# Electrical Conductivity

## Why is it important?

Electrical **conductivity** (EC) estimates the amount of total dissolved salts (**TDS**), or the total amount of dissolved ions in the water. EC is controlled by:

1. *geology* (rock types) - The rock composition determines the chemistry of the watershed soil and ultimately the lake. For example, limestone leads to higher EC because of the dissolution of carbonate minerals in the **basin**.

2. The *size of the watershed* (lake basin) relative to the area of the lake ($A_w : A_o$ ratio) - A bigger watershed to lake surface area means relatively more water draining into the lake because of a bigger catchment area, and more contact with soil before reaching the lake.

3. *"other" sources of ions* to lakes - There are a number of sources of pollutants which may be signaled by increased EC:

   (A) *wastewater* from sewage treatment plants (**point source** pollutants; see: links)

   (B) *wastewater* from septic systems and drainfield on-site wastewater treatment and disposal systems (**nonpoint source** pollutants; see: links )

   (C) *urban runoff* from roads (especially road salt; see: links). This source has a particularly episodic nature with pulsed inputs when it rains or during more prolonged snowmelt periods. It may "shock" organisms with intermittent extreme concentrations of pollutants which seem low when averaged over a week or month (see: *Measures of Variability Lesson* and other links)

   (D) *agricultural runoff* of water draining agricultural fields typically has extremely high levels of dissolved salts (another major **nonpoint source** of pollutants; see: links). Although a minor fraction of the **total dissolved solids**, nutrients (ammonium-nitrogen, nitrate-nitrogen and phosphate from fertilizers) and pesticides (insecticides and herbicides mostly) typically have significant negative impacts on streams and lakes receiving agricultural drainage water. If soils are also washed into receiving waters, the **organic** matter in the soil is decomposed by natural aquatic bacteria which can severely deplete **dissolved oxygen** concentrations (see above).

   (E) *atmospheric inputs* of ions are typically relatively minor except in ocean coastal zones where ocean water increases the salt load ( "salinity" ) of dry aerosols and wet (precipitation) deposition. This oceanic effect can extend inland about 50-100 kilometers and be predicted with reasonable accuracy.

4. *evaporation* of water from the surface of a lake concentrates the dissolved solids in the remaining water - and so it has a higher EC. This is a very noticeable effect in reservoirs in the southwestern US (the major type of lake in arid climates), and is, of course, the reason why the Great Salt Lake in Utah and Mono Lake, California and Pyramid Lake, Nevada are so salty.

5. *bacterial metabolism in the hypolimnion* when lakes are thermally stratified for

long periods of time (in Minnesota this might be May - November depending on the basin shape, lake depth and weather). During this period, there is a steady "rain" of **detritus** (dead stuff, mostly **algae** and washed in particulate material from the watershed) down to the bottom. This material is decomposed by bacteria in the **water column** and after it reaches the sediments. Their **metabolism** releases the potential energy stored in the chemical bonds of the organic carbon compounds, consumes **oxygen** in oxidizing these compounds, and releases **carbon dioxide** ($CO_2$) after the energy has been liberated (burned). This $CO_2$ rapidly dissolves in water to form carbonic **acid** ($H_2CO_3$), **bicarbonate** ions ($HCO_3^-$) and **carbonate ions** ($CO_3^-$) the relative amounts depending on the pH of the water. This newly created acid gradually decreases the pH of the water and the "new" ions increase the TDS, and therefore the EC, of the **hypolimnion**. Essentially, they are "eating" organic matter much as we do and releasing $CO_2$. We oxidize organic carbon using $O_2$ that we breathe out of the air as an oxidant. We use the energy to drive our metabolism and exhale the oxidized carbon as $CO_2$. The oxygen is simultaneously chemically reduced and exhaled as water vapor ($H_2O$; the oxidation state of gaseous molecular oxygen is reduced from 0 to -2 in the process). Other higher aquatic organisms that have aerobic metabolisms, such as **zooplankton**, insects and fish also consume oxygen dissolved in the water while releasing **carbon dioxide** as they metabolize organic carbon (food items).

## What in the world are microSiemens per centimeter (µS/cm)?

These are the units for electrical conductivity (EC). The sensor simply consists of two metal electrodes that are exactly 1.0 cm apart and protrude into the water. A constant voltage (V) is applied across the electrodes. An electrical current (I) flows through the water due to this voltage and is proportional to the concentration of dissolved ions in the water - the more ions, the more conductive the water resulting in a higher electrical current which is measured electronically. Distilled or deionized water has very few dissolved ions and so there is almost no current flow across the gap (low EC). As an aside, fisheries biologists who electroshock know that if the water is too soft (low EC) it is difficult to electroshock to stun fish for monitoring their abundance and distribution.

Up until about the late 1970's the units of EC were micromhos per centimeter (µmhos/cm) after which they were changed to microSiemens/cm (1 µS/cm = 1 µmho/cm). You will find both sets of units in the published scientific literature although their numerical values are identical. Interestingly, the unit "mhos" derives from the standard name for electrical resistance reflecting the inverse relationship between resistance and conductivity - the higher the resistance of the water, the lower its conductivity. This also follows from *Ohm's Law*, V = I x R where R is the resistance of the centimeter of water. Since the electrical current flow (I) increases with increasing temperature, the EC values are automatically corrected to a standard value of 25°C and the values are then technically referred to as *specific electrical conductivity.*

All WOW conductivity data are temperature compensated to 25°C (usually called specific EC). We do this because the ability of the water to conduct a current is very temperature dependent. We reference all EC readings to 25°C to eliminate temperature differences associated with seasons and depth. Therefore EC 25°C data reflect the dissolved **ion** content of the water (also routinely called the TDS or total dissolved salt concentration).

## How much salt is there in lakewater?

The image below was developed to give you an idea of how much salt (dissolved solids and ions) is present in some of the WOW lakes and to compare them to a range of other aquatic systems. TDS, in milligrams per liter (mg/L) stands for total dissolved salts or solids and is the weight of material left behind were you to filter a liter of water to remove all the suspended particulates and then evaporate the water from the container (usually done in a drying oven in the lab unless you work on Lake Mead in southern Nevada where you can just set it outside for a few minutes in the summer). Each of the piles represents the amount of salt present in a liter of water. We used sodium bicarbonate (baking soda) for the lakes and sodium chloride (table salt) for the ocean.