When Things Heat Up

Purpose:

To relate the physical and chemical properties of water to a water pollution issue.

Summary:

In this exercise, students will measure the temperature and dissolved oxygen of a stream (or use their findings from the activity What's in the Water?) and discuss what this information can tell us about possible pollution problems.

Background:

During this activity students will investigate two properties of water in a stream – the temperature and the concentration of dissolved oxygen in the water. Students will explore how natural influences, human activities and pollution may cause these parameters to change. They will compare their results to Utah's water quality standards and investigate possible ways to restore a polluted stream to healthier conditions.

Temperature and oxygen were chosen for this activity because they are easy to measure, the causes of change are both varied and easy to understand, and also the two properties are related to each other. Fish and other animals living in water can be harmed by high temperatures and low oxygen concentrations. As water gets warmer the "saturation concentration" for oxygen gets lower – in other words the warmer the water, the less oxygen it can hold. Therefore, when water temperatures increase, fish are often hit with a double whammy of low oxygen as well. For more information about dissolved oxygen or temperature, see the Utah Stream Team Manual or the Further Discussion questions.

This lesson plan is designed to follow the activity What's in the Water?, during which the students measure several abiotic factors in a stream, or the lesson can be conducted as a stand alone.

Materials:

- Dissolved Oxygen kits *
- Field thermometers *
- Copies of the student worksheets
- Copies of the sampling instructions
- Waste bottles (e.g., empty pop bottles)
- Clipboards
- Bucket

Duration:
Classroom
20 minutes
Outdoors
50 minutes

Setting:
Classroom
Outdoors

Core Standards:
6th grade Science ILO's:
1a, 1b, 1d, 1g-1i, 2a, 2c, 2e, 4a, 5a, 6c

7th and 8th greade Science ILO's:
1a-1c, 2b, 2e, 3c, 4a, 4e, 4f, 5a, 5b, 6c, 6e

8th grade math: Expressions and Equations

8th grade Science Standard:
1.1a, 1.1b, 1.2c, 1.4c, 1.4d, 2.2c

Earth Systems Science:
4.2b, 4.2c

High School Science ILO's:
1a-1f, 1i, 1j, 2b, 3a, 3c, 3d
(continued)

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* For information on equipment for loan or for purchase, contact USU Water Quality Extension at (435) 797-2580 or www.extension.usu.edu/waterquality

4a-4e, 6a-6e, 6h

Biology: 1.3b-1.3d

Chemistry: 4.1e

NR Science I: 3.1d, 4.3h

Classroom Activity:

1. Ask the students to list all the abiotic factors they can think of in an aquatic system *(e.g., solar radiation, physical structure of the stream or lake, surrounding landscape, weather, and the properties of water itself).*

2. Tell them they will be testing two of these factors that relate specifically to the water – dissolved oxygen (DO) and temperature.

3. Define each of these factors, talk about why these factors are important in an aquatic ecosystem, what can naturally influence these factors, and also what humans can do to influence these factors.

4. Explain to the students that they will be going to a stream (or other waterbody) to measure DO and temperature. You may want to review the actual testing procedures before going into the field.

NOTE: If you have already done the activity What's in the Water? skip to field activity step five.

Field Activity:

1. Set up a station for each factor (DO and temperature). You may want to have multiple stations for each factor so your students can work in smaller groups. At each station, provide:

- Sampling instruction sheets (it may be a good idea to laminate these!)
- Waste bottles
- A thermometer or DO kit
- Clipboards

Safety First! Always consider safety factors when working near water.

NOTE: These measurements must be taken at the stream site, as storing them will give an inaccurate measurement.

2. Divide the students into groups. Provide each group with clipboards, pencils, and student worksheets. Explain to the students that each group will start at a different station and rotate so each group will measure both factors.

3. Have the students follow the instructions for measuring each factor found on the sampling instruction sheets.

4. Have the students record their results onto the student worksheet.

5. Have the students compare their results to the state standards for water quality (found on the student worksheet) and determine if the water is in accordance with state standards.

6. If the results are in violation of the state standards, have the students hypothesize what may have caused this. Alternatively, give the students the following hypothetical situation and again have them hypothesize what may be causing the problem.

"You have returned to the same stream site to test the temperature and DO again. This time your data show that the temperature is 20^{o} C and your DO level is 4 ppm." What may have happened to change the results? *(Summer versus winter time temperatures, loss of canopy cover, low flows, thermal source, pooled or widened stream).*

For more information, see the Further Discussion questions at the end of this activity and at the end of the activity What's in the Water?

ACTIVITY EXTENSIONS:

- Give the students the data provided in the resource pages and have them graph the saturation concentrations of oxygen in relation to temperature.
- Have the students graph temperature and oxygen concentration vs. time.

Be sure to point out that factors such as elevation and salt content will affect the ability water has to hold oxygen. At higher elevation, water holds less oxygen and salty water holds less oxygen.

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Further Discussion:

1. Are high temperatures or low dissolved oxygen necessarily a sign of a pollution problem in the stream?

No. Temperatures change throughout the seasons and will also vary from year to year. During warm drought years as opposed to wet years, temperatures in most streams will be higher during the summer because of lower flows and warmer air temperatures. Therefore, the first thing to consider is whether you're just observing natural changes in a stream. Stream standards allow for occasional violations because of this natural variation.

2. Would you expect dissolved oxygen to be lower if the temperature is higher?

Yes. The maximum amount of oxygen that can dissolve in water is called the "saturation concentration." Water can never dissolve a lot of oxygen, and under normal conditions, saturation concentrations will not exceed ~ 12 mg / l (ppm). The amount of oxygen that water will dissolve decreases as the water warms. Therefore, even saturated warm water may have very low concentrations of oxygen (see graph on resource page).

3. How could human activities have increased the temperature in your later (or hypothetical) sample?

Humans can affect the temperature of rivers by discharging heated water. Industrial or energy plants often produce heated water as a byproduct. Also, when we modify the stream banks (riparian area) and reduce the amount of canopy cover, we can have a direct impact on stream conditions without ever dumping in a pollutant.

Example: Discharge water from energy plants and from some other industrial plants may be considerably warmer than the stream it discharges to. This type of "thermal pollution" is considered a point source (it travels from a source to a stream through a pipe or ditch). Your students should consider any such sources in their community.

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Many other human activities affect water quality through indirect means. Urban development, agricultural areas and logging areas may all result in removal of riparian vegetation along a stream. When the shade from these plants disappears, the stream is exposed to more sunlight and heats up. Therefore, your problem may just be some "brush clearing" activities upstream of your site.

4. How could human activities have decreased oxygen in your later sample?

Oxygen can only get into water from the surface (mixing with the atmosphere) or from oxygen produced by plants in the water. Oxygen in water is consumed by animal and plant respiration, during various chemical reactions, and during the decay of organic material. Humans can have a profound effect on how much decaying material is in a stream. Grass clippings, runoff from feedlots, and debris from logged areas are just a few of the sources of material which will ultimately decay in the water and in doing so, use up oxygen. In a rapidly moving stream, the water usually mixes with the atmosphere enough to replace this oxygen. In a pooled up or very slow moving stream, especially if it's warm, oxygen can be used up very quickly.

NOTE: Dumping nutrients into water (e.g., from yard fertilizers), can stimulate plant growth in a stream or lake. When these plants die, you may also see a drop in oxygen.

5. Why would the time of day make a difference when measuring oxygen concentration in a stream?

We often forget that plants not only create oxygen, but also use it for their cell metabolism. During the night, plants do not photosynthesize but still use oxygen. In streams that have become congested with an overabundance of living plants, oxygen may be very high during the day, but can be extremely low just before dawn because of plant uptake.

Worksheet

Dissolved Oxygen and Temperature

Name: ____________________________ Group #: _______________________

Date: _____________________________ Site ID: ________________________

SITE OBSERVATIONS:

Type of waterbody (e.g., stream, lake, wetland):__________________________________

Weather today: ____

Weather yesterday: ____

Air temperature: ____

Water appearance (e.g., clear, brown, foamy, milky):______________________________

What types of land uses are in the immediate area?_______________________________

What types of land uses are in the surrounding area?______________________________

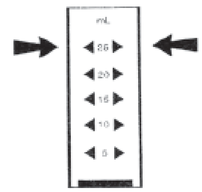
Is the area shaded by trees? ____

ABIOTIC FACTOR	YOUR RESULTS	COMPARE YOUR RESULTS TO ALLOWABLE RANGE IN UTAH	DOES THE WATER MEET UTAH'S REQUIREMENTS? (Y/N)
Dissolved Oxygen	ppm (mg/L)	Minimum of 6.5 mg/l for cold water fisheries and 5.5 mg/l for warm water fisheries.	
Temperature	°Celsius	Maximum of 20° Celsius for cold water fisheries and the maximum temperature for warm water fish is 27 ° Celsius.	

Dissolved Oxygen

Time - 3 minutes
Persons - 1
Materials -
• Chemetrics DO Sampling Kits
Note: Sunlight can damage the ampoules in your DO kit. Keep them shaded at all times

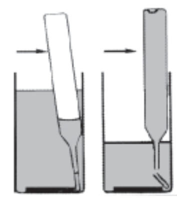
Step 1



1. Pre-rinse collection bottle with stream water.
2. Fill the sample cup to the 25 ml mark with your sample.

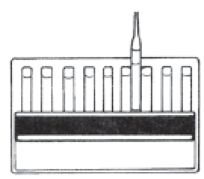
Step 2

1. Place the glass ampoule in the sample cup.
2. Snap the tip by pressing the ampoule against the side of the cup.
3. The ampoule will fill, leaving a small bubble that will help you mix the contents of the ampoule.



Step 3

1. Mix the contents of the ampoule by turning it up and down several times, allowing the bubble to travel from end to end each time.
2. Wipe all liquid from the outside of the ampoule.



Step 4

1. Wait 2 minutes for color development.

Step 5

1. With the sun or another light source shining on the comparator (rack of colored tubes) from directly above, place the dissolved oxygen ampoule between the color standards for viewing. It is important that the ampoule be compared by placing it on both sides of the color standard tube before deciding that it is darker, lighter or equal to the color standard.
2. Record the concentration of the best color match.

In Utah:
The minimum concentration for coldwater fish is 6.5 mg/l.
The minimum concentration for warmwater fish is 5.5 mg/l.

Temperature

Time – 2 minutes
Persons – 1
Materials –
• Thermometer

Step 1

1. Dip the thermometer into a moving part of the stream or river.
2. Wait for the temperature to stop changing (at least 1 minute).

Step 2

1. Read the temperature and record on the student worksheet.

Converting Fahrenheit to Celsius: $°C = (5/9) \times (°F - 32)$

Converting Celsius to Fahrenheit: $°F = [(9/5) \times °C] + 32$

In Utah:
The maximum temperature allowed for warm water fisheries and aquatic wildlife is 27° C (81° F).

The maximum temperature allowed for cold water fisheries and aquatic wildlife is 20° C (68° F).

Temperature

What is Temperature?
Temperature is the measure of how much heat energy water contains. A stream's temperature is affected by the season, the source of water, the geographic area of the stream, the shape of the channel and whether the stream is shaded. Most aquatic organisms require a specific temperature range, and many of our sport fish require cold water.

Refer to the Utah Stream Team Manual for more information on the definition and importance of temperature to fish and other aquatic life, and how natural and human activities affect temperature levels.

Temperature must be measured in the field. The temperature will change if the water is collected and stored, and will not reflect the true value at the site.

Discussion Questions for Temperature:

1. Draw a graph of the temperature of a high mountain stream over an entire year. Draw another line on the graph to show how the temperature might change as you move farther down the river.

Temperatures in streams can change beyond the obvious seasonal differences. Temperatures in streams are often cold near the headwaters, especially if they originate from snowmelt or shallow springs, and get warm from the sun as they move down through the watershed. Shading (riparian vegetation), and the width and depth of the stream will all affect a stream's temperature.

2. How will groundwater entering a stream affect its temperature?

Groundwater is usually colder than surface water and therefore it would probably cool the stream. Some areas in Utah, however, have hot springs which introduce heat and minerals to a stream. Because the temperature of groundwater doesn't fluctuate much throughout a year, a stream with a major groundwater component may show less seasonal variability than a stream fed entirely by surface runoff.

Temperature, Continued

3. Discuss how different land uses (logging, road building, agriculture, urban uses) might affect temperature.

The major influences on temperature in a stream are exposure to the sun, and exposure to heated surfaces. Any activity that causes a stream to become shallower and wider (this can happen when too much sediment enters a stream) will cause the stream to heat more rapidly. When trees along the banks are removed, the loss of shading can cause the stream to heat up. Water that is diverted (such as for irrigation) and then returned to the stream usually heats up. Finally, streams with small flows will heat faster than streams with lots of water, so removing water from a stream can cause an increase in temperature.

Suggested sources of water samples, with expected results and explanation:

Water Source	Expected Result	Explanation
A stream or river in the late summer / early fall	warmer	Warmer air temperatures, plus no source of cold water (e.g., snowmelt) cause streams to be warmer in the later summer / early fall
A stream or river in the spring or winter	cooler	Cold air temperatures plus snowmelt in the spring lower the temperature of the water.
A stream near its headwaters	cool	The water source is snowmelt or groundwater. These streams are also usually shaded by trees and bushes.
A stream after it has traveled through a large valley or through a city	warmer (compared to the headwater stream)	The water warms as it travels away from the headwaters due to solar radiation and heat transfer from the streambed and banks. Areas with little riparian vegetation (no shading) will heat faster. Streams with concrete banks (e.g., urban areas) will absorb heat from these artificial banks.
A stream near a hot spring	warmer	Hot spring water will mix with the stream water, raising the temperature.

Dissolved Oxygen

What is Dissolved Oxygen?
Dissolved oxygen (DO) is a measurement of the concentration of O_2 molecules actually dissolved in water. This is the form of oxygen that fish and aquatic insects need.

Oxygen is not very soluble in water. Usually, about 12 parts of oxygen can dissolve into a million parts of water. In very cold water however, concentrations can be as much as 14 parts per million (ppm) or mg/1. The maximum amount of oxygen that can dissolve in water is called its saturation concentration. The saturation concentration decreases as water temperature or elevation increase.

Refer to the Utah Stream Team Manual for more information on the definition and importance of DO to fish and other aquatic life, and how natural and human activities affect the DO levels.

DO must be measured in the field. The DO will change if the water is collected and stored, and will not reflect the true value at the site.

Discussion Questions for Dissolved Oxygen:

1. How does oxygen get into water?

Oxygen is dissolved into water by contact with the atmosphere, or from aquatic plants that produce oxygen during photosynthesis. Therefore, oxygen will be higher in turbulent stream water (lots of mixing with the atmosphere) or in water with lots of plants (but only during the day, when photosynthesis can occur).

2. How does oxygen get used in water?

The respiration of animals and plants uses oxygen. Bacterial decomposition of dead organic materials can be a major factor, and may cause the dissolved oxygen to be completely consumed in deep pools or lakes. Some chemical reactions (oxidation reactions) also require and consume oxygen.

3. How will dissolved oxygen concentrations be affected by the dumping of yard clippings or the runoff of animal manure?

The decomposition of organic materials such as these may use all the available oxygen in the water. Secondary treatment by municipal treatment plants removes the organic material from the water for just this purpose. Before municipal wastewater was treated properly, many rivers and streams had fish kills and dead zones caused by low oxygen as this waste was decomposed.

Dissolved Oxygen, Continued

Suggested sources of water samples, with expected results and explanation:

Water Source	Expected Results	Explanation
Fast moving cool stream	high (>10 mg/l)	Turbulence mixes atmospheric oxygen into the water. The water may even be supersaturated.
Still water (e.g., productive pond water)	may vary throughout the day: lower at night (<4 mg/l) and much higher in the late afternoon. (>10 mg/l)	No turbulence to mix the oxygen. Plants produce oxygen, but the plant respiration and decay may also use it up.
Warm water	low (<8 mg/l)	Warm water holds less oxygen than cold water.
Stream water in a closed jar without any plants	low to moderate (6-8 mg/l)	No plants to produce oxygen, no opportunity for mixing with atmospheric oxygen. Note: microscopic plants may complicate results.
Stream water in a closed jar with leaf litter (dead or decaying plants)	low (<6 mg/l)	Decaying plants/leaf litter use the oxygen in the water.

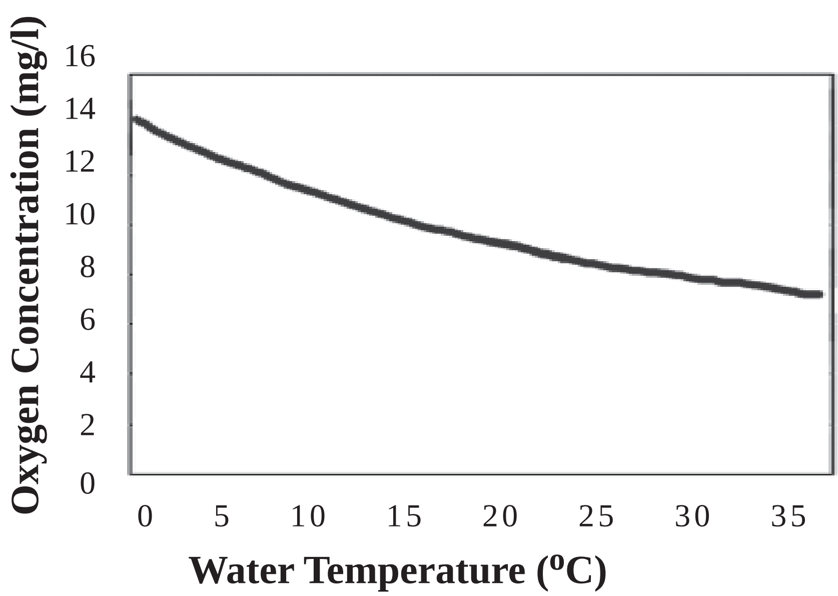
Activity Extension

Effect of Temperature on Dissolved Oxygen Concentrations

The data below show the maximum amount of dissolved oxygen the water can hold at different temperatures. This is called the “saturation concentration” of oxygen.

Temperature (°C)	Dissolved Oxygen (mg/l)	Temperature (°C)	Dissolved Oxygen (mg/l)	Temperature (°C)	Dissolved Oxygen (mg/l)
0	14.2	12	10.4	24	8.2
1	13.8	13	10.2	25	8.1
2	13.4	14	10.0	26	8.0
3	13.0	15	9.8	27	7.9
4	12.7	16	9.6	28	7.7
5	12.4	17	9.4	29	7.6
6	12.1	18	9.2	30	7.5
7	11.8	19	9.0	31	7.4
8	11.5	20	8.8	32	7.3
9	11.1	21	8.7	33	7.2
10	10.9	22	8.5	34	7.1
11	10.7	23	8.4	35	7.0

Have your students use this information to create a graph showing the “saturation concentrations” of water as temperature changes. See the example graph below.



Activity Extension, Continued

Changes in Temperature and Dissolved Oxygen Throughout a Year

The table on the next page contains temperature and dissolved oxygen concentrations measured at the same site in a stream throughout an entire year. The site has slow moving water, and aquatic plants grow in the soft sediments of the stream from spring through fall. The first column of DO measurements were taken at 4:00 p.m. and the second column of DO measurements were taken at 4:00 a.m.

Have your students graph temperature and the first set of dissolved oxygen versus time.

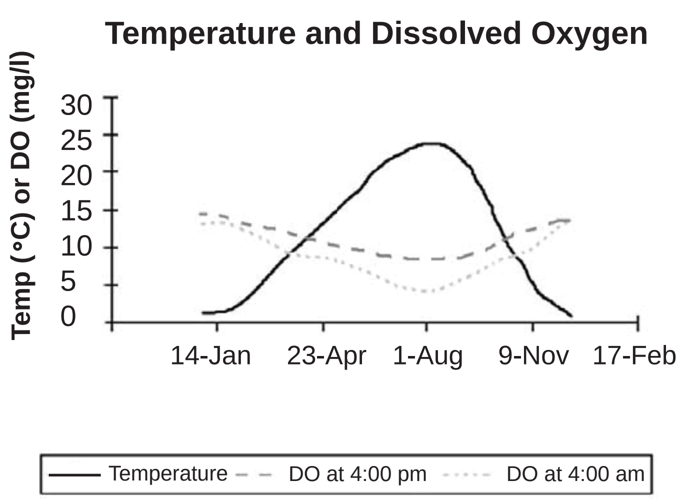
How do temperature and dissolved oxygen change throughout the year?

> *Temperature is highest in summer, while DO is lowest in summer. This is because saturation concentration of dissolved oxygen decreases as the water temperature increases (see graph below).*

Now have your students add the second set of dissolved oxygen data to the graph. Tell them the samples were collected at 4:00 a.m.

Why was the dissolved oxygen lower at 4:00 a.m. than at 4:00 p.m.?

> *The plants in the water consume oxygen at night (due to metabolic respiration), but cannot produce oxygen from photosynthesis at night when there is not light. Therefore DO can be substantially lower in water at one time of day than another.*



Activity Extension, Continued

Day of year	Date	Temp. °C	Dissolved Oxygen	
			mg/l at 4:00 pm	mg/l at 4:00 am
1	1-Jan	1	13.8	13.0
15	15-Jan	1	13.8	13.0
32	1-Feb	2	13.4	12.5
46	15-Feb	3	13.0	11.3
61	1-Mar	5	12.4	10.4
75	15-Mar	7	11.8	9.5
92	1-Apr	10	10.9	9.0
106	15-Apr	12	10.4	8.5
122	1-May	14	10.0	8.0
136	15-May	16	9.6	7.5
153	1-Jun	18	9.2	6.9
167	15-Jun	20	8.8	5.6
183	1-Jul	22	8.5	4.5
197	15-Jul	23	8.4	4.0
214	1-Aug	24	8.2	3.8
228	15-Aug	24	8.2	4.0
245	1-Sep	22	8.5	5.0
259	15-Sep	19	9.2	7.0
275	1-Oct	15	9.8	7.8
289	15-Oct	10	10.9	9.0
306	1-Nov	7	11.8	9.5
320	15-Nov	4	12.7	10.7
336	1-Dec	2	13.4	12.5
350	15-Dec	1	13.8	13.0