oxygen in water. To determine the Q-factor for DO you will have to find the **percent saturation** of oxygen for your sample. This can be done by finding the DO and water temperature and then using a nomograph to find the percent saturation.

There are three ways to determine the DO. The first is a traditional wet chemistry method called the Winkler Method. The second is a test kit with pre-packaged chemicals, and the third an electronic device such as a CBL2 and DO sensor. Your teacher will select the method for this test and inform you of the procedure.

Step 1 Take the temperature of the water where you collect your sample. Hold the thermometer at the top so that your body will not affect the temperature. Lower the thermometer 10 cm (4 in.) into the water and wait for the temperature to stabilize. Record it on your lab sheet.

Step 2 When collecting your sample, it is important that you fill the collecting bottle to overflow and that there are no air bubbles when you cap the bottle.

Step 3 Once you determine the DO for your sample, find the percent saturation using the nomograph (**Fig. 12-1**).

a. Put a pencil mark for your recorded temperature on the temperature scale and another mark for your DO reading on that scale.

b. Now with a ruler connect the two marks with a straight line.

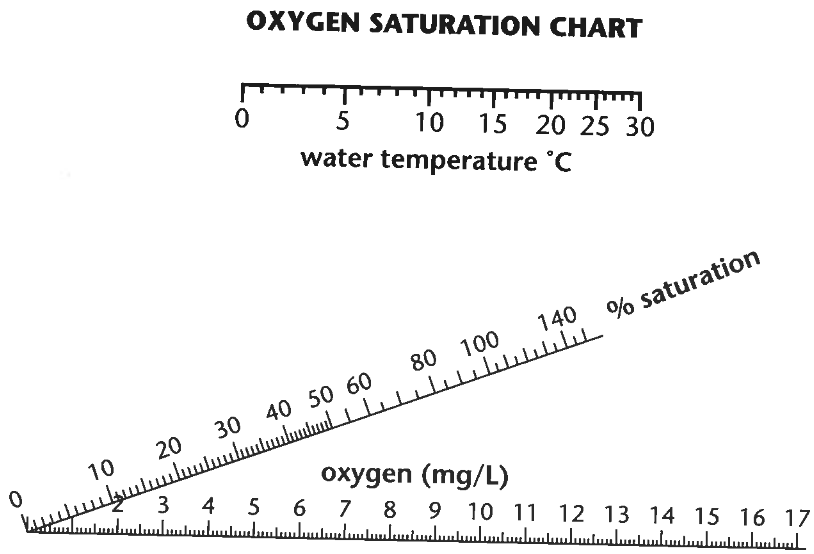
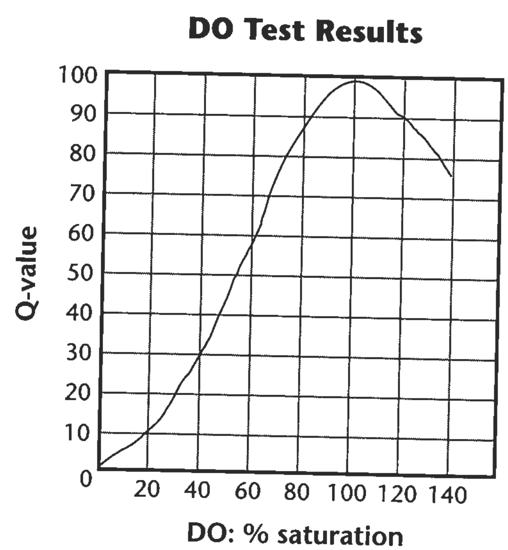


Fig. 12-1

c. The percent saturation can be read from the percent saturation scale where the line crosses the scale. Over 90% saturation is a sign of good water quality.

d. Record the percent saturation on your lab sheet.

Step 4 Now find the Q-value, using **Fig. 12-2**. Locate your percent saturation on the *x*-axis, follow vertically to the curved line on the graph, then read left, across to the *y*-axis.



Note: if DO % saturation > 140.0, Q = 50

Fig. 12-2

Step 5 Record your Q-value on the worksheet for calculating the WQI.

pH Test

As with DO, there are a number of ways to measure the pH of a water sample. Your teacher will give you directions for the method you will follow.

Step 1 Find the Q-value by using the graph. Find your pH measurement on the *x*-axis and read the Q-value for it on the *y*-axis.

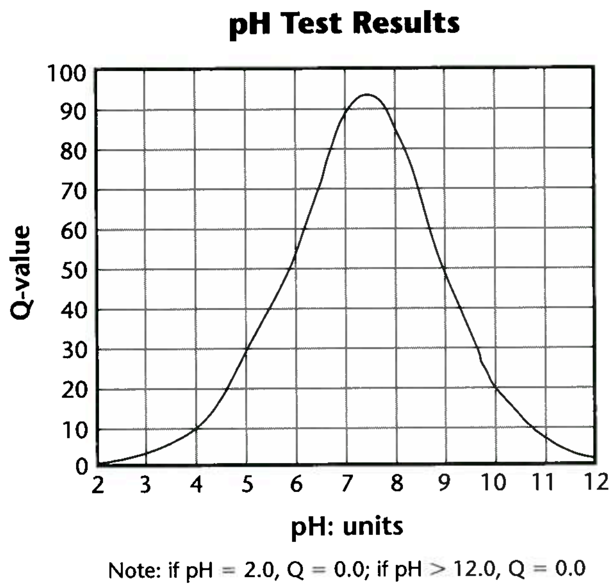


Fig. 12-3

Step 2 Record the Q-value on the worksheet for calculating the WQI.

Change in Temperature (ΔT) Test

To measure the temperature change of your body of water, you will have to record the temperature in two places, about 1 mile apart, using the same thermometer. (*Lab Hint:* It is easier to do this on a stream or river.) Choose conditions as similar as possible—same amount of shade, flow rate, and depth.

Step 1 Hold the thermometer near the top and insert it about 10 cm (4 in.) into the water.

Step 2 Wait for the temperature to stabilize.

Step 3 Go up or down stream, about one mile from your first test site, and record the temperature again.

Step 4 Record your temperatures, in °C, on your lab sheet.

Step 5 Subtract the temperatures and record that value on your lab sheet.

Step 6 Record the difference in temperature to find the Q-value from the graph (**Fig. 12-4**). Record the Q-value on the worksheet for calculating the WQI.

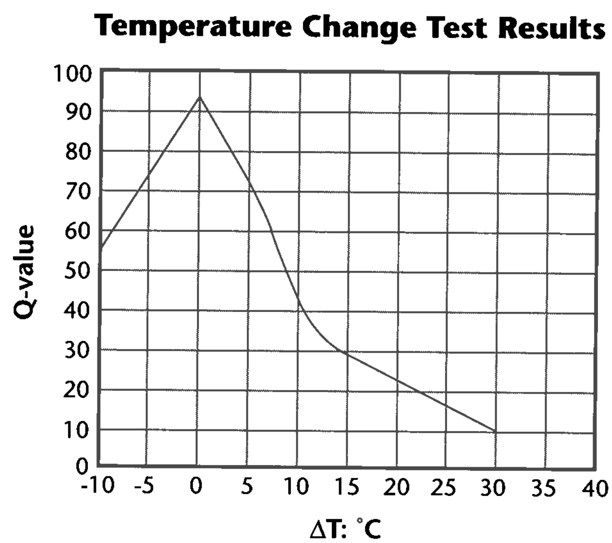


Fig. 12-4

Fecal Coliform Test

Not all schools will elect to do this section of the lab because of time, equipment and procedure constraints. Ask your teacher whether and how you are to perform this test.

Step 1 Be sure to wear goggles, mask, and rubber gloves.

Step 2 These test results are reported as number of colonies/100 mL of solution.

Step 3 Use the number of colonies on the *x*-axis of the graph to find the Q-value on the *y*-axis.

Step 4 Record your Q-value on the worksheet for calculating the WQI.

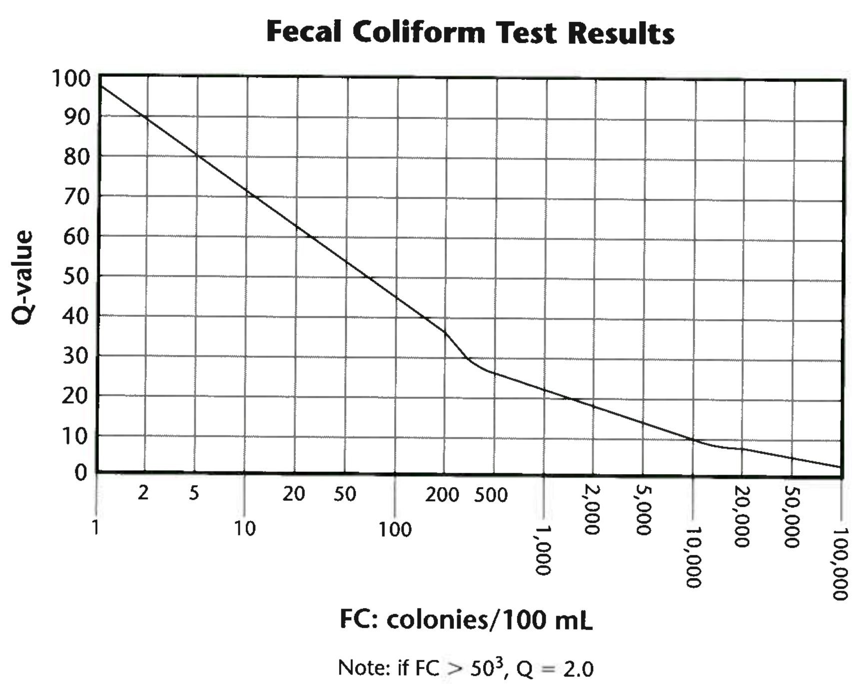


Fig. 12-5

Biological Oxygen Demand (BOD) Test

You will need at least 2 sample bottles for dissolved oxygen, one clear and another black. Be sure that you do not trap any air bubbles in the bottles. The black bottle(s) can be painted black, wrapped in black electrical tape, or completely covered with aluminum foil.

Step 1 To sample the water, reach out as far from shore as you safely can. Collect your samples near the bottom of the body of water, where the BOD will probably be the highest. If you sample by hand, wear gloves. If the water is deep, tape the bottles to the end of a long pole to reach near the bottom.

Step 2 If you suspect the water to have a high BOD, collect 5 black bottle samples, rather than 1, and store them in the dark at 20° C or 68° F (see **Alternative Method** below).

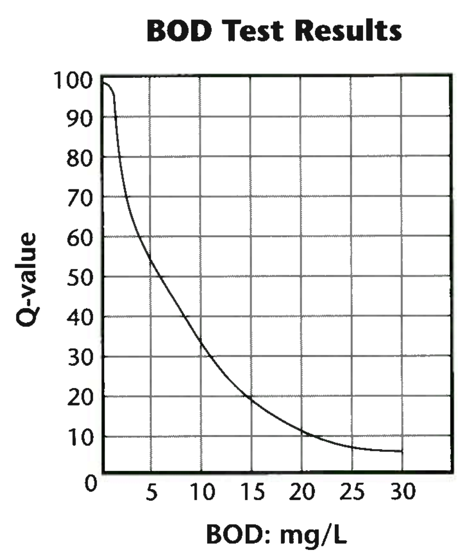
Step 3 For the sample in the clear bottle, follow the procedures you used for the dissolved oxygen test and measure the DO.

Step 4 Place the black bottle in a dark, light-restricted place for 5 days at a temperature of 20° C (68° F). This is close enough to room temperature if you do not have an incubator.

Step 5 After 5 days, repeat the steps needed to measure the DO for the sample in the black bottle.

Step 6 Now determine the BOD by subtracting the DO of the black bottle after 5 days from the DO of the clear bottle measured on the first day.

Step 7 Find the BOD, in mg/L, on the *x*-axis of the graph and read the Q-value on the *y*-axis.



Note: if BOD > 30.0, Q = 2.0

Fig. 12-6

Step 8 Record the Q-value on the worksheet for calculating the WQI.

Alternative Method (In Case of High BOD) If your body of water has a large amount of organic matter or sewage, the oxygen demand may be too high for the procedure above to indicate accurately.

a. One alternative method is to measure the DO initially and then every day for 5 days. If the DO falls below 4 mg/L, resaturate the remaining samples.

b. To resaturate a sample, pour the collected water into a clean, slightly larger bottle, with lid, and strongly shake for 1 minute. Uncap the bottle to let in air for about 1 minute, recap the bottle and again shake vigorously. Pour the water back into the original collection bottle and reseal without air bubbles for further testing.

Nitrate Test

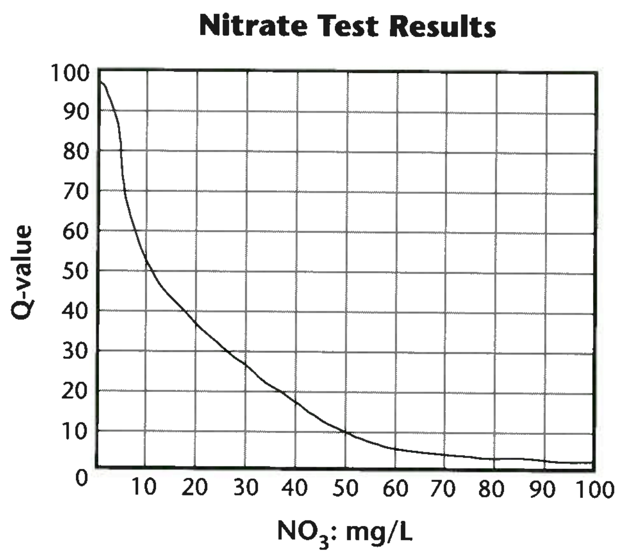
There are several methods that can be used to measure the nitrate level. One method is to use a test kit and follow the directions to determine the nitrate concentration. Another method is to use an electronic sensor such as the Vernier Nitrate Ion Selective Electrode CBL2. Your teacher will have the directions for the method you will use.

Step 1 To measure the nitrate level, you will have to take your 100 mL sample at least 10 cm (4 in.) below the water surface and as far from shore as is safe. If you need to sample the water beyond arm's length, attach your collecting bottle to the end of a long pole and carefully reach the proper depth.

Step 2 Find the nitrate concentration, in mg/L, on the x-axis of the graph.

Step 3 Read up to the line and then find the Q-value on the y-axis.

Step 4 Record the Q-value on the worksheet for calculating the WQI.



Note: if NO_3 > 100.0, Q = 1.0

Fig. 12-7

Total Phosphate Test

There are several methods to measure the total phosphate level. One method is to use a test kit and follow the directions to determine the phosphate concentration. Another method is to use an electronic sensor such as the Vernier Phosphate Colorimeter and CBL2. Your teacher will have directions for the method you use.

Step 1 It is important to use very clean glassware for this test. Phosphates can stick to glass and give an incorrect measurement. Soak all glassware in 0.1M HCl for at least one-half hour and then thoroughly rinse with distilled water. **BE CAREFUL:** HCl is very corrosive, painful on your skin and dangerous to your eyesight. **WEAR EYE PROTECTION.**

Step 2 To measure the total phosphate level in the water, you will have to take your 100 mL sample at least 10 cm (4 in.) below the surface and as far away from shore as is safe. If you need to sample the water beyond arm's length, attach your collecting bottle to the end of a long pole and carefully reach the proper depth.

Step 3 Find the total phosphate concentration, in mg/L, on the *x*-axis of the graph.

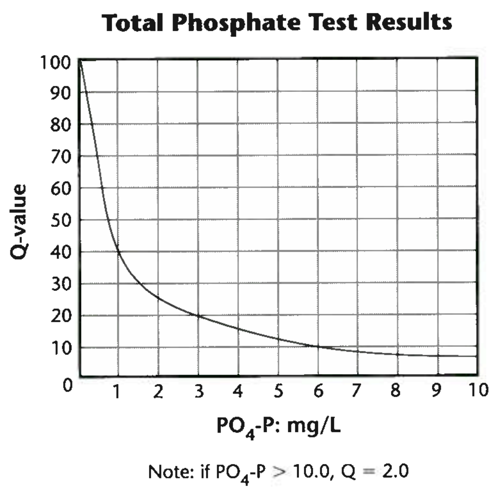


Fig. 12-8

Step 4 Read up to the line and then find the Q-value on the *y*-axis.

Step 5 Record the Q-value on the worksheet for calculating the WQI.

Total Dissolved Solids Test

There are two easy methods to measure the TDS of a water sample. The first method involves evaporating the water away and then recording the mass of the residue. The other is to measure the electrical conductivity of the unfiltered solution and convert the value to TDS. The Evaporation Method is outlined first.

Evaporation Method

Step 1 Heat a clean 250-mL beaker for 3–5 minutes to ensure that it is dry. Let it cool and then record its mass.

Step 2 Set up a funnel and filter in an iron ring on a ring stand.

Step 3 Filter enough of your water sample to collect 200 mL of solution.

Step 4 Carefully add 200 mL of the filtered sample to the clean dry beaker from Step 1 and place it on a hot plate to evaporate away all the water. (*Lab Hint:* If a Bunsen burner is the heat source, use a low flame and be careful not to let the water spatter, which will remove some solids and lead to a significant error.)

Step 5 After you are sure all the water has evaporated, allow the beaker and contents to cool, then record its mass in milligrams (mg).

Step 6 Subtract the mass of the empty beaker from Step 1 and record the change in mass. This is the mass of the TDS in 200 mL of sample.

Step 7 Multiply the mass of solids in your beaker by 5 to calculate the TDS in mg/L.

Step 8 Find the TDS on the x-axis of the graph.

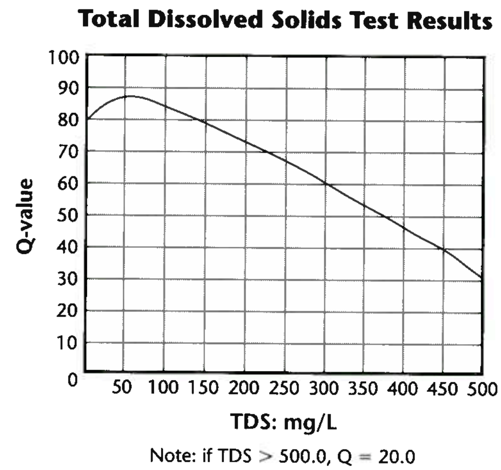


Fig. 12-9

Step 9 Read up to the line and then find the Q-value on the y-axis.

Step 10 Record the Q-value on the worksheet for calculating the WQI.

Electronic Method Your teacher will have detailed instructions if you are to use an electronic conductivity sensor, such as the Vernier Conductivity Sensor and the CBL2 or LabPro. After you get your reading from the sensor, use steps 8–10 above to find the Q-value.

Turbidity or Total Suspended Solids (TSS) Test

This test also can be done two ways. Your body of water and your teacher will determine which method to use. One method uses a Secchi Disk and the other electronic devices such as a spectrophotometer, colorimeter, or turbidity sensor calibrated to NTU's.

Secchi Disk Method The Secchi disk is a flat round plate 8 inches in diameter with pie slice-shaped quarters painted alternately white and black. A weight is suspended beneath it to let it sink when lowered in the water. The disk is attached to a thin nylon rope or chain with depth markings marked off in feet. (If you make your own disk, do not use cotton clothes line, which stretches. If you use a wire-centered cord, be sure it is not kinked and can be stretched out straight for measuring.)

Step 1 From a boat or dock, slowly lower the disk into the water horizontal to the surface.

Step 2 Keep lowering slowly until you cannot see any of the disk.

Step 3 Record the depth, in feet and inches, at which the disk disappears.

Step 4 On the graph, find the depth on the *x*-axis.

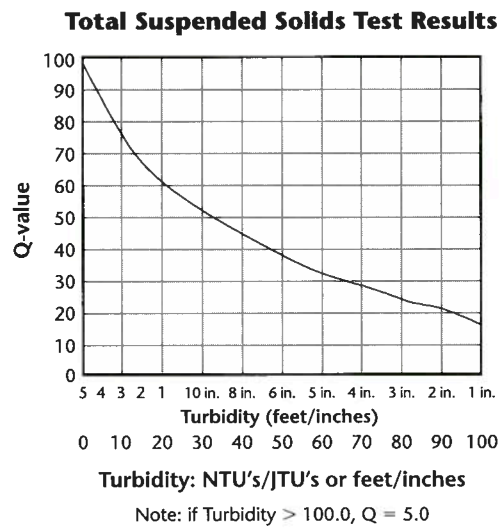


Fig. 12-10

Step 5 Read up to the line and then find the Q-value on the *y*-axis.

Step 6 Record the Q-value on the worksheet for calculating the WQI.

Electronic Method Your teacher will give you instructions on how to use the electronic sensor. It will probably measure in NTU's.

Step 1 On the graph, find the NTU on the *x*-axis.

Step 2 Read up to the line and then find the Q-value on the *y*-axis.

Step 3 Record the Q-value on the worksheet for calculating the WQI.

CALCULATE THE WATER QUALITY INDEX (WQI)

Step 1 Be sure you have recorded all of your test results and Q-values on the worksheet (**Fig. 12-11**).

Step 2 For each test, multiply the Q-value by the weighting factor and place the product in the TOTAL column.

Step 3 Add the totals of all nine tests and record the sum at the bottom. This is the WQI for your body of water.

Fig. 12-11

WQI Worksheet

Test	Test Results	Q-Value	Weighting Factor	TOTAL
Dissolved Oxygen	% Sat		0.17	
pH	units		0.11	
Temperature Change	°C		0.10	
Fecal Coliform	colonies/100mL		0.16	
BOD	mg/L		0.11	
Nitrate	mg/L		0.10	
Total Phosphates	mg/L		0.10	
Total Dissolved Solids	mg/L		0.07	
Total Suspended Solids	feet or NTU's		0.08	

WQI = ___________

Step 4 If you did not do all nine tests, you can approximate the WQI by using the results for those tests that you did perform.

Step 5 Add the totals for those tests performed. Record your result here:

____

Step 6 Add the weighting factors for the tests performed. Record the sum here:

____

Step 7 Divide the Step 5 value by the Step 6 value. Record the quotient here:

____

Step 8 The Step 7 value is your estimated value for the WQI.

Step 9 You are now also able to rate the relative quality of your water samples. Use the chart below:

WQI Value	Water Quality Rating
91–100	Excellent Water Quality
71–90	Good Water Quality
51–70	Average Water Quality
26–50	Fair Water Quality
0–25	Poor Water Quality

Fig. 12-12

Follow-Up Procedures

1. Measure the WQI of the same body of water again after a few months. Keep a permanent record so the quality can be monitored over extended periods of time by other classes in the years to come.
2. If there are changes over time, try to determine the cause, then propose solutions to correct the problem and possible ways to remediate the water.