

EFFECT OF TEMPERATURE ON DISSOLVED OXYGEN CONTENT IN WATER



Westminster College

STANDARDS

- 3.1.12C
- 3.2.10A, 3.2.10B, 3.2.10C
- 3.7.10A, 3.7.10B

INTRODUCTION

Oxygen is an essential element to life, both terrestrial and aquatic. Oxygen gas dissolves in water through several different avenues. Simple diffusion from the air and aeration from water movement affect the dissolved oxygen (DO) content. For example, water in a shallow, fast moving stream is more likely to have DO than a stagnant pool of water. Biological factors that affect DO content are photosynthesis by aquatic plants, the amount of decaying organic material, and even human activities that occur at a body of water. During the day, photosynthesis by aquatic plants increases the DO content of water. At night, plants and animals continue to consume the DO, resulting in a decrease in DO concentration. Decaying organic material is broken down by aerobic bacteria (bacteria that require oxygen), and this process depletes the DO concentration of water as well. Physical factors like temperature, altitude, and atmospheric pressure also affect the DO content of water.

The oxygen content of water is often an important indicator of water quality and directly influences the organisms supported by a body of water. In general, the higher the DO concentration, the more diverse the biological population will be. Table 1 shows the concentrations of DO necessary to support certain species. Catfish and carp require significantly less DO than trout and bass. This explains why catfish and carp (big goldfish) commonly live in ponds where the water is not well aerated and decomposing material decreases the DO concentration. Mosquito larvae require the least DO of all. A small puddle of water is enough to support their growth! This is the reason it is important to be sure that after a heavy rain, there are no standing pools of water in your yard. Especially in western Pennsylvania, where West Nile virus is a concern, it is important to eliminate the type of environment where mosquitoes can breed.

Organism	Minimum DO (mg/L)
Trout/Smallmouth bass	6.5
Caddisfly & mayfly larvae	4.0
Catfish	2.5
Carp	2.0
Mosquito larvae	1.0

The use of laundry detergents that contain phosphorus is good example of how human activity can affect water quality and DO concentrations. All organisms rely on the presence of phosphorus to survive, but in general, levels of this nutrient are low. Up until the 1970's, most laundry detergents in the US contained phosphates as a primary ingredient. These

phosphates were sent with household water to sewage plants, and then would be released into local water supplies. The increase in phosphorus in the water resulted in a process called *eutrophication*. Eutrophication is the name for nutrient enrichment of an ecosystem that is naturally low in nutrients. The increase in dissolved phosphorus in the water resulted in algal blooms, or accelerated growth of algae. Increased growth resulted in increased amounts of decaying organic material in the water. The bacteria that aid in the decomposition of the algae are aerobic species. During the decomposition process, therefore, the bacteria deplete the water supply of DO, resulting in the death of many fish and other organisms that live in the water. Since the relationship between the presence of high concentrations of phosphates in water and the decrease in water quality has been recognized, the use of phosphates in detergents has been terminated. This is only one example of policy changes made to prevent the continuing decline in water quality.

GUIDING QUESTIONS

- What is the effect of temperature on the amount of dissolved oxygen found in water?
- What other factors affect the amount of dissolved oxygen in water?
- How does water temperature affect the organisms that live in it?

MATERIALS

LabQuest	1 L bottle
Vernier dissolved oxygen sensor	Insulated cup
Vernier temperature sensor	100 mL graduated cylinder
250 mL beaker	Water (at 4°C, 20°C, 50°C)

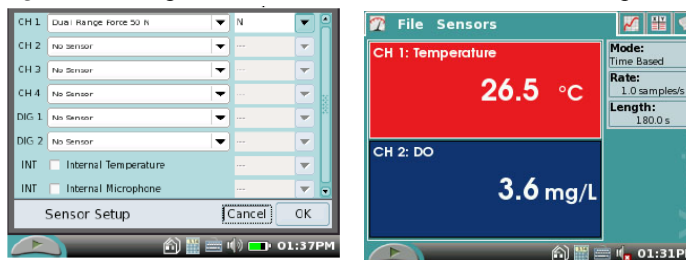
PROCEDURE

Part I LabQuest Set-Up and DO Sensor Calibration

1. Plug the power supply into the left-hand side of the LabQuest. Turn the LabQuest on by pushing the oval button on the top left hand of the instrument. Connect a DO sensor and a temperature sensor to the LabQuest. If you have an older sensor that does not auto-ID, manually set up the sensor. To do this:

- Stay in the Meter mode and select Sensors → Sensor Setup... →. A sensor set-up screen will appear showing all the available probe ports (Fig. 1a).
- Select the channel that the DO sensor is

Figure 1. Example of LabQuest Screens and Sensor Set-Up



a. Sensor set-up screen

b. Meter mode screen

plugged into (ex. CH1 for channel 1), and tap the arrow to the side of the channel box.

c. A list of compatible probes will appear in alphabetical order. Scroll down the list and select “Dissolved Oxygen”. Select to return to the Meter mode screen.

d. Two boxes will now be in this window, one displaying DO (mg/L) and the other, temperature (°C).

2. **Important:** Prior to each use, the Dissolved Oxygen Probe must warm up for a period of 5–10 minutes as described below. If the probe is not warmed up properly, inaccurate readings will result. Perform the following steps to prepare the Dissolved Oxygen Probe.

- a. Gently remove the blue protective cap.
- b. Unscrew the membrane cap from the tip of the probe.
- c. Using a disposable pipet, fill the membrane cap with 1 mL of DO Electrode Filling Solution (0.1 M KCl).
- d. Carefully thread the membrane cap back onto the electrode.

3. Place the probe into a 250 mL beaker containing distilled water and let it equilibrate for 10 min before calibration. The probe must stay connected at all times to keep it warmed up.

4. Your instructor will tell you which method to use for calibrating the DO sensor.

- a. If your instructor directs you to use the calibration stored in the experiment file, continue directly to the Procedure.
- b. If your instructor directs you to manually enter the calibration values, choose Calibrate ► Dissolved Oxygen from the Sensors menu. Tap Equation. Enter the values for the Slope and the Intercept. Select Apply. Select OK and continue directly to the Procedure.
- c. Follow steps 5 and 6 to perform a manual calibration.

5. The DO sensor will need to be calibrated. You must take into account the barometric pressure and ambient room temperature for the day of the calibration. Use the tables **Table 4. Barometric Pressure Conversion Table** and the **Table 3. 100% Dissolved Oxygen Capacity Table** found at the very end of the lab handout to determine the 100% DO Capacity, and record this information below. The 100% DO Capacity is the number you will when calibrating the DO sensors.

Barometric pressure: _____ in mmHg: _____
Room temperature: _____ Elevation (optional): _____
100% DO Capacity _____

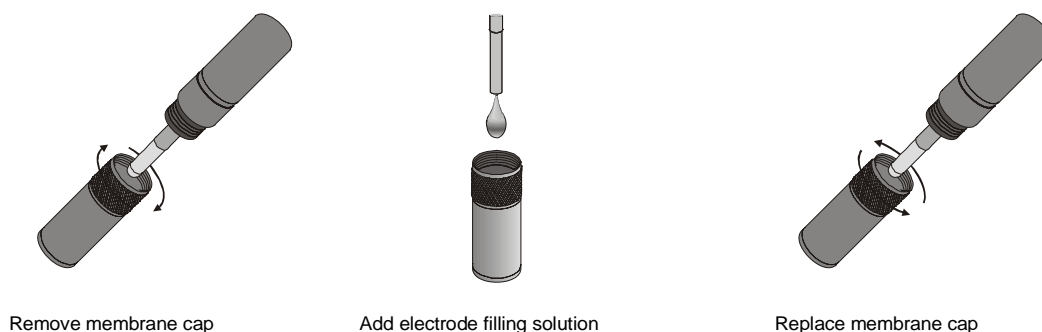


Figure 2

6. Calibrate the Dissolved Oxygen Probe.

- a. Choose Calibrate ► Dissolved Oxygen from the Sensors menu.
- b. Select Calibrate Now.

Zero-Oxygen Calibration Point

- c. Remove the probe from the water bath and place the tip of the probe into the Sodium Sulfite Calibration Solution. **Important:** No air bubbles can be trapped below the tip of the probe or the probe will sense an inaccurate dissolved oxygen level. If the voltage does not rapidly decrease, tap the side of the bottle with the probe to dislodge the bubble. The readings should be in the 0.2 to 0.6 V range.
- d. Enter 0 as the known value in mg/L for Reading 1.
- e. When the voltage stabilizes (~1 minute), tap Keep.

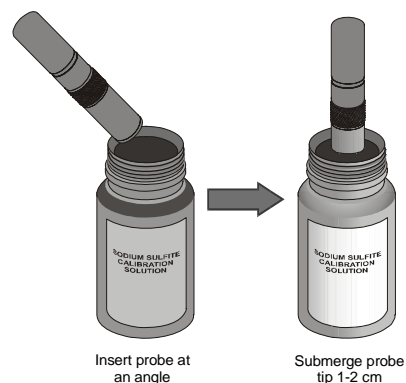


Figure 3

Saturated DO Calibration Point

- f. Rinse the probe with distilled water and gently blot dry.
- g. Unscrew the lid of the calibration bottle provided with the probe. Slide the lid and the grommet about 1/2 inch onto the probe body.

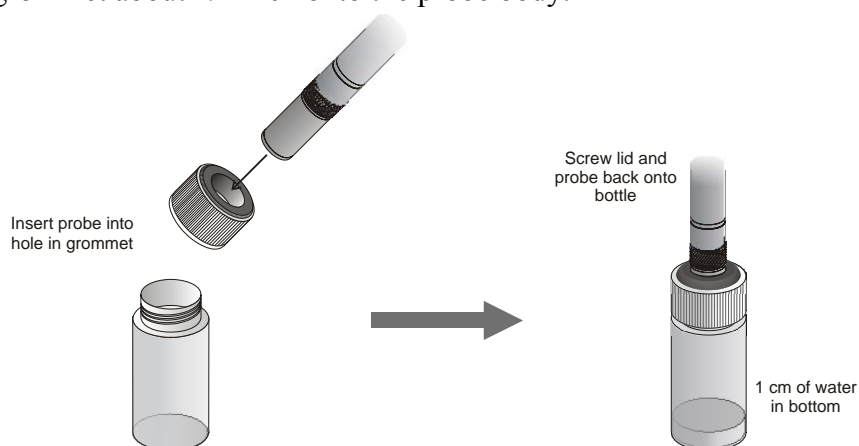


Figure 4

- h. Add water to the bottle to a depth of about 1/4 inch and screw the bottle into the cap, as shown. **Important:** Do not touch the membrane or get it wet during this step.
- i. In the Reading 2 field, enter the correct saturated dissolved-oxygen value in mg/L from Table 3 (for example, **8.66** for 760 mm at 23°C) using the current barometric pressure and air temperature values. If you do not have the current air pressure, use Table 5 to estimate the air pressure at your altitude.
- j. Keep the probe in this position for about a minute. The readings should be above 2.0 V. When the voltage reading stabilizes, tap Keep.
- k. Return the Dissolved Oxygen Probe to the distilled water beaker.
- l. Select OK.

Part II Dissolved Oxygen in Water at Different Temperatures

7. Obtain a 250 mL beaker. Fill it with ice and water.

8. Place approximately 100 mL of cold water and a couple small pieces of ice into a clean 1 L plastic container. Seal the container and vigorously shake the water for a period of 2 minutes. This will allow the air inside the container to dissolve into the water sample and give a maximum DO reading for each temperature. Pour the water into a clean Styrofoam cup.

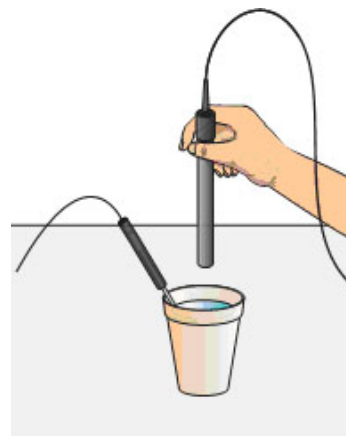


Figure 5

9. Place the Temperature Probe in the Styrofoam cup as shown in Figure 5. Place the shaft of the Dissolved Oxygen Probe into the water and gently stir. Avoid hitting the edge of the cup with the probe.

10. Monitor the dissolved oxygen readings displayed on the screen. Give the dissolved oxygen readings ample time to stabilize (90–120 seconds). At colder temperatures the probe will require a greater amount of time to output stable readings (120-180 seconds). Record the temperature (°C) and the DO reading (in mg/L) in **Table 1** on your Data Sheet.

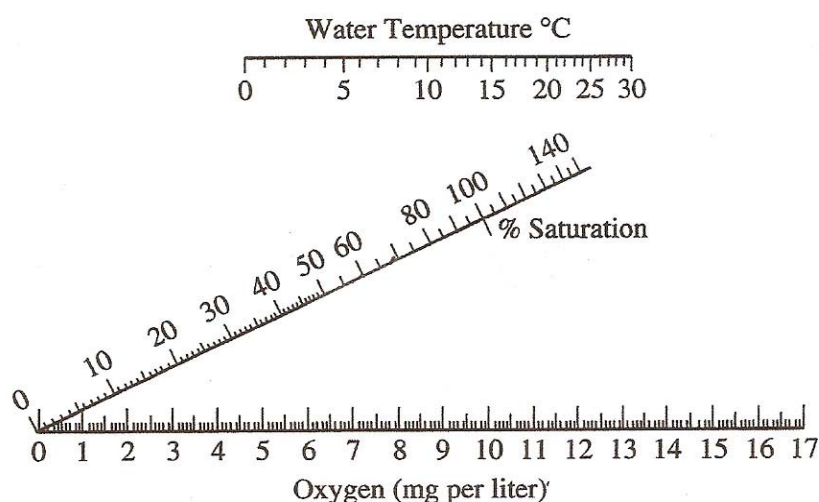
11. Discard the cold water in the Styrofoam cup. Place the Dissolved Oxygen Probe back into the distilled water beaker.

12. Obtain 100 mL water that is at room temperature and pour it into the 1 L container. Seal the container and shake the water vigorously for 2 minutes. Pour the water back into the Styrofoam cup.

13. Repeat Steps 9 and 10. After the room temperature data is recorded, pour the room temperature water out of the Styrofoam cup and place the Dissolved Oxygen Probe back into the distilled water beaker.

14. Obtain 100 mL water that is at approximately **50-55 °C** (hot tap water) and pour it into the 1 L container. Seal the container and shake the water vigorously for 2 minutes. Pour the water back into the Styrofoam cup.
15. Repeat Steps 9 and 10 and record the data for the warm water sample.
16. When you are finished taking readings, select the File menu, then Quit. To turn the equipment off, press and hold the oval button on the top left of the LabQuest until the screen goes dark. If you plan to use the probes the following day, keep them attached to the LabQuest and store them with their tips submerged in a beaker of water.

Figure 6. Nomogram of Oxygen Saturation



17. Use the nomogram of oxygen saturation in *Figure 6* to determine the percent saturation of DO in your samples. Line up the edge of a ruler with the temperature of the water on the top scale and the DO (mg/L) on the bottom scale, then read the percent saturation from the middle scale. Record this information in **Table 1** on your Data Sheet.
18. Use the graph paper provided in the lab to make a graph of temperature (°C) vs. DO (mg/L). Plot a best-fit line for your individual DO data. Use this graph to determine the class mean DO. For example, if your instructor wants to know the class mean at 15°C, use the best-fit line to determine the DO for your group at this temperature. Once the class mean is determined for 3 different temperatures, record this information in **Table 2** on your Data Sheet and plot these data on the graph as well.

REFERENCES

The College Board Advanced Placement Program. Biology Lab Manual for Students. Lab Twelve: Dissolved Oxygen and Aquatic Primary Productivity. © 2001 by the College Examination Board. Pp. 136-144.

The College Board Advanced Placement Program. Biology Lab Manual for Teachers.
Lab Twelve: Dissolved Oxygen and Aquatic Primary Productivity. © 2001 by the
College Examination Board. Pp. 81-88.

Kelly Redding and David Masterman. Advanced Biology with Vernier. (2008)
Dissolved Oxygen in Water (12A). Vernier Software & Technology; 13979 S.W.
Millikan Way, Beaverton, OR pp. 12A-1 to 12A-6); 12A-1T to 12A-2T.

CREDITS

Special thanks to Connie White and the Environmental Biology class at Wilmington High School, New Wilmington, PA for testing, reviewing and editing this protocol. This lab was revised and adapted from the above references by Dr. Stephanie Corrette-Bennett.

DATA SHEET

Name: _____
Group: _____
Date: _____

DATA ANALYSIS

Record the primary data in the following tables as indicated in the protocol.

DATA TABLES

Table 1. Individual DO at Different Temperatures		
Temperature (°C)	Lab Group DO	Lab Group % DO Saturation

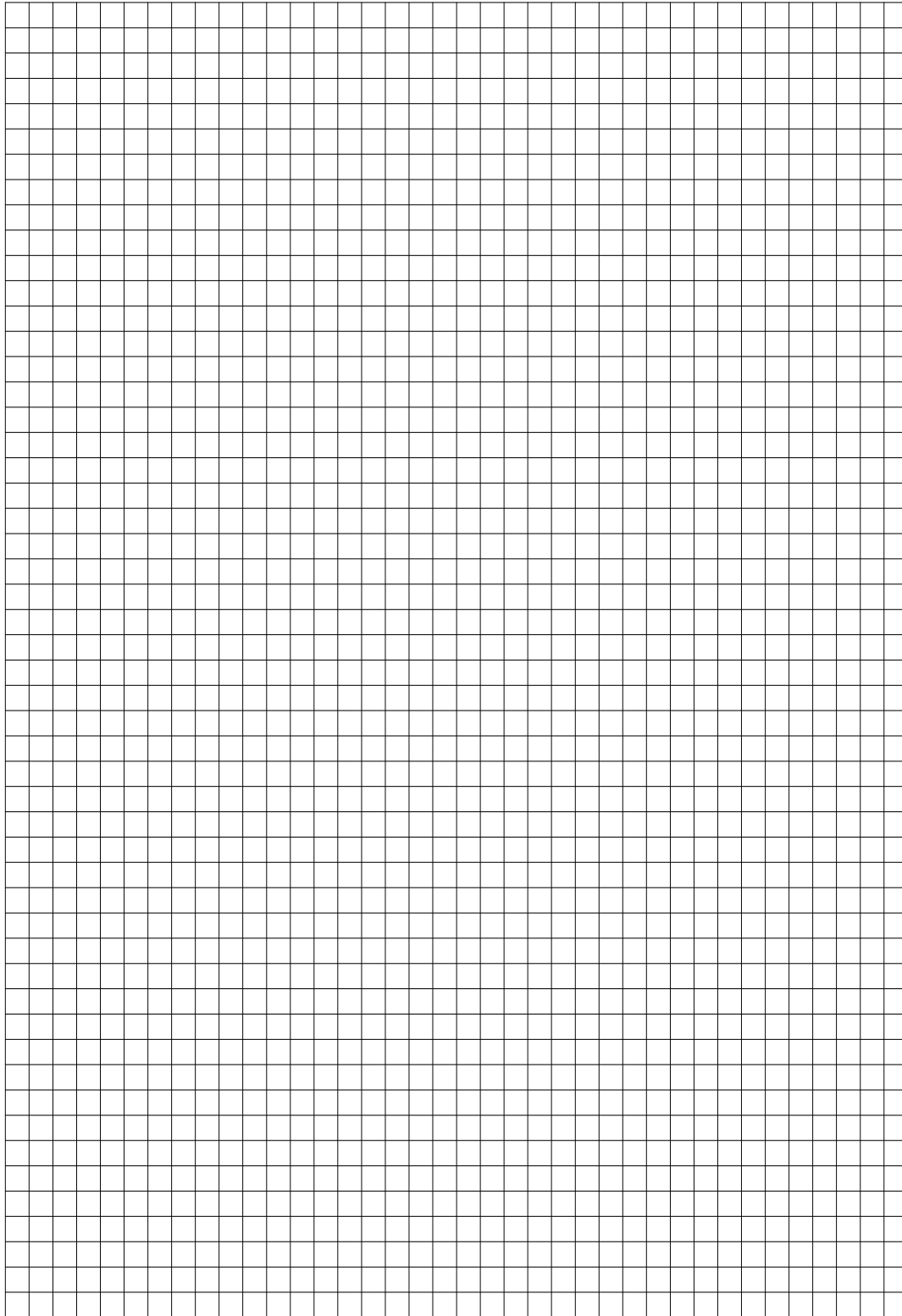
Table 2. Class Mean DO at Different Temperatures	
Temperature (°C)	Class Mean DO
15	
20	
25	

QUESTIONS

1. Why is it important to know the temperature of the water and the barometric pressure when you determine the DO content of your water?

2. Consider the difference between a stream and a pond. What factors (biological or physical) do you think affect the DO concentration in these two samples?

3. Which water could support more organisms, the pond or the stream? Why?



BAROMETRIC PRESSURE AND TEMPERATURE TABLES

Table 3: 100% Dissolved Oxygen Capacity (mg/L)												
	770 mm	760 mm	750 mm	740 mm	730 mm	720 mm	710 mm	700 mm	690 mm	680 mm	670 mm	660 mm
0°C	14.76	14.57	14.38	14.19	13.99	13.80	13.61	13.42	13.23	13.04	12.84	12.65
1°C	14.38	14.19	14.00	13.82	13.63	13.44	13.26	13.07	12.88	12.70	12.51	12.32
2°C	14.01	13.82	13.64	13.46	13.28	13.10	12.92	12.73	12.55	12.37	12.19	12.01
3°C	13.65	13.47	13.29	13.12	12.94	12.76	12.59	12.41	12.23	12.05	11.88	11.70
4°C	13.31	13.13	12.96	12.79	12.61	12.44	12.27	12.10	11.92	11.75	11.58	11.40
5°C	12.97	12.81	12.64	12.47	12.30	12.13	11.96	11.80	11.63	11.46	11.29	11.12
6°C	12.66	12.49	12.33	12.16	12.00	11.83	11.67	11.51	11.34	11.18	11.01	10.85
7°C	12.35	12.19	12.03	11.87	11.71	11.55	11.39	11.23	11.07	10.91	10.75	10.59
8°C	12.05	11.90	11.74	11.58	11.43	11.27	11.11	10.96	10.80	10.65	10.49	10.33
9°C	11.77	11.62	11.46	11.31	11.16	11.01	10.85	10.70	10.55	10.39	10.24	10.09
10°C	11.50	11.35	11.20	11.05	10.90	10.75	10.60	10.45	10.30	10.15	10.00	9.86
11°C	11.24	11.09	10.94	10.80	10.65	10.51	10.36	10.21	10.07	9.92	9.78	9.63
12°C	10.98	10.84	10.70	10.56	10.41	10.27	10.13	9.99	9.84	9.70	9.56	9.41
13°C	10.74	10.60	10.46	10.32	10.18	10.04	9.90	9.77	9.63	9.49	9.35	9.21
14°C	10.51	10.37	10.24	10.10	9.96	9.83	9.69	9.55	9.42	9.28	9.14	9.01
15°C	10.29	10.15	10.02	9.88	9.75	9.62	9.48	9.35	9.22	9.08	8.95	8.82
16°C	10.07	9.94	9.81	9.68	9.55	9.42	9.29	9.15	9.02	8.89	8.76	8.63
17°C	9.86	9.74	9.61	9.48	9.35	9.22	9.10	8.97	8.84	8.71	8.58	8.45
18°C	9.67	9.54	9.41	9.29	9.16	9.04	8.91	8.79	8.66	8.54	8.41	8.28
19°C	9.47	9.35	9.23	9.11	8.98	8.86	8.74	8.61	8.49	8.37	8.24	8.12
20°C	9.29	9.17	9.05	8.93	8.81	8.69	8.57	8.45	8.33	8.20	8.08	7.96
21°C	9.11	9.00	8.88	8.76	8.64	8.52	8.40	8.28	8.17	8.05	7.93	7.81
22°C	8.94	8.83	8.71	8.59	8.48	8.36	8.25	8.13	8.01	7.90	7.78	7.67
23°C	8.78	8.66	8.55	8.44	8.32	8.21	8.09	7.98	7.87	7.75	7.64	7.52
24°C	8.62	8.51	8.40	8.28	8.17	8.06	7.95	7.84	7.72	7.61	7.50	7.39
25°C	8.47	8.36	8.25	8.14	8.03	7.92	7.81	7.70	7.59	7.48	7.37	7.26
26°C	8.32	8.21	8.10	7.99	7.89	7.78	7.67	7.56	7.45	7.35	7.24	7.13
27°C	8.17	8.07	7.96	7.86	7.75	7.64	7.54	7.43	7.33	7.22	7.11	7.01
28°C	8.04	7.93	7.83	7.72	7.62	7.51	7.41	7.30	7.20	7.10	6.99	6.89
29°C	7.90	7.80	7.69	7.59	7.49	7.39	7.28	7.18	7.08	6.98	6.87	6.77
30°C	7.77	7.67	7.57	7.47	7.36	7.26	7.16	7.06	6.96	6.86	6.76	6.66
31°C	7.64	7.54	7.44	7.34	7.24	7.14	7.04	6.94	6.85	6.75	6.65	6.55

Table 4. Barometric Pressure Conversion			
in Hg	mm Hg	in Hg	mm Hg
20.0	508.0	26.0	660.4
20.5	520.7	26.5	673.1
21.0	533.4	27.0	685.8
21.5	546.1	27.5	698.5
22.0	558.8	28.0	711.2
22.5	571.5	28.5	723.9
23.0	584.2	29.0	736.6
23.5	596.9	29.5	749.3
24.0	609.6	30.0	762.0
24.5	622.3	30.5	774.7
25.0	635.0	31.0	787.4
25.5	647.7	31.5	800.1

Table 5. Approximate Barometric Pressure at Different Elevations					
Elevation (m)	Pressure (mm Hg)	Elevation (m)	Pressure (mm Hg)	Elevation (m)	Pressure (mm Hg)
0	760	800	693	1600	628
100	748	900	685	1700	620
200	741	1000	676	1800	612
300	733	1100	669	1900	604
400	725	1200	661	2000	596
500	717	1300	652	2100	588
600	709	1400	643	2200	580
700	701	1500	636	2300	571

= approximate elevation of schools in Lawrence /Mercer counties

How to use the tables:

1. The first item you need to determine is the barometric pressure in Hg. Most household barometers and internet weather sites express air pressure in Hg.
2. Use **Table 4. Barometric Conversion Table** to convert to mmHg.
3. Find the closest number in mmHg on the **Table 3. 100% Dissolved Oxygen Capacity** table. Move down this column until you find the box that corresponds to the ambient temperature. The number displayed in this box is the maximum amount of oxygen that can be found in water under the current environmental conditions. For example, if the pressure is 740 mmHg and the temperature is 20°C, the maximum amount of oxygen that could be present in the water is 8.93 mg/L.
4. Use the **Approximate Barometric Pressure at Different Elevations** table only if the actual barometric pressure is not available.