DISSOLVED OXYGEN (DO or Dissolved O2)

Among the most important variables affecting stream health is the concentration of dissolved oxygen present in the water. Dissolved oxygen in a stream is essential to numerous life forms and is readily affected by many human activities. In this activity, students will measure the amount of dissolved oxygen in a water sample from the Huron River watershed.
Although the pre and post discussions are necessary to provide important information about each topic, it is the activity that is most vital to this unit. Be sure to allow plenty of time to complete the activity.

Equipment needed

- Hach field test kit for dissolved oxygen: Azide-modified Winkler method
- Scissors or small cutting pliers to open powder pillows in Hach kit
- Small table
- Long-handled dipper (if you need to sample water from a steep bank)
- Display board
- Data sheets and clipboard
- Wastewater jug for disposal of spent solutions
- Safety glasses and gloves (rubber, vinyl)
- Paper towel roll (nice to have but not essential)

Using the Hach Kit

You will be using a Hach portable field test kit for this measurement. The procedure is below and is easy to follow if you do each step carefully. But the chemistry, explained in the following paragraph, is complicated.

In brief, you will be removing interfering NO2 (nitrite ion) from the water sample with alkaline sodium azide. Manganous sulfate (MnSO4) and potassium iodide (KI) are then added to the sample. A white precipitate of manganous hydroxide (MnOH2) is formed which rapidly reacts with any dissolved oxygen present to form brown manganese dioxide (MnO2). The solution is then made acid by adding sulfamic acid (H3NSO3). In this acidic solution the manganese dioxide reacts with iodide ion (from the potassium iodide added earlier) to form an amount of iodine (I2) chemically equivalent to the amount of dissolved oxygen originally present in the sample. Lastly, the released I2 is titrated using a carefully measured amount of sodium thiosulfate (Na2S2O3) solution. This converts the yellow brown I2 to colorless I^- leaving a colorless solution. The amount of sodium thiosulfate needed to turn the water colorless is proportional to the concentration of dissolved oxygen in the original sample.

Toxicity and Disposal Information for Activity Leaders and Students

These chemicals are toxic (some quite toxic) and very irritating to the eyes. Wear safety goggles, avoid spills, DO NOT TASTE ANY OF THE CHEMICALS, and rinse your hands well with water after completing the activity. If you get any of these chemicals in an eye, wash the eye with clean water (such as drinking water) for 5 minutes and then seek medical attention at once. Dispose of liquid wastes from the activity in the jug provided for later disposal in a sink or toilet.

Dissolved Oxygen Lesson Narrative

The mission of this lesson is to make these points:

- Dissolved oxygen measures how much oxygen is in the water
    - Fish and other organisms need high oxygen levels to survive (5 mg oxygen/L water)
- DO is affected by many variables
    - Temperature (impacted by seasons, turbidity, stormwater runoff)
    - Turbulence (how bubbly the water is)
    - Depth
- We can do things to keep our DO levels high and the river ecosystem healthy:
    - Reduce erosion by planting plants and placing rocks near banks
    - Reduce stormwater runoff by planting rain gardens and using permeable surfaces

Introduction: 5 min

1. My name is ________, and I'm a volunteer with the Dissolved Oxygen station.

2. How do we get oxygen into our bodies? (*We breathe it into our lungs.*) Where does it go next? (*Into our blood*) Then what do we use it for? (*We use oxygen to burn our food for energy.*)

3. How do water organisms get oxygen? (*Most use gills or tubes to get dissolved oxygen from the water*) What do they use the dissolved oxygen for? (*To burn their food for energy*.)

4. We are going to test this water today to see how much dissolved oxygen it contains.

The Activity: 10 - 15 min

1. Today we are going to collect a sample of stream water, and test it for DO. Let's go down to the water to collect a sample! *(Select a site with easy access to the stream. You will need to be upstream from activities that may cause a lot of turbidity - macroinvertebrate collection, stream speed).*

2. We will use a can on a stick to take a sample. *(Don't use the turbidity pail because it can add too much oxygen to the sample.)*

3. *While down by the stream, mention:* Oxygen gets dissolved into the water through contact with the air. Places in the stream where the water is shallow and turbulent (riffles, rapids, windy conditions) are where lots of oxygen can get mixed in. Do we see anywhere in this stream where we see lots of bubbles? Where is it calmer?

4. *Choose a calm location by the shore to collect a sample.* We are going to collect the water sample by gently dipping the water collection device into the water. We don't want to stir up oxygen in the water by forming bubbles.

5. *Once students are back at the tables, hand out gloves and safety glasses.* When working with chemicals, it is important to wear proper safety equipment to protect ourselves. We are now going to start our experiment!

6. *Once students are seated, use the laminated Dissolved Oxygen Procedure page to give each student a turn reading and performing the directions in order.* Let's read the first step of this procedure.

    a. Collect the water sample by gently dipping the water collection device into the water. We don't want to stir up oxygen in the water by forming bubbles.

b. Remove the stopper from the glass bottle. Sink the bottle in the water sample. Fill the glass-stoppered bottle with sample water. While holding the glass bottle under the water, put the stopper into the bottle. Be sure there are no air bubbles.

c. Add the contents of DO 1 reagent envelope to the glass bottle. Cover with the stopper and turn back and forth several times to gently mix. Be careful to avoid trapping air when replacing the stopper and mixing.

d. Then add DO 2 reagent envelope to the glass bottle and gently mix again. Be careful to avoid trapping air when replacing the stopper and mixing.

e. A precipitate will form called floc. Let it settle to the bottom until it fills ½ of the volume of the bottle, about 4 - 5 minutes. *(If you are pairing this activity with a second one, use this time to get started on that other activity - either with pre discussion, or collecting more water)*

f. Tip the bottle back and forth again and then let the floc resettle, about 4-5 minutes. *(If you are pairing this activity with a second one, use this time to get started on that other activity - either with pre discussion, or collecting more water)*

g. Remove stopper and add DO 3 reagent. Gently invert the bottle again to mix and then let settle for at least 5 minutes. Observe the reaction and take notes about what is changing. *(If you are pairing this activity with a second one, use this time to get started on that other activity - either with pre discussion, or collecting more water)*

h. Fill the small round tube with this solution.

i. Put the square bottle over the top of the filled tube. Invert the bottle and tube to pour the solution from the round tube to the square bottle.

j. Add sodium thiosulfate one drop at a time to the solution in the square bottle until the solution is colorless. Swirl after adding each drop. BE SURE to count the drops. Set the bottle on a white sheet of paper to help detect when the solution becomes colorless.

k. The number of drops = mg/l of DO. Record this number on your data sheet.

Wrap Up: 5 min

1. How does oxygen get into the water?
   a. *aeration from wind, waves, rapids, waterfalls; direct diffusion into surface (slow); aquatic plants release oxygen*

2. Name 3 factors that affect or can change Dissolved Oxygen concentration in a stream.
   a. ***How well oxygen can enter from the atmosphere.*** *In shallow, turbulent streams it is easy for oxygen to enter; it is much slower in deep, slow moving or stagnant streams.*
   b. ***Temperature.*** *Think of soda or other carbonated beverages: what happens when they get warm? What about cold? The point to make is that cold water can hold more oxygen.*
      i. *The solubility of oxygen in water decreases with increasing temperature. For example, at*

14oC the solubility of oxygen in pure water (no dissolved salts) is 10.30 mg/L, while at 30oC it is only 7.56 mg/L.

   c. ***Presence of Biochemical (Biological) Oxygen Demand, BOD****. BOD consists of organic material (food processing wastes, human and animal feces and urine, paper mill wastes, dead and decomposing algae and leaves, etc.) that can be used as food by bacteria naturally present in surface waters. As the bacteria feed upon the BOD, they use oxygen. They also multiply. If there is sufficient BOD present, its metabolism by the stream bacteria will use up all of the dissolved oxygen in the water. At this point fish and most benthic macro-invertebrates die of suffocation.*

3. Does this water meet the Michigan state requirement of 5.0 mg/L as the minimum acceptable DO concentration?
   a. *Answers may vary*

4. Based on your DO measurements, could trout and smallmouth bass live in this stream?
   a. *Note: DO requirements for fish depend on a number of factors, so the numbers on this chart are not precise and other sources may give slightly different figures. Nevertheless, it provides useful approximate information about the DO needs of aquatic life.*

5. Would you expect similar DO concentrations in this stream during the summer? Why or why not?
   a. *Likely answer is no. Higher water temperatures mean that less oxygen is dissolved in the water, lowering the DO.*

   Does that change your answer to #5? If yes, explain why.

   b. *Lower O2 concentrations make it less likely these can survive*

6. How could the DO concentration over time affect the <u>types</u> and <u>numbers</u> of critters (BMIs)?
   a. *Answers may vary but student predictions could hypothesize that higher DO concentrations over time would lead to a greater diversity in BMI's. However, the key idea is that the minimum DO requirements ALWAYS must be met. This is a case in which the average is not enough.*

7. What can people do to improve the DO concentration in our watershed?
   a. *Help maintain natural streamsides by limiting erosion, leaving rocks in river bottoms. Remove un-needed dams since sediments can increase stream temperatures.*
   b. *Rain gardens reduce runoff and so reduce both erosion and organic (dog poop) pollution into streams*

Background Information

Dissolved oxygen is essential for fish and benthic macroinvertebrates to live. When there is not enough oxygen, the food web for the whole ecosystem is affected. It must be remembered that the oxygen that is bound to hydrogen to make water is not available for respiration. Although the concentration of oxygen in the air is quite high, O2 is not very soluble in water. At a pressure of one atmosphere (atm) of air, the oxygen concentration in water at room temperature is about 8.2 mg/L or 8.2 parts per million (ppm) at saturation level.

Levels of DO are affected by discharges from industrial facilities and water treatment plants. They are also affected by water released from dams. DO concentrations in Michigan waters are monitored by the Michigan Department of Natural Resources. Violations are investigated and corrective action is taken. According to the laws of the State of Michigan, the minimum permissible DO in most Michigan streams is 5.0 mg/L. This is enough to support most aquatic life (but not trout or small-mouth bass) however the margin is not large. Another reason that the DNR monitors DO levels is to determine where to stock fish and the kind of fish to stock.

Dissolved oxygen can enter stream or lake water in many ways. Below are some common sources.

1) Diffusion from the atmosphere
2) Aeration as water moves over rocks and debris, riffles, rapids, waterfalls, etc.
3) Aeration from wind and waves
4) Photosynthesis of aquatic plants

There are a number of factors that affect the DO concentration including:

1. Efficiency of re-aeration from the atmosphere: Oxygen is easily transported from air to water in shallow, turbulent streams. It is poorly transported in deep, slow-moving or stagnant streams.
2. Organic materials in water such as food processing wastes, human and animal feces and urine, paper mill wastes, dead and decomposing algae and leaves, etc. can affect the levels of DO in water. These materials when present in water are referred to as Biochemical (or Biological) Oxygen Demand (BOD) and can be used as food by bacteria naturally present in surface waters. As the bacteria feed upon these materials, they use oxygen. They also multiply. If there is sufficient BOD present, its metabolism by the stream bacteria will use up all of the dissolved oxygen in the water. At this point fish and most benthic macroinvertebrates die of suffocation.
3. Temperature: The solubility of oxygen in water decreases with increasing temperature. In other words, colder water is capable of holding more dissolved oxygen than warmer water. For example, at 14^{o}C the solubility of oxygen in pure water (no dissolved salts) is 10.30 mg/L, while at 30^{o}C it is only 7.56 mg/L.

There are a number of human-caused conditions that can cause stream temperature to rise. Some strategies for remediation for each of these are listed.

1. Runoff: Impervious surfaces, cultivated fields and lawns cause water to run into lakes and streams quickly. When this happens, the water is much warmer than if it soaks into the ground and slowly moves as groundwater to enter streams and lakes. Buffer zones, retention ponds, rain barrels and water gardens can be helpful. Greater use of permeable asphalt that allows water to penetrate through to the soil would also reduce runoff.
2. Discharged water: Water that is discharged from industrial operations or water treatment plants is generally warmer than the bodies of water it is discharged into. Here, too, retention ponds for cooling could be helpful.
3. Health of Riparian Zones: Water that is shaded is cooler than water that is exposed to sunlight. When trees and shrubs that shade streams and rivers are removed, the increase in sunlight warms the water. Restoring streamside vegetation with a mix of trees, shrubs, grass and other plants will create more

shade and also reduce erosion of stream banks.

4. Erosion: When soil enters the water through erosion, the increased concentration of sediment (dirt in the water) increases turbidity. Water heats up more quickly when it has high turbidity. Good vegetation buffer zones to prevent soil from entering streams will improve stream health in many ways.

For this and other units, advanced level information is available if desired. Contact HRWC and request an electronic version of the unabridged manual.

DO Student Procedure Hand-Out

1. **Collect the water sample by gently dipping the water collection device into the water. We don't want to stir up oxygen in the water by forming bubbles.**

2. **Remove the stopper from the glass bottle. Sink the bottle in the water sample. Fill the glass-stoppered bottle with sample water. While holding the glass bottle under the water, put the stopper into the bottle. Be sure there are no air bubbles.**

3. **Add the contents of DO 1 reagent envelope to the glass bottle. Cover with the stopper and turn back and forth several times to gently mix. Be careful to avoid trapping air when replacing the stopper and mixing.**

4. **Then add DO 2 reagent envelope to the glass bottle and gently mix again. Be careful to avoid trapping air when replacing the stopper and mixing.**

5. **A precipitate will form called floc. Let it settle to the bottom until it fills ½ of the volume of the bottle, about 4 - 5 minutes.**

6. **Tip the bottle back and forth again and then let the floc resettle, about 4-5 minutes.**

7. **Remove stopper and add DO 3 reagent. Gently invert the bottle again to mix and then let settle for at least 5 minutes. Observe the reaction and take notes about what is changing.**

8. **Fill the small round tube with this solution.**

9. **Put the square bottle over the top of the filled tube. Invert the bottle and tube to pour the solution from the round tube to the square bottle.**

10. **Add sodium thiosulfate one drop at a time to the solution in the square bottle until the solution is colorless. Swirl after adding each drop.BE SURE to count the drops. Set the bottle on a white sheet of paper to help detect when the solution becomes colorless.**

11. **The number of drops = mg/l of DO. Record this number on your data sheet.**

Dissolved Oxygen (DO) Data Sheet

Student Observations:

Minimum DO requirements for some aquatic organisms

Trout	6.5 mg/L
Smallmouth bass	6.5 mg/L
Caddisfly larvae	4.0 mg/L
Mayfly larvae	4.0 mg/L
Catfish	2.5 mg/L
Carp	2.0 mg/L
Mosquito larvae	1.0 mg/L

1. Drops of thiosulfate solution added to decolorize one measuring tube of sample:

_____DO concentration = ______ mg/L

2. How does oxygen from the atmosphere get into the water?

3. Name 3 factors that affect or can change Dissolved Oxygen concentration in a stream.

4. Does this water meet the Michigan state requirement of 5.0 mg/L as the minimum acceptable DO concentration?

5. Based on your DO measurements, could trout and smallmouth bass live in this stream?

6. Would you expect similar DO concentrations in this stream during the summer? Why or why not?

Does that change your answer to #5? If yes, explain why.

7. How could the DO concentration over time affect the <u>types</u> and <u>numbers</u> of critters (BMIs)?

8. What can people do to improve the DO concentration in our watershed?

KEY Dissolved Oxygen Data Sheet

1. **Answers will vary**

2. How does oxygen from the air get into the water?
   Oxygen can dissolve into the water at the edge (surface) between the water and the air. This happens more when the water gets turbulent, such as in a waterfall, or riffle.

3. Name 3 factors that can change Dissolved Oxygen concentration
   a. Efficiency of re-aeration from the atmosphere. Efficiency of oxygen transport from air to water is high in shallow, turbulent streams; it is poor in deep, slow moving or stagnant streams.
   b. Temperature. The solubility of oxygen in water decreases with increasing temperature. For example, at 14^{o}C the solubility of oxygen in pure water (no dissolved salts) is 10.30 mg/L, while at 30^{o}C it is only 7.56 mg/L.
   c. Presence of Biochemical (Biological) Oxygen Demand, BOD. BOD consists of organic material (food processing wastes, human and animal feces and urine, paper mill wastes, dead and decomposing algae and leaves, etc.) that can be used as food by bacteria naturally present in surface waters. As the bacteria feed upon the BOD, they use oxygen. They also multiply. If there is sufficient BOD present, its metabolism by the stream bacteria will use up all of the dissolved oxygen in the water. At this point fish and most benthic macro-invertebrates die of suffocation.

4. Does this water meet the Michigan state requirement of 5.0 mg/L as the minimum acceptable DO concentration? **Answers will vary**

5. Based on your DO measurements, could trout and smallmouth bass live in this stream? **Answers will vary**

6. Would you expect similar DO concentrations in this stream during the summer? Why or why not?
   Likely answer is no. Higher water temperatures mean that less oxygen is dissolved in the water, lowering the DO.

   Does that change your answer to #5? If yes, explain why. **Lower O2 concentrations make it less likely these can survive**

7. How could the diversity (number of kinds) of aquatic critters (BMI's) relate to the DO concentration over time? **Answers may vary but student predictions could hypothesize that higher DO concentrations over time would lead to a greater diversity in BMI's. However, the key idea is that the minimum DO requirements ALWAYS must be met. This is a case in which the average is not enough.**

8. What can people do to improve the DO concentration in our watershed?
   a. **Help maintain natural streamsides by limiting erosion,** leaving rocks in river bottoms. Remove un-needed dams since sediments can increase stream temperatures.
   b. **Help maintain natural streamsides by limiting erosion**
   c. **Rain gardens reduce runoff and so reduce both erosion and organic (dog poop) pollution into streams**