Teaming Up for Clean Water

A WATER QUALITY STUDY

Respect Rule: Look, Listen, Learn, and Leave Alone (until instructed).

Overview

To understand the importance of water, look beyond its liquid, invisible nature, and test its inherent properties, its essential qualities. Water quality scientists rely on five parameters to give them a snapshot of water's nature. These parameters are temperature, dissolved oxygen, pH, turbidity, and conductivity. Measuring these parameters in the laboratory and understanding their importance to stream organisms will help students prepare for field work, and future study of stream ecology.

Background

Water is taken for granted. For a liquid that is critical to survival, and which is taken from the tap, from bottles flavored, caffeinated, mineralized or carbonated, very little is known about the true nature of water. Is water just a clear liquid essential for survival? What is in water, and what makes it healthy for aquatic animals?

Protecting the water quality of streams in California is the responsibility of the State Water Resources Control Board, or Water Board. This state agency has a program called the Clean Water Team which encourages citizens to protect their local waterways. During this study of water quality, students will be part of the Clean Water Team. The fact sheets used by students for research are developed by the Water Board, and available on their website at www.waterboards.ca.gov/nps/cwtguidance.html#10. (Scroll down to Section 3, and view the fact sheets for each parameter.)

This lesson focuses on five measurements of water quality often taken by aquatic biologists when assessing stream health. These parameters, temperature, dissolved oxygen, pH, turbidity, and conductivity, are critical to the survival of aquatic organisms. They are not the most important parameters for the quality of drinking water. However, they are readily measured and are a valuable prelude to more detailed laboratory experimentation in a high school, college, or commercial chemistry lab.

Temperature

Water temperature is a measure of the kinetic energy of water molecules. It is very important to aquatic organisms. As it not only affects metabolic rates, it alters environmental conditions important to survival (see dissolved oxygen discussion below). For example, cold-blooded animals, like fish, will double their metabolic rates for each 18°F increase in temperature and be reduced by one-half for each 18°F decrease in temperature.

Temperature will vary naturally primarily with the energy of sunlight, water flow, and depth of water. On dammed streams, like the Mokelumne River and Stanislaus River, temperature can be dependent on the regulation of flow from dams and the depth at which water was removed from the upstream reservoir. Water released from the bottom will be colder than water spilled from the surface.

A stream's temperature can inadvertently be changed in numerous ways. Removing riparian vegetation for flood control can reduce shade provided by overhanging limbs. Chanelizing a stream for flood control can alter stream flow, reduce the depth of pools or reduce groundwater recharge. Water diversions and dams can also affect temperature. Soil erosion can increase temperatures since soil particles absorb heat.

An accurate picture of stream temperature and its effect on stream health is a difficult monitoring task unless there are automated, computerized recorders that take ongoing, regular temperature measurements. However, temperature is an important measurement to monitor when sampling a creek because of its influence on oxygen solubility and its importance to aquatic organisms.

Objectives
Students will:
1. measure five parameters in water: temperature, dissolved oxygen, pH, turbidity, and conductivity; 2. design an experiment to evaluate these parameters in different water sources, or in different experimental conditions;
3. travel to a stream to monitor these parameters.

Grade Levels
7–12

Adult/Student Ratio
Normal class size

Where
Classroom wet laboratory (creeks must have safe public access). Water should be flowing but low enough for students to safely sample from streamside.

Skills
Analyzing, formulating hypotheses and questions, generalizing, graphing, predicting, researching, writing a report in scientific format

Key Words
Algal, Conductivity, Dissolved oxygen, Diurnal, pH, Temperature of water, Turbidity

> If facts are the seeds that later produce knowledge and wisdom, then the emotions and the impressions of the senses are the fertile soil in which the seeds must grow.
>
> —Rachel Carson

Dissolved Oxygen

Dissolved oxygen (often referred to as "D.O.") is the amount of oxygen gas dissolved in water. Some species like trout and certain stoneflies require high amounts of oxygen. These organisms are usually found in high gradient, cold and/or fast moving waters where oxygen enters the stream as water tumbles over boulders or stones. Since higher concentrations of oxygen gas can dissolve in water that is cold compared to warm, temperature is an important factor to consider when sampling dissolved oxygen or evaluating the effect of low dissolved oxygen. Another natural condition, altitude, affects dissolved oxygen concentrations. At higher altitudes, water holds less oxygen. At sea level and low temperature, the oxygen saturated in freshwater is in concentration of approximately 14 mg/l.

Dissolved oxygen is measured in milligrams per liter (mg/l) or parts per million. (A liter of fresh water is 1000 grams.) In streams where trout like to live, dissolved oxygen levels should not generally fall below 6 to 8 mg/l. In streams where bass or other warm water fish live, concentrations should not fall below 5 to 6 mg/l.

Chemistry classes can discuss important chemical principles such as the Ideal Gas Law and Henry's Law. Remember that the Ideal Gas Law states that the volume of a gas is inversely proportional to pressure, and directly proportional to temperature. And Henry's Law states that the concentration of a gas dissolved in a solution is directly proportional to the partial pressure of the gas above the solution.

Reducing dissolved oxygen can kill sensitive species, reduce the growth of organisms, or prevent egg hatching. D.O. may vary diurnally with temperature change, and algal photosynthesis and respiration. D.O. may be reduced by human activities or pollutants. Several factors that may reduce the D.O. are removal of riparian vegetation that shades the creek, increased nutrients and subsequent algal blooms, and increased sediment. Sediment may enter a stream if construction, logging, dirt roadways, or other soil erosion factors cause sediment loaded water to run off the watershed and into a stream. Once in the stream, sediment captures heat, temperatures can thus rise, causing oxygen levels to decline.

Measuring dissolved oxygen requires a titration called the Winkler Method. A dissolved oxygen kit, including sample vials and reagents, can be purchased from chemical supply companies such as LaMotte or Hach. Kits are also available locally through the Upper Mokelumne River Watershed Council at the Central Sierra Resource Conservation and Development office in Jackson.

For chemistry classes, the titration equations (below) will be of interest. More simply put, the titration uses several reactions to produce iodine in equal concentration to the original dissolved oxygen. The iodine can be observed in the reaction vessels, and is noticeably darker in samples with high dissolved oxygen. The iodine sample is then titrated with a sulfate compound, altering the iodine to form a charged iodine which is colorless. The reaction has a very clear endpoint, and is a good example of the value of titrations in chemical analyses.

Here are the equations. O_2 is reduced by Mn^{2+} at high pH. Divalent maganous hydroxide, a brown precipitate, is formed.

$$4e^- + 4H^+ + O_2 \rightarrow 2H_2O$$
$$2Mn^{2+} + 4OH^- \rightarrow 2MnO_2(s) + 4H^+ + 4e^-$$
$$\overline{2Mn^{2+} + 4OH^- + O_2 \rightarrow 2MnO_2(s) + 2H_2O}$$

Upon addition of iodine and H_2SO_4 to create an acid environment, MnO_2 oxidizes I^-,

$$4e^- + 2\,MnO_2(s) + 8H^+ \rightarrow 2Mn^{2+} + 4H_2O$$
$$4I^- \rightarrow 2I_2 + 4e^-$$
$$\overline{MnO_2(s) + 4H^+ + 2I^- \rightarrow I_2 + Mn^{2+} + 2H_2O}$$

to form a yellow brown solution.

The I_2 is then titrated with thiosulfate, $S_2O_3^{2-}$, to form I^- and tetrathionate, $S_4O_6^{2-}$.

$$2e^- + I_2 \rightarrow 2I^-$$
$$2S_2O_3^{2-} \rightarrow S_4O_62^- + 2e^-$$
$$\overline{2S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^-}$$

The endpoint is enhanced visually by the addition of a blue starch indicator.

pH

pH (the power of hydrogen) is a measure of the strength of the hydrogen ion in water. In familiar terms, pH tells how acidic or basic the water is. It is defined as the negative log of the hydrogen ion concentration. The more acidic the water is the lower the pH. For each whole number increase (e.g. from 1 to 2) the hydrogen ion concentration decreases tenfold and the water becomes less acidic. The range of measurements is 0 (high concentration of positively charged hydrogen ions, very acidic) to 14 (high concentration of negatively charged hydroxide ions, very basic). When both types of ions are in equal concentrations the pH is 7 or neutral.

Alkalinity is a slightly different measurement than pH. Alkalinity tells how well water can withstand a change in pH if an acid is added.

Most natural aquatic systems have a pH range between 4 and 9. The pH of the outside environment will affect cellular reactions inside aquatic organisms. Most freshwater organisms live within the range of 6.5 to 8.5. However, some fish such as carp and catfish can tolerate higher pHs.

Natural environmental factors affect the pH of water. Streams carve their way through rocks of different types, such as granite and limestone. The chemical nature of these rocks will determine the minerals that are leached from the rocks into the stream. Areas rich in carbonate minerals such as limestone will help buffer a stream's pH. Granite soil contains few buffering agents and streams running through granite areas are more susceptible to acidic pollution such as smog.

Tree leaves dropping into a stream can alter pH. Pine needles and oak leaves are acidic, while maple leaves are more basic. Waters with high algal blooms can show a diurnal change in pH. When algae grow and reproduce they use carbon dioxide. This loss of CO_2 causes the pH to increase and the water to become more basic. pH will increase at the height of photosynthesis when temperatures are warmest and decline at night when algae are respiring and using CO_2. These algal changes in pH are most problematic in standing waters or pools with high algal growth.

Turbidity

Turbidity is a measure of the amount of suspended particles in water. Sediment is an important component, but algae and organic matter may also make the water less clear, or turbid.

Streams erode and transport sediment downstream. Views of the Mokelumne River canyon from Highway 49 give Sierra residents an idea of how water can carve away soil and move rocks. This natural process is accelerated in stormy weather, thus local streams appear muddier after storms. Sediment can be suspended in the water during high flows and then settle out in low flows. The natural process of transporting sediment obviously varies depending on the river system. A large river, like the Sacramento River, flowing through a long, large flat valley, naturally carries more sediment than a river like the American River, where much of the upstream sediment is trapped behind Folsom Dam. The difference in these two river systems can be seen in the colors of the rivers as they merge in Sacramento at Discovery Park.

While sediment transport is a natural process, one of the greatest pollutants in California is sediment. Erosion from inappropriate land practices can add too much sediment to a stream. Logging on steep slopes in the riparian corridor can cause erosion and sedimentation in streams. Overgrazing in the riparian corridor or failure of appropriate barriers on large construction sites may also cause high sediment load.

Once in the stream, suspended sediment can affect stream health in several ways. First, sediment particles absorb heat and can increase temperature. Second, sediment settles onto the gravel and cobble of a stream bed. Sediment may smother fish eggs nestled in the gravel of a stream bed.

A rough estimate of turbidity can be determined in the field using a transparency tube. The student fills a long cylinder with stream water and then views a dark dot at the bottom of the tube. The clarity of the dot is compared to water standards of a known turbidity. This method could be compared to a laboratory measurement if a turbidity meter is available. These meters pass a light through the water sample and measure the amount of light absorbed by the sample.

Conductivity

Since streams naturally transport sediment, minerals will be dissolved in the stream. These dissolved minerals can be positively charged ions (cations) or negatively charged ions (anions). Conductivity is a measure of the ability of water to carry an electrical current. As in a liquid battery, conductivity increases with the amount of negatively charged ions present.

Conductivity will vary depending on the geology of the watershed. Streams following through sedimentary rocks like limestone will have higher conductivity than streams following through granite deposits. The most important anions in streams are generally bicarbonate (HCO_3^-), chloride (Cl^-), and sulfate (SO_4^{2-}).

Changes in conductivity can indicate a pollution source. If a sewage pipe ruptures, raw sewage would have a much higher conductivity than the stream water. Industrial or agricultural waste (e.g. animal waste, wastewater from food processing) would also have high conductivities.

Conductivity is measured using a small electrical probe. A drop in voltage between the two electrodes measures resistance, which is the reciprocal of conductivity. Conductivity is measured in "mho" because it is the inverse of "ohm," the unit of resistance. The natural levels of conductivity in water fall in the one thousandths (mmhos) or one millionths of a mho (umhos) over a certain area (cm). Thus, the units observed in the field are in umhos/cm. Tap water ranges between 50 and 800 umhos/cm.

Before-the-Field-Trip Activities

Activity 1: Water Quality Research
Time: One Class Period
Materials: Water Quality Fact Sheets, Water Quality Parameters Student Worksheet and Answer Key

1. Introduce the importance of water quality to stream organisms.
2. Introduce the five parameters.
3. Divide the class into five groups to research a specific parameter. Studying temperature will take the least time, so that topic would be suitable for students who need more time. The dissolved oxygen packet takes the most time.
4. For early finishers, ask them to find the value or range of values that protect aquatic life.
5. Pass out Water Quality Fact Sheets for background information.
6. Have students read about the parameter and record what it is, how it is measured, importance to aquatic life, and what factors will change.
7. Have a group spokesperson sell the importance of this parameter to other groups, while they record information on their worksheet.

Activity 2: Water Quality Measurements
Time: One Class Period
Materials: Water Quality Parameters Student Worksheets, thermometers, pH probes, conductivity probes or meters, pH standard solutions (7 or 10), conductivity standard solution, Dissolved, Oxygen Kit, Turbidity Kit, Turbidity meter (if available), gloves, protective eyewear (Some of the above water quality instruments can be borrowed from the Upper Mokelumne River Watershed Council.) *Water Quality Monitoring Kit* (STE Lending Library)

1. Have students learn how to measure the water quality parameters. They will use the methods that are approved by the State Water Board for Clean Water Teams.
2. Discuss care of equipment. Both the pH and conductivity probes should not be submerged more than a couple inches. The Winkler titration uses sulfuric acid; discuss risks of handling and disposing of a strong acid.
3. Demonstrate the Winkler titration method. Discuss the chemical reactions. (See background information.) Discuss color changes and what that reflects about dissolved oxygen levels. Make sure students know the intervals on the syringe and can read the endpoint. Discuss the validity of recording an answer that is more accurate (e.g. +/− 0.1 ppm) than the method allows. Discuss what would happen if over titrated. Would the measurement be high or low? This would be a good time to introduce or reinforce types of errors in analysis.
4. Demonstrate the use of the pH and conductivity probes. An important first step on both these methods is calibration using standard pH or standard conductivity. Discuss what would happen if the standards were contaminated with sample water, or if samples were taken before calibration.
5. Demonstrate the use of the turbidity tube. Discuss the difference, and the likelihood of error in this measurement compared to other measurements.

6. Set up a thermometer in a water bath. Review how to read a thermometer. Students may measure temperature as they complete another parameter.
7. Divide the class into four groups or four stations to learn how to take measurements of dissolved oxygen, pH, conductivity and turbidity. The dissolved oxygen test will take the most time. Consider having two kits set up so groups may complete this station more quickly.
8. When students have completed all tests, review their measurements. Did groups get similar results? If there are differences, what could account for them? Discuss the validity of averaging the measurements to get a more accurate measurement. Include a standard deviation in the final measurement. What does the standard deviation tell you about the accuracy of the work or the experimental conditions?

Activity 3: Water Quality Experiments
Time: One class period
Materials: Use the materials from Before-the-Field-Trip Activity 2 and variety of water samples

1. Prior to lesson, consider asking students to collect water samples. These water samples will be used to evaluate different water quality parameters, particularly pH, conductivity, and turbidity. Dissolved oxygen will change over time and the reaction must be started in the field to a stage where oxygen is no longer in a volatile state. Possible sources include local creeks. If there is access to high elevation mountain streams, collect a sample to compare to local streams. Call the wastewater treatment plant and see if they will provide a sample of creek water downstream of their effluent. Consider sampling bottled waters and mineral waters.
2. Prior to lesson, have available or ask students to bring in materials that would change pH, turbidity, or conductivity. Possibilities include leaf litter (let it steep in water on a windowsill), soil, compost, waste from pens of confined animals on campus, rain water, or rain water directly from a roof gutter.
3. Set up possible water sources to be tested.
4. Have students brainstorm specific hypotheses for various water sources and their parameters. For example, the pH of water with leaf litter will be lower (more acidic) than the same source water without leaf litter. Or, the conductivity of rain water will be lower than the conductivity of stream water.
5. Have students design a data sheet for their experiments. Will they take multiple measurements of a parameter and average?
6. Test and record results. Make sure pH and conductivity probes are calibrated by the first group of students using these probes.
7. Discuss results.

Field Trip Activity

Activity: Sampling Design
Time: Half Day
Materials: Water Quality Parameters Student Worksheets as from Before-the-Field-Trip Activity 2, field clothes and appropriate shoes, equipment, pencils, clipboards

1. Prior to the field trip, discuss possible sampling design options. One design is to monitor upstream and downstream of an activity that might alter water quality. For example, do they want to take water quality measurements upstream and downstream of a wastewater treatment facility? If so, contact the treatment operator and find out where there current monitoring sites are and schedule a visit. Another design is sampling one location over time. How would water quality change at a given site over the course of several hours. A third sampling design is to test specific inputs and the mainstream of a creek. Consider storm drain outflows and compare them to the main stream.
2. Discuss safety precautions around flowing water.
3. Discuss appropriate field trip behavior.
4. At the field location, follow the water quality instructions and use the Water Quality Parameters Student Worksheets. Make sure students uniformly and accurately identify their locations.

After-the-Field-Trip Activity

Activity: Water Quality Field Report
Time: One class period
Materials: Data from field trip

1. Discuss the results of the field trip: What did they learn about water quality?
2. The students should write a quick field report. It should include the parts of a scientific report (per previous instruction) or based on accepted protocols—abstract, introduction, materials and methods, results, and discussion.
3. Guide the reporting process as needed for students and assign completion for homework. Remind students that the discussion section is the appropriate place to discuss possible follow-up investigations.

Source

Clean Water Team (CWT) 2004. The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0 Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento CA.

Resources

For the Teacher

Clescerl, Lenore S. (Editor), Arnold E. Greenberg (Editor), Andrew D. Eaton (Editor), *Standard Methods for Examination of Water and Wastewater*, Hardcover, 20th edition, 1999, by American Public Health Association.

Wetzel, Robert G. and Gene E. Likens Springer, *Limnological Analyses*, 3rd edition, 2000, .

Wetzel, Robert G., *Limnology: Lake and River Ecosystems*, 3rd edition, 2001, Academic Press.

For the Student

There are many citizen groups across the world that monitor stream health. Many of these groups have web sites. Several good places to visit on the Internet are:

Izaak Walton League—Save Our Streams, http://www.iwla.org/sos/

EPA's Volunteer Monitoring Efforts, http://www.epa.gov/owow/monitoring/vol.html

State Water Resources Control Board's Volunteer Monitoring Programs, http://www.swrcb.ca.gov/nps/volunteer.html

Clean Water Team—Student Research Information

Name Date

Water Quality Parameters

Student Worksheet

Parameter	What is it?	Importance	Factors Affecting It	How is it measured? (Units)

Water Quality Parameters
Answer Key

Parameter	What is it?	Importance	Factors Affecting It	How is it measured? (Units)
temperature	kinetic energy of water molecules	temperature tolerance ranges for survival, affect on metabolic rates, affects sensitivity to pollutants	season, sunlight vs. shade of a stream bed, sediment absorbs heat, different sources of water, flow of stream	thermometer Celsius or Fahenheit
dissolved oxygen (D.O.)	amount of oxygen dissolved in water	critical for all aquatic organisms' survival, some sport fish like trout and salmon require high D.O.	temperature (inversely); salinity (inversely) altitude (reduces) respiration, photosynthesis; organic matter—decomposition lowers	Winkler Titration mg/l or ppm
pH	concentration of hydrogen ion in water (negative log of that concentration); how acidic or basic water is	pH affects aquatic animals internal processes; can show pollution sources such as acid rain; can affect toxicity of other chemicals in water like metals	amount of minerals—buffering capacity input of acidic or basic materials	pH probe or meter with a glass electrode and a reference electrode; unitless; ranges from 0 to 14
turbidity	amount of suspended particles in water	measure of sediment, problems with sediment—smother fish eggs and benthic insects.	sediment, algae, storm events, natural sources of sediment, erosion, nutrient sources	various—secchi disks (depth) , transparency tubes (cms.or inches), dual cylinder kit (JTU), turbidity meter (NTUs, FTUs)
conductivity	ability of water to carry an electrical charge	all aquatic life have a tolerance range for dissolved minerals, effect drinking water taste, can help identify pollutant inputs.	rain water, geology of watershed, dissolved minerals, sources of sewage, animal waste, industrial pollutants	conductivity probe measures resistance than converts to conductivity; micromhos/cm (umhos/cm)

Name Date

Temperature

Fact Sheet

What is Water Temperature?

Temperature is a measure of the average kinetic energy of water molecules. It is measured on a linear scale of degrees Celsius or degrees Fahrenheit.

Why is it Important?

It is one of the most important water quality parameters. Temperature affects water chemistry and the functions of aquatic organisms. It influences the:

- amount of oxygen that can be dissolved in water
- rate of photosynthesis by algae and other aquatic plants
- metabolic rates of organisms
- sensitivity of organisms to toxic wastes, parasites and diseases
- timing of reproduction, migration, and aestivation of aquatic organisms

How is Stream Temperature Measured?

- Bulb Thermometers with colored alcohol (avoid mercury thermometers)
- Temperature probes and meters

Conversion between Fahrenheit and Celsius is: deg C = (deg F - 32) X 5/9.

What Factors Affect Temperature?

Natural Factors

- Sunlight Energy: Seasonal and daily changes, shade (cover), air temperature
- Color and turbidity of water: suspended sediment absorbs heat
- Flow
- Depth of water
- Inflow of groundwater: Usually colder than stream
- Inflow of surface water into stream which is at a different temperature than the stream (Example: A drainage ditch or another stream)

Human Influence

- Removal of riparian vegetation enabling direct sunlight
- Alterations to stream morphology (e.g., pool depth)
- Water diversions decreasing flow
- Accelerated soil erosion, increase in turbidity and heat absorption
- Increased storm water runoff
- Cooling water discharges from power plants

Name Date

Temperature

Fact Sheet (continued)

What are Acceptable Ranges?

Acceptable ranges cannot be assigned without understanding the aquatic ecosystem. The maximum temperature tolerated by organisms depends on the species.

Maximum weekly average temperature for growth and short-term maximum temperatures for selected fish (degree C or F) Adapted from *EPA's Draft Volunteer Stream Monitoring: A Methods Manual.*

Species	Growth	Maxima	Spawning**	Embryo Survival**
Bluegill	32 C (90 F)	35 C (95 F)	25 C (77 F)	34 C (93 F)
Carp		21 C (70 F)	33 C (91 F)	
Channel catfish	32 C (90 F)	35 C (95 F)	27 C (81 F)	29 C (84 F)
Largemouth bass	32 C (90 F)	34 C (93 F)	21 C (70 F)	27 C (81 F)
Rainbow trout	19 C (66 F)	24 C (75 F)	9 C (48 F)	13 C (55 F)
Sockeye salmon	18 C (64 F)	22 C (72 F)	10 C (50 F)	13 C (55 F)

* The optimum or mean of the range of spawning temperatures reported for the species.

** The upper temperature for successful incubation and hatching reported for the species.

What are the Water Quality Objectives?

The water quality objectives for freshwater ecosystems protect coldwater ("COLD") or warm water ("WARM") fishes. In general, the water quality objective does not allow temperature of any water supporting these fishes to be increased by more than 5°F above natural receiving water temperature. However, the water quality objectives vary from region to region in California. Therefore, you should check with the Regional Water Quality Control Board in your area. Water quality objectives are included in their Basin Plan.

For bays, estuaries, and ocean waters, elevated waste discharges cannot cause surface water temperatures to rise greater than 4°F above the natural temperature.

Sources and Resources

This Fact Sheet is implemented by the Clean Water Team (CWT), the Citizen Monitoring Program of the California State Water Resources Control Board. This fact sheet has been revised by CWT from an original document authored by Gwen Starrett, former State Coordinator for Citizen Monitoring. Please contact your Regional CWT Coordinator for further information and technical support. For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit www.swrcb.ca.gov/nps/volunteer.html. If you wish to cite this FS in other texts you can use "CWT 2004" and reference it as follows: "Clean Water Team (CWT) 2004. Temperature Fact Sheet, FS-3.1.2.0(Temp). in: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA."

Name Date

Dissolved Oxygen

Fact Sheet

What is Dissolved Oxygen?

It is the amount of oxygen dissolved in water.

Why is it Important?

Most aquatic organisms need oxygen to survive and grow.

- Some species require high DO such as trout and stoneflies.
- Other species do not require high DO, like catfish, worms and dragonflies.

If there is not enough oxygen in the water the following may happen:

- Death of adults and juveniles
- Reduction in growth
- Failure of eggs/larvae to survive
- Change in species present

How it is Measured?

Measuring DO

- Color production: DO chemical test kit for field work with freshwater
- Winkler titration method: This method is valid for ocean water and fresh water, but not highly alkaline water.
- DO Meter: electrical conductance based on a chemical reaction

Reporting DO

- Dissolved oxygen concentration is reported in units of mg/l, or milligrams per liter (mg/l is also referred to as parts per million (ppm) because a liter is 1000 grams of fresh water, and a milligram is a millionth of that).
- Percent saturation is reported in units of percent. Oxygen dissolves in water to saturation, a value typical of a given temperature. Percent saturation tells us what part of the holding capacity is actually taken.

What Affects the Concentration in Water?

1. **Physical Factors affecting saturation (temperature, salinity, etc.)**
2. **DO Sources (inputs)**
3. **DO Sinks (outputs)**

1. Physical Factors

Temperature: As temperature increases, less oxygen can be dissolved in water. When water holds all the DO it can at a given temperature, it is said to be 100 percent saturated with oxygen. Water can be supersaturated with oxygen under cer-

Name Date

Dissolved Oxygen

Fact Sheet (continued)

tain conditions (e.g. when algae are growing rapidly and producing oxygen more quickly than it can be used up or released to the atmosphere). The following table shows the concentration of dissolved oxygen that is equivalent to the 100 percent saturation for the noted temperature (and normal barometric pressure). Note: these values are for fresh water only!

Temperature degC	DO (mg/l)	Temperature degC	DO (mg/l)
0	14.6	16	9.9
1	14.2	17	9.7
2	13.8	18	9.6
3	13.5	19	9.3
4	13.1	20	9.1
5	12.8	21	8.9
6	12.5	22	8.7
7	12.1	23	8.6
8	11.8	24	8.4
9	11.6	25	8.3
10	11.3	26	8.1
11	11.0	27	8.0
12	10.8	28	7.8
13	10.5	29	7.7
14	10.3	30	7.6
15	10.1	31	7.5

Other Physical Factors:

- Altitude: Water holds less oxygen at higher altitudes.
- Salinity/Mineral content: As salinity or mineral content increases, dissolved oxygen decreases.

2. DO Sources

Oxygen is added to water by:

- Re-aeration: Oxygen from air is dissolved in water at its surface, mostly through turbulence. Examples of this include: Water tumbling over rocks (rapids, waterfalls, riffles); Wave action.
- Photosynthesis (during daylight): Plants produce oxygen when they photosynthesize. DO is generally highest in the late afternoon, and lowest in the early morning hours before sunrise.

Name Date

Dissolved Oxygen

Fact Sheet (continued)

3. DO Sinks

Dissolved oxygen is used in two major ways:

- Respiration: Aquatic organisms breathe and use oxygen. Large amounts of O2 are consumed by algae and aquatic plants at night (where large masses of plants are present). Large amounts are consumed by decomposing bacteria (when there are large amounts of dead material to be decomposed, there will be significant numbers of bacteria). Examples: Dead organic matter (i.e. Algae); Sewage; Yard Clipping—yard waste; Oil and grease.
- Chemical Oxidation: Some materials are oxidized naturally (without involvement of microorganisms) and this chemical process utilizes oxygen. Oxygen uptake through chemical oxidation is very marginal compared to biological uptake (i.e., respiration).

What are generally the biggest causes of low DO?

- Increases in water temperature
- Algal blooms
- Human waste
- Animal waste—from feedlots, dairies, etc.

What are Acceptable Ranges?

The following table gives specific DO values for the survival of different species:

Biologic effects of decreasing dissolved oxygen (DO) levels on salmonids, non-salmonids fish, and aquatic invertebrates		
	Dissolved oxygen (mg L^{-1})	
	Instream	Intergravel
I. Salmonid waters		
A. Embryo and larval stages		
No production impairment	11	8
Slight production impairment	9	6
Moderate production impairment	8	5
Severe production impairment	7	4
Limit to avoid acute mortality	6	3
B. Other life stages		
No production impairment	8	
Slight production impairment	6	
Moderate production impairment	5	
Severe production impairment	4	
Limit to avoid acute mortality	3	

table continued on next page

Name Date

Dissolved Oxygen

Fact Sheet (continued)

	Dissolved oxygen (mg L^{-1})	
	Instream	Intergravel
II. Non-Salmonid waters		
A. Early Life stages		
No production impairment	6.5	
Slight production impairment	5.5	
Moderate production impairment	5	
Severe production impairment	4.5	
Limit to avoid acute mortality	4	
B. Other life stages		
No production impairment	6	
Slight production impairment	5	
Moderate production impairment	4	
Severe production impairment	3.5	
Limit to avoid acute mortality	3	
III. Invertebrates		
No production impairment	8	
Some production impairment	5	
Limit	4	

What are the Water Quality Objectives?

The water quality objectives for dissolved oxygen vary from region to region. Check with the Regional Water Quality Control Board in your area. Water quality objectives are included in their Basin Plan. For waters that support coldwater fishes, the objective requires that the dissolved oxygen concentration shall not fall below 6 to 8 mg/l (depending on the region of California). For waters that support warm water fishes, the objective requires that the dissolved oxygen concentration shall not fall below 5 to 6 mg/l (depending on the region of California). Some Regional Water Boards describe objectives in terms of percent saturation. For example, the dissolved oxygen shall not fall below 80% saturation.

For ocean waters, the dissolved oxygen concentration shall not be depressed more than 10 percent from that which occurs naturally.

Sources and Resources

This Fact Sheet is implemented by the Clean Water Team (CWT), the Citizen Monitoring Program of the California State Water Resources Control Board. This fact sheet has been revised by CWT from an original document authored by Gwen Starrett, former State Coordinator for Citizen Monitoring. Please contact your Regional CWT Coordinator for further information and technical support. For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit www.swrcb.ca.gov/nps/volunteer.html. If you wish to cite this FS in other texts you can use "CWT 2004" and reference it as follows: "Clean Water Team (CWT) 2004. Dissolved Oxygen Fact Sheet, FS-3.1.1.0(DO). in: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA."

Name Date

pH

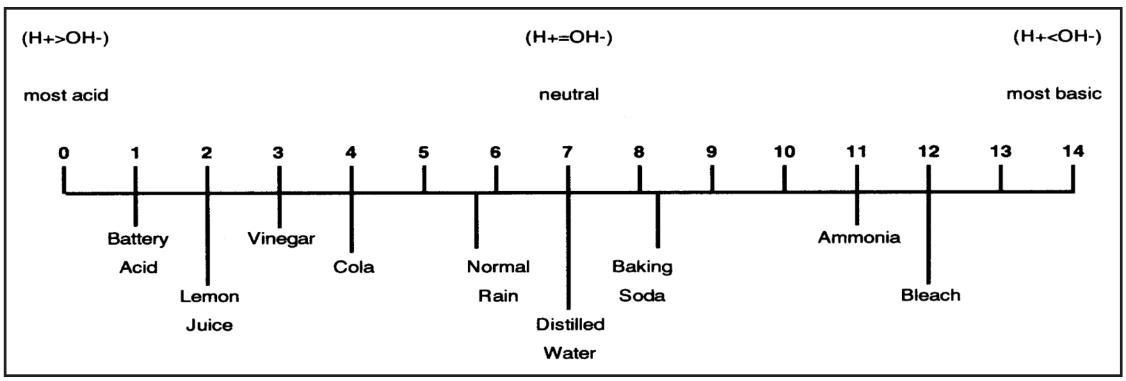
Fact Sheet

What is pH?

pH is a measure of how acidic or basic (alkaline) the water is (the term pH comes from the French: "puissance d'Hydrogène" which means strength of the hydrogen). It is defined as the negative log of the hydrogen ion concentration.

The pH scale is logarithmic and goes from 0 to 14. For each whole number increase (i.e. 1 to 2) the hydrogen ion concentration decreases ten fold and the water becomes less acidic.

As the pH decreases, water becomes more acidic. As water becomes more basic, the pH increases.



pH scale showing the values of some common substances. (Source: U.S. Fish and Wildlife Service)

Why is pH Important?

- Many chemical reactions inside aquatic organisms (cellular metabolism) that are necessary for survival and growth of organisms require a narrow pH range.
- At the extreme ends of the pH scale, (2 or 13) physical damage to gills, exoskeleton, fins, occurs.
- Changes in pH may alter the concentrations of other substances in water to a more toxic form. Examples: a decrease in pH (below 6) may increase the amount of mercury soluble in water. An increase in pH (above 8.5) enhances the conversion of nontoxic ammonia (ammonium ion) to a toxic form of ammonia (un-ionized ammonia).
- The pH of human tissue fluid ranges from 7.35. to 7.45. To protect mucous membranes recommended pH ranges for swimming pools is 7.2-7.8.

How is pH Measured?

Indicators:

- pH test kits. Colorimetric tests are based on indicator dyes that change color over a range of pH.
- pH paper. The famous litmus test is based on a vegetable dye that changes

pH

Fact Sheet (continued)

color. Other indicator dyes are more sensitive to changes in pH. Only pH strips with non-bleeding indicators are suitable for water monitoring.

Electrodes (pH meters and probes):

- A two electrode system consisting of a glass electrode containing an electrolyte solution and a reference electrode. When placed in water, an electrical force produced between the internal solution and the water can be measured. This force is a measure of pH.

What Affects it in Water?

Pure water (de-ionized) has a pH of 7.0. What causes the pH to change? There are two major factors:

- Buffering capacity
- Input of basic or acidic substances (manmade or natural)

Buffering Capacity

A buffer is like a chemical cushion that neutralizes acids or bases when added to the water. All natural waters (except rain) have some natural buffering capacity. Examples of natural buffer are:

- CO_2 from the air dissolves in water and forms a buffer (carbonic acid H_2CO_3)
- Minerals (calcium, magnesium, others) which come from rocks, such as lime-stone, dissolve in water

Input of basic or acidic substances (manmade or natural)

pH can change because of external inputs. You might measure a difference in pH along a stream due to:

- A change in tree type, for example: conifer needles are acidic and maple leaves are basic
- A change in stream bottom material, e.g., gravel vs silt vs bedrock
- A large change in temperature
- A change in human activity affecting the stream

Other Factors

- In fresh water, increasing temperature decreases pH.
- Waters with high algal growth can show a diurnal change in pH. When algae grow and reproduce they use CO_2. This reduction causes the pH to increase. This increase in pH may exceed 8.5, especially during the spring when nutrients are readily available. Therefore, if conditions are favorable for algal growth (sun-

Name Date

pH

Fact Sheet (continued)

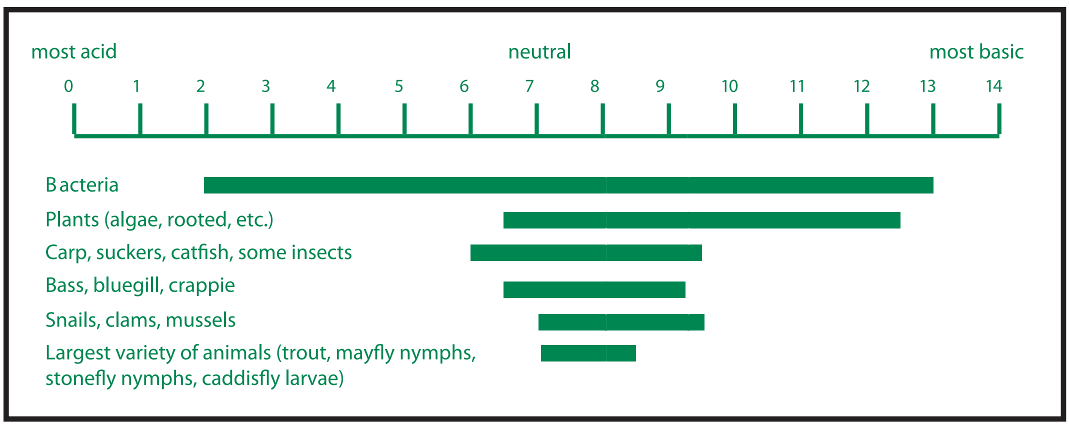
light, warm temperatures), the water will be more alkaline. Maximum pH usually occurs in late afternoon, and pH will decline at night when cellular respiration adds CO_2 to water. Because algal growth is restricted to light penetrating zones, pH can vary with depth in lakes, estuaries, bays and ocean water.

- Manmade inputs that reduce pH include acid rain (from automobiles or industrial sources), and acid mine drainage. Nutrients can indirectly affect pH by stimulating algal growth.

What are Acceptable Ranges?

Most natural environments have a pH between 4 and 9. The pH of seawater is usually between 7.5 and 8.4. In fresh water, pH in the range of 6.5 to 8.5 should protect most organisms. However, the range of pH tolerated by organisms varies, as can be seen in this chart.

pH Ranges that Support Aquatic Life



What are the Water Quality Objectives?

The water quality objectives for pH vary from region to region. Check with the Regional Water Quality Control Board in your area. Water quality objectives are included in their Basin Plan. A general objective states that for ocean waters of California, the pH shall not be changed at any time more than 0.2 pH units from that which occurs naturally.

- For the North Coast Region (Region 1): There are numerical objectives for pH in the Basin Plan. In general, these require the pH to not fall below a certain value (6.5 to 7.5, depending on the water body) or to exceed a certain value (8.0 to 9.0, depending on the water body). For waters without specific objectives, the pH shall not be depressed below 6.5 nor raised above 8.5. Changes in normal pH shall not exceed:
  - 0.2 units, for waters with marine (MAR) or saline (SAL) beneficial uses,
  - 0.5 units, for fresh waters supporting coldwater (COLD) or warmwater (WARM) fisheries.
- For the San Francisco Bay Region (Region 2): The pH shall not be depressed below 6.5 nor raised above 8.5.

Name Date

pH

Fact Sheet (continued)

- For the Central Coast Region (Region 3): The objective depends on the beneficial uses of the water. The pH shall not be depressed below 6.5 nor raised above 8.5 for waters that have the following designated uses: municipal and domestic supply, agricultural supply, water contact recreation, and non-contact water recreation. For waters that support cold (COLD) or warm (WARM) freshwater habitat, or marine (MAR) habitat, the pH shall not be depressed below 7.0 nor raised above 8.5. Changes in normal pH shall not exceed 0.5 (COLD, WARM) or 0.2 units (MAR).
- For the Los Angeles Region (Region 4): The pH of inland surface waters and bays or estuaries shall not be depressed below 6.5 or raised above 8.5 as a result of waste discharges. Ambient pH levels shall not be changed more than 0.5 units (inland surface waters) or 0.2 units (bays and estuaries) from natural conditions as a result of waste discharge.
- For the Central Valley Region (Region 5): For the Sacramento and San Joaquin Valleys, the pH shall not be depressed below 6.5 or raised above 8.5. Ambient pH levels shall not be changed more than 0.5 units in fresh waters with designated COLD or WARM beneficial uses. For the Tulare basin, the pH shall not be depressed below 6.5 or raised above 8.3 or changed at any time more than 0.3 units from normal ambient pH.
- For the Lahontan Region (Region 6): In fresh waters with designated beneficial uses of COLD or WARM, changes in normal ambient pH levels shall not exceed 0.5 pH units. For all other waters of the Region, the pH shall not be depressed below 6.5 nor raised above 8.5. However, some waters may have natural pH levels outside this range. Compliance for those waters will be determined on a case-by-case basis. There are pH objectives specfic to certain waters (e.g. Eagle Lake, Lake Tahoe) in the Region.
- For the Colorado River Basin Region (Region 7): Since the regional waters are somewhat alkaline, pH shall range from 6.0 - 9.0. Discharges shall not cause any changes in pH detrimental to beneficial uses.
- For the Santa Ana Region (Region 8): The pH shall not be depressed below 6.5 nor raised above 8.5 as a result of controllable water quality factors.
- For the San Diego Region (Region 9): The pH shall not be depressed below 6.5 nor raised above 8.5 for inland surface waters. For bays and estuaries, the pH shall not be depressed below 7.0 nor raised above 9.0. Changes in normal pH shall not exceed:
  - 0.2 units, for waters with marine (MAR), estuarine (EST), or saline (SAL) beneficial uses,
  - 0.5 units, for fresh waters supporting cold (COLD) or warm (WARM) water fisheries.

Sources and Resources

This Fact Sheet is implemented by the Clean Water Team (CWT), the Citizen Monitoring Program of the California State Water Resources Control Board. This fact sheet has been revised by CWT from an original document authored by Gwen Starrett, former State Coordinator for Citizen Monitoring. Please contact your Regional CWT Coordinator for further information and technical support. For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit www.swrcb.ca.gov/nps/volunteer.html. If you wish to cite this FS in other texts you can use "CWT 2004" and reference it as follows: "Clean Water Team (CWT) 2004. pH Fact Sheet, FS-3.1.4.0(pH). in: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA."

Name Date

Electrical Conductivity/Salinity

Fact Sheet

What is Electrical Conductivity/Salinity/TDS?

Solids can be found in nature in a dissolved form. Salts that dissolve in water break into positively and negatively charged ions. Conductivity is the ability of water to conduct an electrical current, and the dissolved ions are the conductors. The major positively charged ions are sodium, (Na^{+}) calcium (Ca^{+2}), potassium (K^{+}) and magnesium (Mg^{+2}). The major negatively charged ions are chloride (Cl^{-}), sulfate (SO_4^{-2}), carbonate (CO_3^{-2}), and bicarbonate (HCO_3^{-}). Nitrates (NO_3^{-2}) and phosphates (PO_4^{-3}) are minor contributors to conductivity, although they are very important biologically.

Salinity is a measure of the amount of salts in the water. Because dissolved ions increase salinity as well as conductivity, the two measures are related. The salts in sea water are primarily sodium chloride (NaCl). However, other saline waters, such as Mono Lake, owe their high salinity to a combination of dissolved ions including sodium, chloride, carbonate and sulfate.

Why is it Important?

Salts and other substances affect the quality of water used for irrigation or drinking. They also have a critical influence on aquatic biota, and every kind of organism has a typical salinity range that it can tolerate. Moreover, the ionic composition of the water can be critical. For example, cladocerans (water fleas) are far more sensitive to potassium chloride than sodium chloride at the same concentration.

Conductivity will vary with water source: ground water, water drained from agricultural fields, municipal waste water, rainfall. Therefore, conductivity can indicate groundwater seepage or a sewage leak.

How is it Measured?

Conductivity is measured by a probe, which applies voltage between two electrodes. The drop in voltage is used to measure the resistance of the water, which is then converted to conductivity. Conductivity is reciprocal to resistance and is measured in the amount of conductance over a certain distance. The conductivity unit has been called "mho" because it is the inverse of "ohm," the resistance unit.

The basic unit is "mho/cm," otherwise known as 1 Siemen. However, this unit does not really occur in water and we are using one thousandth (mili-) or one millionths (micro-) of it for natural waters (1000 milimhos and 1,000,000 micromhos are equal to one mho). The useful unit for seawater is milimhos/cm (mS); ocean waters are around 55 mS. The useful unit for freshwater is micromhos/cm (umhos/cm, or uS); tap water ranges between 50 and 800 uS (depending on the source). Because electrical conductivity greatly depends on temperature, scientists use the term

Name Date

Electrical Conductivity/Salinity

Fact Sheet (continued)

"specific conductivity" if the value has been corrected to reflect the measurement temperature.

Salinity can be measured using a hydrometer or a refractometer. The hydrometer measures specific gravity which can then be converted to salinity. The refractometer measures the ability of the water to refract light. Scientists also measure salinity by determining the amount of chlorine in seawater. Salinity can also be measured gravimetrically (i.e., as the weight of the total dissolved solids per a given volume of water). The results are usually expressed in grams/liter (g/l) or parts per thousand (ppt) for sea water (Pacific Ocean water are around 32 g/l in winter). In freshwater the term "total dissolved solids" (TDS) is often used for the same thing instead of "salinity". Useful TDS units are milligrams/liter (mg/l) or parts per million (ppm).

What Affects it in Water?

1. Rain! In pristine environments, rainwater conductivity equals zero (i.e., the rain is essentially distilled water). Rain falling into a waterbody, or rain runoff flowing into it, will decrease conductivity/salinity.
2. Minerals: Soil and rocks release ions into the waters that flow through or over them. The geology of a certain area will determine the amount and type of ions. Spring water typically shows higher conductivity than inland rain water.
3. Ocean Spray: The salinity/conductivity of coastal rivers is influenced by sea spray that can carry salts into the air, which then fall back into the rivers with rainfall.
4. Tides and mixing zones: In flat areas, water at the river mouths are often salty because of salt water intrusion during high tides. The flow of rivers into estuaries can greatly affect salinity as well as the location of the estuarine mixing zone. This is very important to the survival of estuarine organisms.
5. Evaporation: Evaporation and loss of fresh water will increase the conductivity and salinity of a waterbody. Warm weather can even increase ocean salinity.

What are the Typical Ranges?

Conductivity of Water

Water Type	Conductivity (umhos/cm)
Distilled water	0.5–3.0
Melted snow	2–42
Potable water in U.S.	30–1500
Freshwater streams	100–2000

Name Date

Electrical Conductivity/Salinity

Fact Sheet (continued)

The table above shows some ranges of conductivity values you might encounter in the field. Conductivity can be much higher than the maximum values shown above under special conditions in some waters, for examples:

- rivers or drainage ditches dominated by subsurface agricultural return flows,
- ephemeral streams or pools late in the season,
- tidally influenced coastal waters, and
- naturally saline or brackish lakes or ponds

The salinity of some naturally saline waters is indicated in the following table:

Salinity of Water

Water Type	Salinity (g/l)
Sea water	33 - 37
Salton Sea	46
Mono Lake	90

What are the Water Quality Benchmarks?

Water quality benchmarks (including criteria, objectives, targets, standards, action levels, limits, etc.) are developed **for individual parameters** to protect the environment and the human users, based on what is perceived as or known to be harmless or safe. Each of these benchmarks has a different meaning and a different use; some are generic and some are specific to a given waterbody or to a given legal process.

A Water Quality Objective (WQO) is a law or regulation that "factors in" three elements: the beneficial designated use or uses of a particular waterbody, the generic water quality criteria that are necessary to protect these types of beneficial uses, and an anti-degradation statement. Most of the WQOs refer to the average or to the median of several measurements rather than to a single value (e.g., they would specify a "50% upper limit" which is defined as the 50 percentile value of monthly means for a calendar year). In addition, WQOs change over time as we learn more about the effects of each parameter and the ecological requirements of the organisms we are trying to protect.

In California, each of the Regional Water Quality Control Boards (Regional Board) develops a Basin Plan for the Region and keeps updating it over time. The Plan includes a list of water bodies and associated beneficial uses for each. The Plan also has the water quality objectives developed for the Region. As you may have gathered, the WQOs for conductivity vary from Region to Region. In some cases, there are no objectives for conductivity, but there are for total dissolved solids (TDS). If

Name Date

Electrical Conductivity/Salinity

Fact Sheet (continued)

you want the latest value, please be sure to contact the Regional Board in your area. Some examples are provided below.

The following examples were taken from Basin Plans in 1996 and are applicable to surface waters only (excluding the Pacific Ocean).

- North Coast (Region1): There are numerical objectives for conductivity in the Basin Plan. The objective is specific to the water body. It is expressed as a number that should not be exceeded, either the 90% upper limit or the 50% upper limit. The 50% upper limit ranges in value from 100 to 1300 umhos/cm, depending on the water body.
- San Francisco Bay (Region 2): The narrative objective states that, "Controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the state so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat". There is also a conductivity objective for agricultural supply water, and a total dissolved solids objective for the Alameda Creek watershed.
- Central Coast (Region 3): There are no objectives for conductivity. However, there are objectives for total dissolved solids. The TDS objectives range from 150 to 1400 mg/l depending on the water body.
- Los Angeles (Region 4): There are no objectives for conductivity. However, there are objectives for total dissolved solids. The TDS objectives range from 225 to 2000 mg/l depending on the water body.
- Central Valley (Region 5): The objectives are specific to the water body. They are expressed as either a 90% upper limit, a 50% upper limit, a running average for a specific period of time, or a median value. The objectives are designed to protect fish and wildlife in the Sacramento-San Joaquin Delta. Conductivity objectives are also established to protect the quality of water used for irrigation.
- Lahontan (Region 6): The mean annual electrical conductivity of Lake Tahoe shall not exceed 95 umhos/cm at 50 degrees F at any location in the Lake. For other water bodies, there are objectives for conductivity or TDS.
- Colorado River Basin (Region 7): There are no objectives for conductivity. However, there are waterbody-specific objectives for TDS which range from 2000 to 4000 mg/l as an annual average.
- Santa Ana (Region 8): There are no objectives for conductivity. However, there are waterbody-specific objectives for TDS which range from 110 to 2000 mg/l.
- San Diego (Region 9): There are no objectives for conductivity. However, there are waterbody-specific objectives for TDS which range from 300 to 2100 mg/l. These concentrations are not to be exceeded more than 10% of the time during any one year period.

Sources and Resources

This Fact Sheet is implemented by the Clean Water Team (CWT), the Citizen Monitoring Program of the California State Water Resources Control Board. This fact sheet has been revised by CWT from an original document authored by Gwen Starrett, former State Coordinator for Citizen Monitoring. Please contact your Regional CWT Coordinator for further information and technical support. For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit www.swrcb.ca.gov/nps/volunteer.html. If you wish to cite this FS in other texts you can use "CWT 2004" and reference it as follows: "Clean Water Team (CWT) 2004. Electrical conductivity/salinity Fact Sheet, FS-3.1.3.0(EC). in: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA."

Name Date

Turbidity

Fact Sheet

What is it?

Turbidity is a measure of the amount of suspended particles in the water. Algae, suspended sediment, and organic matter particles can cloud the water making it more turbid.

Why is it Important?

Suspended particles diffuse sunlight and absorb heat. This can increase temperature and reduce light available for algal photosynthesis. If the turbidity is caused by suspended sediment, it can be an indicator of erosion, either natural or man-made. Suspended sediments can clog the gills of fish. Once the sediment settles, it can foul gravel beds and smother fish eggs and benthic insects. The sediment can also carry pathogens, pollutants and nutrients.

How is it Measured?

- Secchi disc (for standing water only): The observer measures the depth at which the secchi disc is no longer visible. The results are measured in feet or meters.
- Transparency tubes: The observer views an object or a Secchi pattern through the water in a tube, adding water gradually till the object is no longer visible. The results are measured in centimeters or inches.
- Dual cylinder kit: The observer views an object through the water in a cylindrical tube and visually compares it to increasing amounts of a standard added to clean water in an identical tube, till the turbidities match. The results – amount of standard added until it matched the sample -can be converted to Jackson Turbidity units (JTUs).
- Turbidity meter: This measures how much light is scattered when directed at a water sample. The units are reported in nephelometric turbidity units (NTUs) or Formazin turbidity Units (FTU) which, numerically, mean the same thing. The meters are also called nephelometers or turbidimeters.

Note: NTUs and JTUs should not be used interchangeably. JTUs are based on viewing an object through a tube of water. NTU or FTU are a measure of the light scattered at 90 degrees.

What Factors Affect It?

Natural Factors

- Algae and nutrient loading
- Suspended sediment from erosion and sediment transport
- Seasonal weather, storm events
- Local stream morphology will determine whether sediments are deposited or eroded

Name Date

Turbidity

Fact Sheet (continued)

Human Factors

- Erosion due to removal of riparian vegetation, changes in stream morphology or stream flow patterns
- Excessive nutrient loading and algal growth

What are Expected Turbidity Levels?

Since the rivers, lakes, bays, and ocean waters of California are home to small, suspended plants and animals called plankton, turbid water is natural. The level of turbidity will vary from lake to lake and river to river depending on the nutrient loading, geology and stream dynamics. For example, Lake Tahoe is renowned for its clear water. On the other hand, algae in the presence of nutrients produce very turbid water in Clear Lake. Another source of turbidity is sediment, which is naturally transported and deposited. Here are some typical turbidity values for different water bodies:

Water type	Turbidity Level
Water bodies with sparse plant and animal life	<0.1 NTU
Drinking water	<0.1 NTU
Typical groundwater	<1 NTU
Water bodies with moderate plant and animal life	1–10 NTU
Water bodies enriched with nutrients, supporting large plumes of planktonic life	10–50 NTU
Winter storm flows in creeks and rivers	20 –1000 NTU

What are the Water Quality Benchmarks?

Water quality objectives are included in the Regional Water Quality Control Board's Basin Plans. The water quality objectives vary from region to region in California. Therefore, you should check with the Regional Water Quality Control Board in your area.

Most of the nine Regions' water quality objectives for turbidity require that surface waters (except ocean waters) be free of changes in turbidity that cause nuisance or adversely affect the beneficial uses of water. In addition, most of the nine Regions' Basin Plans state that turbidity should not increase by a certain percent above naturally occurring levels. The following examples were taken from Basin Plans in 1996 and are applicable to surface waters only (excluding the Pacific Ocean).

- In the North Coast Region (Region 1), turbidity shall not increase more than 20 percent above natural levels.
- In the San Francisco Bay Region (Region 2), turbidity (due to waste discharge) shall not increase more than 10 percent above natural levels where natural tur-

Name Date

Turbidity

Fact Sheet (continued)

bidity is greater than 50 NTU.

- In the Central Coast Region (Region 3), increases in turbidity shall not exceed the following limits:

Natural Turbidity	Maximum Increase
0–50 JTU	20%
50–100 JTU	10 JTU
> 100 JTU	10%

- In the Los Angeles Region (Region 4), increases in turbidity shall not exceed the following limits:

Natural Turbidity	Maximum Increase
0–50 NTU	20%
> 50 NTU	10%

- In the Central Valley Region (Region 5), increases in turbidity (attributable to controllable water quality factors) shall not exceed the following limits:

Natural Turbidity	Maximum Increase
0–5 NTU	1 NTU
5–50 NTU	20%
50–100 NTU	10 NTU
> 100 NTU	10%

- In the Lahontan Region (Region 6), turbidity shall not increase more than 10 percent above natural levels.
- The Colorado River Basin Region (Region 7) has a Basin Plan that does not include a numerical turbidity objective.
- In the Santa Ana Region (Region 8) and the San Diego Region (Region 9), increases in turbidity (due to controllable water quality factors) shall not exceed the following limits:

Natural Turbidity	Maximum Increase
0–50 NTU	20%
50–100 NTU	10 NTU
> 100 NTU	10%

- The San Diego Region Basin Plan also has transparency objectives for lagoons, estuaries, and San Diego Bay. The objectives are based on Secchi disc measurements.

Name Date

Turbidity

Fact Sheet (continued)

Sources and Resources

This Fact Sheet is implemented by the Clean Water Team (CWT), the Citizen Monitoring Program of the California State Water Resources Control Board. This fact sheet has been revised by CWT from an original document authored by Gwen Starrett, former State Coordinator for Citizen Monitoring. Please contact your Regional CWT Coordinator for further information and technical support. For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit www.swrcb.ca.gov/nps/volunteer.html. If you wish to cite this FS in other texts you can use "CWT 2004" and reference it as follows: "Clean Water Team (CWT) 2004. Turbidity Fact Sheet, FS-3.1.5.0(Turb). in: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA."