

# Conductivity

## What is conductivity?

Conductivity is the measure of water's ability to conduct electricity, depending on the concentration of dissolved ions in the water. Dissolved ions in natural waters consist mainly of some combination of the following: calcium ( $\text{Ca}^{2+}$ ), magnesium ( $\text{Mg}^{2+}$ ), sodium ( $\text{Na}^+$ ), aluminum ( $\text{Al}^{3+}$ ), potassium ( $\text{K}^+$ ), carbonate ( $\text{CO}_3^{2-}$ ), bicarbonate ( $\text{HCO}_3^-$ ), phosphate ( $\text{PO}_4^{3-}$ ), chloride ( $\text{Cl}^-$ ), nitrate ( $\text{NO}_3^-$ ), and sulfate ( $\text{SO}_4^{2-}$ ).<sup>1</sup>

Conductivity is commonly measured using a specially designed probe and is expressed in units of microsiemens per centimeter ( $\mu\text{S}/\text{cm}$ ). Conductivity is the reciprocal of resistivity—a measure of how resistive water is to conducting an electrical current. Thus, conductivity can also be expressed in units of mhos/cm as the reciprocal of resistance measured in ohms.<sup>1</sup> Mhos is the same as seimens and is the reciprocal of ohms. The term mhos comes from the term ohms, spelled backwards.

## Why measure conductivity?

Measuring conductivity is a quick and easy way to estimate the amount of total dissolved solids (TDS) in natural waters, since most of these solids dissolve to form ions. Whereas total dissolved solids can include organic as well as inorganic molecules, conductivity depends only upon dissolved ions.

Conductivity measurements can also be a useful tool for monitoring the inflow of saline water in estuaries and identifying sources of pollution, such as mining or industrial waste or agricultural runoff. Conductivity is an important factor in soil analysis, as transport of micronutrients through plant roots can be affected by the conductivity of the soil. The salinity of soil dramatically affects the types of plants that can grow in soil, and can be measured indirectly with a Conductivity Sensor.

Municipal water supplies are monitored for conductivity, as increased dissolved solids in the water supply can create hard water, add scale build-up to plumbing, and change the taste of the water.

Conductivity analysis is important in aquariums and fish spawning habitats, as many species are sensitive to abrupt changes in the salinity of their environment.

### Desirable conductivity levels, by designated use

Designated Use	Conductivity ( $\mu\text{S}/\text{cm}$ at 25°C)	Reference
Drinking water	Less than 750* (lower levels—400 $\mu\text{S}/\text{cm}$ or lower—are better)	EPA Secondary Drinking Water Standard <sup>3</sup>
Freshwater aquatic life	150 to 500**	Ref <sup>1</sup>
Marine aquatic life	50,000	Ref <sup>1</sup>
Agricultural irrigation***	Less than 750*	Ref <sup>3</sup>

\*As computed from 500 ppm TDS, using the 0.67 conversion factor;

\*\*Many species can tolerate much higher levels<sup>3</sup>

\*\*\*Many plants can grow at much higher levels (see the accompanying table in this section).

### Dissolved solids hazard for irrigation water<sup>3</sup>

Effect	Conductivity (µS/cm)*
No adverse effects	Less than 750**
Adverse effects on sensitive crops	750–1500
Adverse effects on many crops unless carefully managed	1500–3000
Adverse effects for all plants except for some tolerant species, even with careful management	3000–7500

\*As computed from 500 ppm TDS, using the 0.67 conversion factor  
\*\*less than 250 µS/cm is best<sup>4</sup>

### More specific measurements may be necessary

A high conductivity determination may indicate the need to conduct more specific analyses of specific ions to determine whether the water contains high levels of an ion that would make it unsuitable for a designated use. For example, water that is high in sodium is unsuitable for drinking by individuals who have difficulty metabolizing high levels of sodium, such as some people suffering from cardiac disease or toxemia of pregnancy.<sup>3</sup>

Water that has a high level of aluminum (along with a low pH) may inhibit plant growth.

Water that has very high levels of nutrients, such as phosphate or nitrate, is said to have undergone eutrophication, which stimulates plant growth, followed by an undesirable drop in dissolved oxygen content when this excess plant life dies, supporting high levels of bacterial respiration. The pH of water that is very low in conductivity is very sensitive to added acids, such as occurs with acid rain.

### What factors affect conductivity?

Conductivity is determined by several factors related to the concentration, degree of dissociation, valencies, and mobilities of ions in solution; thus the temperature of the solution also plays an important part.

The watershed of a body of water is the primary contributor of the ions that affect the conductivity of water. Melted snow running through granite, such as that in high mountain streams, has low levels of conductivity. Conversely, water that runs off from limestone or agricultural regions has higher levels of conductivity. Ground water, such as that pumped from wells, can have high conductivity levels because of long-time exposure to rock that contributes ions. Water in arid regions can have high conductivity because of high levels of evaporation. Infiltration of sea water can raise conductivity, as can inflows of certain mining or industrial wastes.

### Temperature effects must be considered

Temperature affects conductivity; each increase of 1 °C causes an increase of about 2% in the conductivity. Therefore, when making comparisons between measurements, temperature should be controlled or accounted for. This is particularly important for measurements in mountain streams, where the temperature effect would be large.

### What are desirable levels of conductivity?

The range of conductivity levels that are considered good depends upon the designated use of the water. For example, low conductivity is desirable in drinking water. Natural waters with low conductivity are very susceptible to changes in pH in response to added acids or bases, and they have low nutrient value for aquatic organisms. Irrigation water with high conductivity levels

reduces plant growth and yield (see the tables above). Marine fish require water with high conductivity (salinity) to survive.

Additional information regarding conductivity and water quality is available from the cited references. <sup>1-4</sup>

## Measuring Procedure

**Plug the Conductivity Sensor into the data collection system <sup>◆(2.1)</sup>, and turn on the system.**

**Note:** The Water Quality Sensor or the Salinity Sensor can also be used.

### Calibration note

The Conductivity Sensor does not need to be calibrated for general studies. Press the button for the  $\mu\text{S}/\text{cm}$  range of your sample.

If it is found that the Conductivity Sensor factory calibration is inadequate, calibrate the Conductivity Sensor using a standard value <sup>◆(2.5)</sup>.



for 0–1,000  $\mu\text{S}/\text{cm}$



for 1,000–10,000  $\mu\text{S}/\text{cm}$



for 10,000–100,000  $\mu\text{S}/\text{cm}$

### Taking a conductivity measurement

1. **If required for your data collection system, begin by building an experiment. Otherwise, set the display to show conductivity measurements. <sup>◆(2.2)</sup>**
2. **Set your data collection system to Manual Sampling. <sup>◆(2.3)</sup>**
3. **Immerse the end of the Conductivity or Salinity probe into the water to be measured. When the reading stabilizes, record the conductivity reading. <sup>◆(2.4)</sup>**

**Note:** Be sure to immerse the holes near the end of the sensor. Swirl the probe to be sure any air bubbles are removed from the end of the probe.

4. **Take additional measurements as needed, following the procedure above.**

### More background information

More information about conductivity and its role in water quality may be found in the references listed below, or in the Recommended Reading and Resources section.

#### References

1. *Healthy Water, Healthy People Testing Kit Manual*. 2002, Bozeman, Montana: The Watercourse, International Project WET.
2. *National Secondary Drinking Water Regulations. Current Drinking Water Standards*. 2006. Environmental Protection Agency.
3. *Quality Criteria for Water (Red Book)*. 1976, Washington, D.C.: U.S. Environmental Protection Agency.
4. Stover, H. S. and S. L. Seager, *Environmental Chemistry: Air and Water Pollution*. (2nd ed.) 1976, Glenview, Illinois: Scott, Foresman, and Co.