Cleaning our water

You just learned that water comes from our homes, businesses and restaurants and is 'cleaned' at a wastewater treatment plant. We create wastewater every day by adding trash (toys, wipes, cell phones, etc.), organics (food, poop, pee, etc.), chemicals (soap, cleaning products, medicines, etc.), and germs to our water. The wastewater treatment plant takes most of these things out of the water and then puts the cleaned water back into Puget Sound. In the world outside of our homes and businesses, water can be contaminated by both natural and man-made sources. For example, our waterways such as rivers, creeks, and lakes can get filled with sediment from erosion during a heavy rain or contaminated with oil, trash, or chemicals as water runs off our roadways. This water doesn't go to a treatment plant to be cleaned; it goes directly into our waterways and needs to be 'cleaned' by our natural systems. Plants, soil, and bacteria all help clean our water. Sometimes our natural systems do a great job of keeping the water in our rivers and streams clean, but sometimes there are too many contaminates and nature can't keep up! In this lesson, you will be testing the quality of water in a natural waterway.

What is water quality?

Generally when we look at water our initial impression runs the gamut from "clean" to "dirty". In our country, our point of reference for "clean" is the water that leaves our tap as cool, clear water with nothing floating in it; water that is safe for us to drink. This makes sense, of course. After all, the presence of dirt, bugs, algae, and plant matter in our tap water might lead us to question what our water bill is actually paying for! When we're analyzing water quality we need to focus on that word, quality, and distance ourselves from our preconceived notions of what qualifies as "dirty" and what qualifies as "clean". In a natural system such as a creek or a pond, a cool, clear, and barren ecosystem may initially appear more pleasant to us than a murky, brown, and plant-filled marsh, but the reality behind those differences may be more sinister.

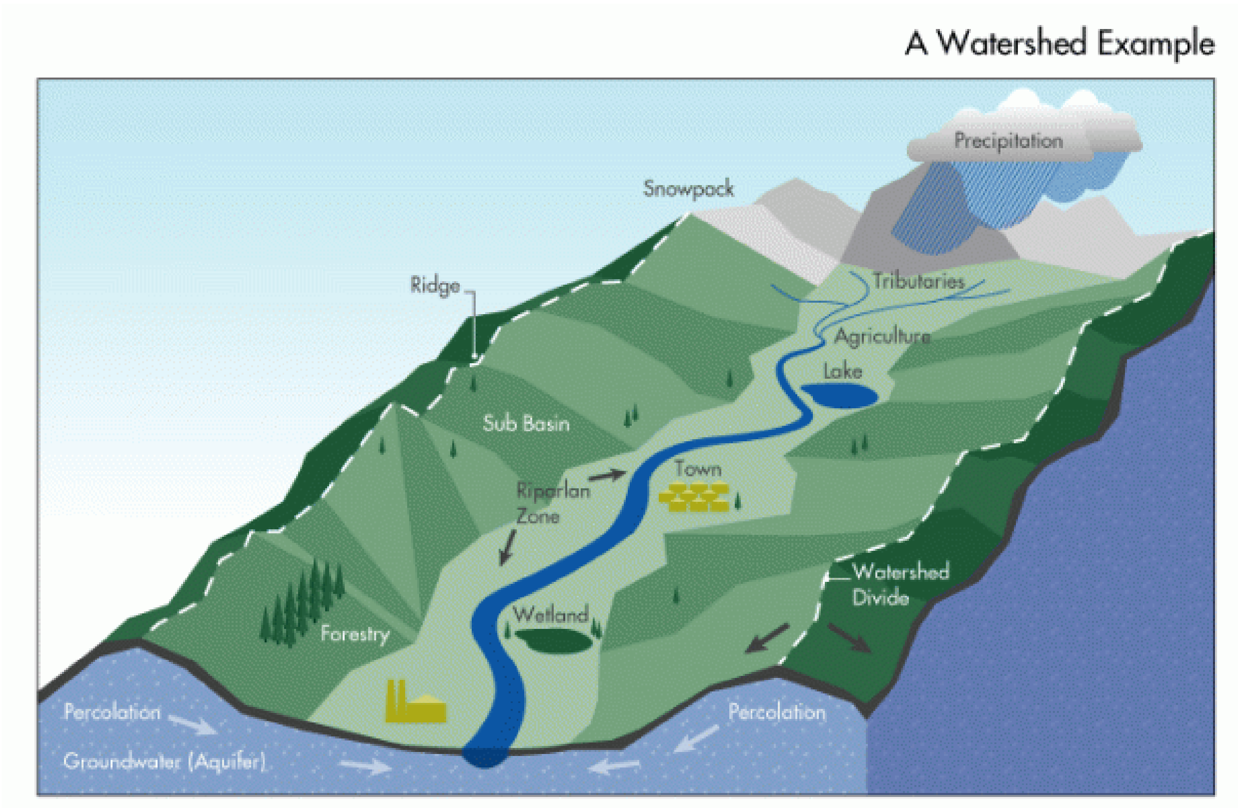
Water quality can be affected by many factors, not all of which are caused by humans. Pollution and deforestation may be the most dramatic and easily deducible cause of poor water quality, but seasonal changes, forest fires, and decomposition all can change water quality as well. As you move through the lessons in this binder, you'll further explore how our actions can affect water quality and what we can do to help maintain healthy habitats not only for our use, but for use by plants and animals as well. You'll test the abiotic factors (oxygen, temperature, pH, etc.) to develop a more complete picture of water quality.

Water is important, we all know that. We drink it, we cook with it, and we bathe in it (hopefully!). There are a lot of people working very hard to make sure that we have clean water for our use and we can't be blamed for sometimes taking that for granted, especially in a region where we are so inundated with water that most of the time we don't know what to do with all of it. Think about it this way; no one is creating new water. In fact, the water that we're using right now is the same water that was here when the dinosaurs were around. No joke. So keeping it clean has to be a priority. Otherwise we're up a certain sewage-filled creek without a paddle.

There is no escaping the water cycle. Everyone one of us lives, goes to school, plays, and works in a watershed and sometimes in even more than one! To get an idea of what a watershed is, imagine that you are standing anywhere in the entire Puget Sound region. If you placed a drop of water in any given spot and followed its journey, the body of water where it ended up would be the watershed that you were standing in. If it ended up in the Snohomish River, you are in the Snohomish River watershed. If it ended up in Little Bear Creek, you are in the Little Bear Creek watershed. If you repeated this experiment an infinite number of times and mapped where every drop flowed, you would have a complete map of all of the watersheds of the entire region. Every body of water has an associated watershed. A watershed is the entire area of land where the water ends up in that particular waterway, be it a lake, river, pond, creek, or drainage ditch. A small creek likely has a small watershed, but as it flows into another body of water, it is itself part of that water's watershed and so on. Think of Russian nesting dolls. You get the idea.

Eventually, all of our water winds up in the Puget Sound and the Puget Sound is connected to the Pacific Ocean, so it's part of the Pacific Ocean watershed and the Pacific Ocean is connected to…wait for it…all of the oceans around the entire planet! Our huge planet becomes very small, very quickly and we begin to realize that we're all part of something much bigger than just our local stream or lake.

These lessons provide a step-by-step procedural description of the activity and also some questions that can help to challenge your students to think deeply about the topics that are being covered. We'll start by making some predictions about water quality based on our assumptions and then well test those predictions by testing the chemical and physical composition of the water itself.


A Watershed Example
Precipitation
Snowpack
Tributaries
Ridge
Agriculture
Lake
Sub Basin
Town
Riparian
Zone
Watershed
Divide
Wetland
Forestry
Percolation
Groundwater (Aquifer)
Percolation

Lesson 1: Observe and Predict

Here's an idea!

Have your students create Water Quality Journals that can be used throughout your unit. This way, all of their data and observations will be located in the same place.

Introduction

In this lesson, your students will record observations of the landforms around a waterway and make predictions about the quality of the water. This lesson serves as a way to involve your students in the scientific processes of making observations and predicting outcomes.

Time	20 minutes
Materials Needed	• Copies of Landforms Observation Sheet • Pencils or colored pencils
Location	At the site of the water that is being tested.

Background Information

Good scientific work is based on accurate observations. Observations provide scientists with the raw information that will help to guide their research and the questions that they will attempt to answer. It may not seem like hardcore science to your students, but simply taking the time to look around and note what they see provides the foundation for meaningful research.

Description - Sketching landforms

When you go into the field to collect data, you first need to record any information that might possibly affect the results of the data you are collecting. What is the date? What is the weather like? Where are we? Who are we? It may be useful here to have your students work in small groups or in pairs.

1. On the attached landform sheet, fill out the observational information at the top.
2. Take a couple of minutes to really look around the site. Do you notice anything that may directly affect the quality of the water (homes nearby, storm drains, etc.)? If so, make note of it (you can use the back of your sheet as well if needed).

The next step is to make a sketch of our immediate watershed. Make sure to include the following; direction that water is flowing, location of any buildings or other structures, any different habitats within the water (pools, riffles, waterfalls, etc.), vegetation. Remember that this is just a sketch; it doesn't have to be museum quality. Depending on whether it has been covered with your students or not, you may want to reinforce the concept of abiotic, biotic, and cultural factors and have your students label or color code the ABC's that they add to their sketch.

1. Start by drawing the water. Which way is it moving? What shape is it? Note how fast is it moving?
2. Look at the areas around the waterway. Are their slopes? Are they steep or shallow? Are there signs of erosion, if so, draw these and make notes.
3. Do you notice anywhere that water is moving from disturbed areas and may be entering the waterway, such as water flowing off of concrete, roads or trails, then make sure you draw these and make notes.
4. Now add in different habitats within the water. Logs or large rocks can create shelter. Deep pools or riffles (areas where the water is shallow and moving quickly, like rapids) create different conditions that are needed by a variety of creatures.
5. Next draw in the vegetation that you see around the water. Where are the large trees that might shade the water? Why is shade important for water quality? Where are there grasses and other plants in the shallow water that might provide shelter for aquatic creatures and can also help with erosion?
6. Be sure to include any cultural (man-made) structures as well. Are there houses nearby? A road or a trail? A lawn or a parking lot? How might each of these things affect the water quality?
7. Again, make sure to note anything else that you observe that might affect the water quality. An area with a high level of erosion is a good example.
8. Working in small groups, have your students make a prediction about the water quality. Remember that scientists have to justify their predictions so make sure your students are prepared to explain their answer.

Discussion Questions

- Based on your observations, how healthy is this waterway? If you had to guess on a scale of 1 to 10 with 1 being poor and 10 being excellent, what would it be? Why?
- If you were an animal, would you choose this as a place to live and raise your children? Why or why not?
- Where is the water in this creek/pond/river coming from? Where is it going?
- What types of pollution are humans adding to this water? Where are they adding it? What effect will that have on the water quality?

Lesson 2: Landforms and Water Testing – Chemical Testing (Abiotic)

> ***A little perspective…***
> *2.5 billion of the world's 7 billion people don't have access to proper sanitation. 90% of sewage in developing countries is discharged straight into waterways.*[1]

Introduction

In this lesson, students will be able to make a prediction regarding water quality of a local water source and test their prediction with water sampling. They will be able to compare data, reach conclusions and describe the landform factors that might influence water quality in a variety of water sources.

Time	45-60 minutes
Materials Needed	• Water Quality Monitoring Kits (white buckets) • Copies of Water Quality Testing Data Sheet • Gloves for handling chemical tablets
Location	Ideally at the site of the water that is being tested. Water may be collected prior and brought to the classroom but this could skew results so it should be noted if done.

Background Information

All creatures require a certain range of conditions in order to survive. If water gets too hot, too acidic, too basic, or too cloudy the consequences for organisms can be catastrophic. Conditions in a healthy aquatic ecosystem may naturally vary seasonally or even daily, but they generally remain within the acceptable range for most living things.

One of the most challenging problems with pollution in our waterways is that we often can't see it. Chemical compounds such as nitrates and phosphates (generally from agricultural or sewer contamination) are so small that it isn't immediately apparent that they're present. When talking about pH or dissolved oxygen levels it is again not possible to evaluate water just by observation. It's important to remember that what we're testing for when we're looking at water quality is not whether this water is safe for drinking, but whether it provides high quality habitat for the plants and animals that inhabit it.

There are a number of different tests that can be done to determine water quality. Our kits provide you with the materials to test up to six different metrics of water quality, but feel free to alter the testing regimen however you see fit. Some concepts such as pH, phosphates, and nitrates require more prior knowledge in order to fully grasp. It may be that you don't have the time to fully cover the implications of high phosphate and nitrate levels or the difference between acids and bases. Don't fret about only doing some of the tests; even just doing a couple of different tests can be a valuable experience for your students. Our recommended testing for most students is dissolved oxygen, temperature, turbidity, and pH.

- **Dissolved Oxygen (DO)** measures the amount of oxygen that is dissolved or carried in the water being tested. Low levels of DO can have a severe effect on the ability of aerobic organisms (animals that need oxygen to survive like fish, tadpoles, and macroinvertebrates) to survive. Water that is low in DO is said to be *hypoxic*. DO is measured in parts per million (ppm); this is the measure of the approximate number of oxygen molecules per one million molecules of water. Common causes of decreases in DO are high levels of bacteria from sewage or large amounts of rotting plants. Increases in water temperature can also affect DO as warmer water holds less oxygen.
- **Nitrate** is an important nutrient that is needed by plants and animals that live in the water. High levels of nitrate cause an increase in plant growth and decay, leading to high levels of decomposition by aerobic (oxygen-using) bacteria. These bacteria use a large amount of the DO in the water, making it difficult for animals to survive. Nitrate pollution can come from untreated sewage, fertilizer runoff, and agricultural runoff.
- **Phosphate** is also an important nutrient for plant and animal growth. High levels of phosphate have the same effect as high levels of nitrate, leading to less DO. Phosphate pollution can come from untreated sewage, fertilizer runoff, and agricultural runoff.
- **pH** is a measure of the acidic or basic quality of water. Freshwater pH typically ranges from 6.5 to 8.2, and most aquatic organisms are adapted to live within a certain range. pH can change significantly due to pollution and many organisms will die with even slight changes. The pH scale goes from 0 (very acidic) to 14 (very basic). For example, battery acid is less than 1 on the scale, while baking soda is 9. Industrial, mining, and agricultural runoff are the most common causes of man-made changes in pH.
- **Temperature** is an important measurement of water quality. It can affect the amount of DO in the water, the rate of photosynthesis by plants, and the ability of organisms to fend off parasites and disease. Thermal pollution is the unnatural increase in water temperature most often caused by the industrial release of heated water. Dams may also increase temperature by slowing down rivers and increasing the surface area of the water that is exposed to direct sunlight. Vegetation often provides shading for bodies of water, thereby helping to regulate water temperature. When vegetation is removed along streams, lakes, and ponds, the resulting increase in direct sunlight can also affect water temperature.

Did you know?

Extremophiles are organisms that survive in extreme conditions that would be much too harsh for most living things (geothermal springs for example). Most of them are microbes.

- **Turbidity** is the measure of the clarity or cloudiness of the water. It is important to note that turbidity is NOT the measure of the color of the water as dark-colored water may still have a very low turbidity. Turbidity is essentially a measurement of the amount of "stuff" that is floating around in the water. At Brightwater, we measure the turbidity of the water that is leaving our filtration system to make sure that it is working correctly. High turbidity would mean that our filters are not catching the solids that they are supposed to. Turbidity is measured in JTUs or Jackson Turbidity Units. The higher the JTU, the more turbid the water.

Testing Instructions *

The following are test instructions for your reference. These instructions are also included on small flip charts for the students' use. It is helpful to read through these instructions on your own first so that you can answer any questions your students might have about the testing process. For younger students, it may be best for the instructor to be responsible for the handling of the chemicals.

*Water temperature should be taken first. The other tests can be done in any order. To interpret test results, see the data chart following the test instructions.

WARNING: The chemicals contained in this kit are harmful. Adult supervision is required. Gloves should be worn when handling any of the chemical tabs and hands should always be washed after handling any chemicals.

DISPOSAL: After testing, tubes should be disposed of by dumping them down the drain and flushing with excess water. DO NOT dump the tubes into the water source that you are testing.

TEMPERATURE

Testing time: 1 minute

1. Remove all contents from the white Water Monitoring Kit bucket.
2. Fill the bucket to the "turbidity test fill line" shown on the right side of the yellow label on the outside of the bucket.
3. Wait one minute. There are two thermometers attached to the inside of the bucket. The longer thermometer measures temperatures between 14 and 40 degrees Celsius. The smaller thermometer measures 0 to 14 ^{o}C.
4. Read the temperature. Look for a green square (or the square that is closest to green) on the larger thermometer. This is your temperature. If there is no square on the large thermometer, the number displayed on the smaller thermometer is your temperature. Use the chart below to convert from Celsius to Fahrenheit. Record your temperature.

^{o}C	^{o}F	^{o}C	^{o}F	^{o}C	^{o}F	^{o}C	^{o}F
0	32	11	51.8	22	71.6	33	91.4
1	33.8	12	53.6	23	73.4	34	93.2
2	35.6	13	55.4	24	75.2	35	95
3	37.4	14	57.2	25	77	36	96.8
4	39.2	15	59	26	78.8	37	98.6
5	41	16	60.8	27	80.6	38	100.4
6	42.8	17	62.6	28	82.4	39	102.2
7	44.6	18	64.4	29	84.2	40	104
8	46.4	19	66.2	30	86		
9	48.2	20	68	31	87.8		
10	50	21	69.8	32	89.6		

DISSOLVED OXYGEN

Testing time: 10 minutes

1. Submerge one of the small tubes (the ones with the black cap) into the bucket. Allow the tube to fill completely and remove, being careful to keep the tube completely full.
2. Carefully drop 2 DO tablets into the tube. The water will overflow a little bit. This is perfectly OK.
3. Screw the black cap on the tube. Make sure there are no bubbles in the tube.
4. Continuously mix the tube by inverting it over and over until the tablets have dissolved. This step should take about 4 minutes.
5. Let the tube sit for 5 minutes.
6. Compare the color of the tube to the Dissolved Oxygen color chart. Record the ppm of which color it is *closest* to.
7. Using the chart below and your temperature reading, find your saturation percentage. For example, if your water is 16 ^{o}C and your DO is 4 ppm, your water is 41% saturated with oxygen. That is, your water is holding 41% of the maximum amount of oxygen possible at that temperature.

Temp ^{o}C	0 ppm	4 ppm	8 ppm
2	0	29	58
4	0	31	61
6	0	32	64
8	0	34	68
10	0	35	71
12	0	37	74
14	0	39	78
16	0	41	81
18	0	42	84
20	0	44	88
22	0	46	92

24	0	48	95
26	0	49	99
28	0	51	102
30	0	53	106

NITRATE

Testing time: 7 minutes

1. Fill one of the large plastic test tubes to the 5 mL line with the water from the source you are testing.
2. Find one of the silver protective sleeves from your kit.
3. Add one Nitrate test tab and IMMEDIATELY slide the tube into the silver sleeve. The nitrate test tabs are sensitive to UV light and the results may be skewed if the sleeve is not used.
4. Cap the tube and mix by inverting for 2 minutes until the tab is disintegrated. Don't worry if there are some small bits of the tab left.
5. Wait 5 minutes for the color to develop.
6. Compare the color of the sample to the Nitrate color chart. The result will be in ppm, or the number of nitrate molecules per 1 million molecules of water.
7. Record your result.

PHOSPHATE

Testing time: 5 minutes

1. Fill one of the large plastic test tubes to the 10mL line with the water from the source you are testing.
2. Add one PHOS WR tab.
3. Cap the tube and mix by inverting until the tab has disintegrated. Don't worry if there are some small bits of the tab left.
4. Wait 5 minutes for the blue color to develop.
5. Compare the color of the sample to the color phosphate color chart. If the sample does not turn blue, the result is 0 ppm.
6. Record your result.

pH

Testing time: 1 minute

1. Fill one of the large plastic test tubes to the 10mL line with the water from the source you are testing.
2. Add one pH WR tab.
3. Cap the tube and mix by inverting until the tab has disintegrated. Don't worry if there are some small bits of the tab left.

4. Compare the color of the sample to the pH color chart.
5. Record your result.

TURBIDITY

Testing time: 1 minute

1. Hold the turbidity chart on the top edge of the white bucket. Looking down in the bucket, compare the appearance of the white and black disk in the jar to the one on the chart.
2. Record your result.

Lesson Procedure

If there is a local water source nearby (pond, stream, lake, etc.) the instructor can either gather water from the source in a bucket and bring it to the classroom or take the students to the source and do the testing there (if water is brought into the classroom it may become warmer, increasing the temperature and skewing the dissolved oxygen results). Kits are designed to be portable and waterproof, although data sheets are not!

1. The instructor should have the students work in small groups to come up with a water quality prediction for the water source they are testing.
   - What different factors in the ecosystem around the water source might affect the water quality?
   - Where does the water in the water source come from? Where does it go?
   - Who uses the water before it gets to the source? Who uses it after?
2. The instructor should review the six parameters that will be used to test water quality (temperature, pH, turbidity, nitrate, phosphate, dissolved oxygen) and also review the testing procedures including chemical safety.
3. The instructor divides the students into small groups of 4-5 and gives each group a water quality testing kit.
4. One student in each group should be responsible for handling the chemical tablets. This student is given a pair of gloves to reduce the chance of skin contact.
5. Students should test for temperature first and then do the remaining tests in order from longest time to shortest time. The order should be as follows: temperature, dissolved oxygen, nitrate, phosphate, pH, and turbidity. Remember that some samples must sit for several minutes before results will be accurate.
6. Students should record their data on the data sheet, using the ranking system below the chart, should enter the rank of poor, fair, good, or excellent accordingly.
7. Each small group should discuss their results to report out to the large group.
8. The instructor should compile all the data and get an average for each parameter.

Discussion Questions

- Is the overall water quality high or low? Why?
- How does this compare to their prediction?

- How is the water quality being affected by the landforms around the waterway?
- What does the water quality tell us about the health of the larger ecosystem? If the water quality is poor, what are some things we can do to improve it? If the water quality is good, what are some things we can do to keep it that way?
- Looking at the larger system, how does sewage treatment affect the water quality in this water source? What might this water source be like if we (like most of the world) didn't have sewage treatment?

Extensions:

- Testing from different locations provides the opportunity to compare results and reach some interesting conclusions as to why they might be different. After this lesson, there is an example of a graph comparing results from three different sources. Have your students graph the class results by location and have a discussion about what factors are causing the difference in water quality.
- Water quality and availability provides the perfect opportunity to integrate social and environmental issues. 80% of the world does not have sewage treatment and has very little environmental regulation to protect their water resources. Why might other countries not have the same access to clean water? What are the implications of this unequal access? How might your daily life change if you didn't have clean water to drink? If you had to manually gather all of your water each day?