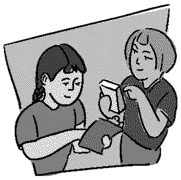
Exhibit 23

Electrical Conductivity Protocol



Purpose

To measure the conductivity of the water at a freshwater hydrology site

Overview

Students will indirectly measure electrical conductivity measurements using an electrical conductivity meter.

Students will estimate the total dissolved solids from the electrical conductivity measurements.

Student Outcomes

Students will learn to,

- use an electrical conductivity meter;
- examine reasons for changes in the electrical conductivity of a water body;
- communicate project results with other GLOBE schools;
- use technology in classrooms
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Science

Earth materials are solid rocks, soils, water and the atmosphere.

Water is a solvent.

Each element moves among different reservoirs (biosphere, lithosphere, atmosphere, hydrosphere).

Physical Sciences

Objects have observable properties.

Life Sciences

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a conductivity meter to measure conductivity of water.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes

Level

All

Frequency

Weekly

Materials and Tools

Hydrology Investigation Data Sheet
Electrical Conductivity Protocol Field Guide
Electrical Conductivity Meter
Thermometer
Distilled water in wash bottle
Soft tissue
Two 100-mL beakers
Latex gloves
600-700 ml plastic water bottle
For Calibration, the above plus:
- Standard solution
- Small screwdriver (if required)
- *Electrical Conductivity Calibration Protocol Lab Guide*

Preparation

Suggested Learning Activities:
Practicing Your Protocols: Electrical Conductivity
Water Detectives (e-guide only)

Prerequisites

None

Electrical Conductivity Protocol – Introduction

Have you ever left water to evaporate from a dish? What was left after the water evaporated?

Fresh water has many natural impurities – including salts or minerals dissolved in the water that we cannot always see or smell. As water comes in contact with rocks and soil, some minerals dissolve in the water. Other impurities can enter a water body through runoff or wastewater releases. If water contains high amounts of dissolved salts, it may be harmful to use for watering crops.

We call the amount of mineral and salt impurities in the water the total dissolved solids (abbreviated TDS). We measure TDS as parts per million (ppm). This tells us how many units of impurities there are for one million units of water, by mass. For water we use at home, we prefer a TDS of less than 500 ppm, although water with higher TDS can still be quite safe. Water used for agriculture should have TDS below 1200 ppm so sensitive crops are not harmed. Manufacturing, especially of electronics, requires impurity-free water.

We use an indirect measure to find the TDS of water. One way to measure impurities in water is to find out if it conducts electricity. Pure water is a poor conductor of electricity. When certain solids (typically salts) are dissolved in water, they dissociate and form ions. Ions carry an electrical charge (either positive or negative). More ions in water mean the water will conduct electricity better.

The electrical conductivity meter measures how much electricity is being conducted through a centimeter of water. If you look at the probe end of the meter you will see that there are electrodes 1 cm apart. Conductivity is measured as microSiemens per cm (µS/cm). This is the same unit as a micromho, mho.

To convert the electrical conductivity of a water sample (µS/cm) into the approximate concentration of the total dissolved solids (ppm) in the sample, you must multiply the conductivity (µS/cm) by a conversion factor. The conversion factor depends on the chemical composition of the dissolved solids and can very between 0.54 - 0.96. For instance, sugars do not affect conductivity because they do not form ions when they dissolve. The value 0.67 is commonly used as an approximation.

TDS (ppm) = Conductivity (µS/cm) x 0.67

It is better to use a conversion factor that has been determined by your water body instead of the approximation since the impurities between water bodies can vary greatly. Drinking water with a conductivity of 750 µS/cm will have an approximate concentration of total dissolved solids of 500 ppm. Pure alpine snow from remote areas has a conductivity of about 5 - 30 µS/cm.

Table HY-EC-1: Estimated Conversion from Conductivity (µS/cm) to Total Dissolved Solids (ppm) based on Average Conversion Factor of 0.67

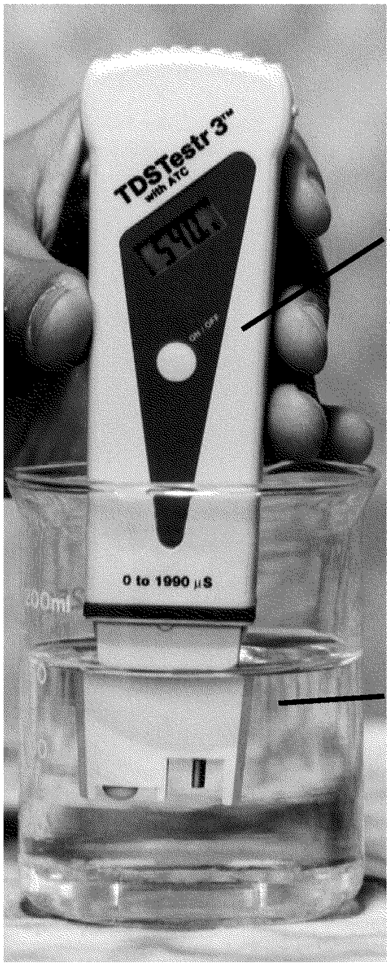
Conductivity (µS/cm)	TDS (ppm)	Conductivity (µS/cm)	TDS (ppm)
0	0	1050	704
50	34	1100	737
100	67	1150	771
150	101	1200	804
200	134	1250	838
250	168	1300	871
300	201	1350	905
350	235	1400	938
400	268	1450	972
450	302	1500	1005
500	335	1550	1039
550	369	1600	1072
600	402	1650	1106
650	436	1700	1139
700	469	1750	1173
750	503	1800	1206
800	536	1850	1240
850	570	1900	1273
900	603	1950	1307
950	637	2000	1340
1000	670	>2000	>1340

Teacher Support

Measurement Procedure

There are several manufacturers and models of conductivity meters. Some models may measure conductivity in increments of 10µS/cm; others in increments of 1.0µS/cm. If your model measures in increments of 10µS/cm, you will have to calibrate it as closely as you can to the standard solution. Your accuracy and precision will never be better than ± 10µS/cm. The meters need to be calibrated before testing the water sample. This can be done in the classroom shortly before going to the hydrology site or at the hydrology site.

Figure HY-EC-1: Using the Conductivity Meter



For measuring electrical conductivity, you will hear references to either conductivity probes or meters. For clarification, probes are the instruments that measure voltage or resistance in a water sample. Meters are instruments that convert electrical (voltage or resistance) measurements to concentrations. In order to measure electrical conductivity (or other types of measurements), both a probe and meter are required. Sometimes the probe and meter are within one instrument and cannot be taken apart. Other instruments have probes that are separate from the meters and need to be connected to the meters in order to take the water measurements.

Some conductivity meters may indicate that they have an automatic temperature compensation (ATC). Testing by the GLOBE Hydrology team has indicated that the temperature compensation on conductivity meters is generally not reliable. For this reason, all water should be brought to room temperature (20˚ - 30˚ C) for testing, even if the manufacturer claims that the meter is temperature compensated. It is very important to take the temperature of the water when doing the conductivity measurement. The temperature of the solution when the conductivity measurement is taken will help to identify errors resulting form meter error instead of actual changes in total dissolved solids.

If the water at your Hydrology Site is not between 20˚ - 30˚ C, you need to either let the water warm in the sample bucket or separate container while students take other hydrology measurements at the hydrology site, or collect a sample in a water bottle and take back to the classroom. After the water reaches 20˚ - 30˚ C, students can take the conductivity measurement.

Never immerse the meter totally in water. Only the part indicated in the instructions for the meter should be immersed in water.

Most Conductivity Meters cannot measure the high conductivity characteristic of salt waters. If your hydrology site is in salt water, you will need to follow the *Salinity Protocol*.

Quality Control Procedure

Electrical conductivity meters must be calibrated before use. Check with your meter manufacturer to be sure it stores the most recent calibration. If it does, the conductivity meter should be calibrated in the classroom or lab before going to the Hydrology Site. If your meter does not keep the most recent calibration, you will need to calibrate it just before you take your measurements taking care not to turn the meter or any associated software off. The temperature of the conductivity standard should be about 25° C.

Supporting Protocols

Water Temperature: It is important to take the temperature of water at the hydrology site following the *Water Temperature Protocol*. If the temperature at the site is not between 20° - 30° C, it is important to let a sample of water reach this temperature range.

Soil Characteristics and *Land Cover:* Soil Characteristics and Land Cover data provide information on the possible source of the materials dissolved in the water.

Atmosphere: Atmosphere data, especially precipitation, may also affect the concentration of total dissolved solids in your water.

Supporting Activities

A discussion of good conductors and poor conductors may help students understand the measurement better. To illustrate the conductivity of water, have students measure distilled water with the conductivity meter. They will find a reading near zero. Stir a small amount of salt into the water and watch the reading go up! What happens when sugar is added?

Students may also benefit from a discussion of indirect measures. Some things are difficult to measure directly. For instance, it would take a long time to count the fingers of everyone in the school! But we could estimate the number of fingers indirectly by counting the students and multiplying by 10. What other indirect measures can students think of?

Safety Precautions

Students should wear gloves when handling water that may contain potentially harmful substances such as bacteria or industrial waste.

Helpful Hints

It is a good idea to keep an extra set of batteries on hand for the conductivity tester. Many use small, flat 'watch' type batteries.

Instrument Maintenance

Electrical Conductivity Meter

1. The meter should be stored with the cap on. Never store the meter in distilled water.
2. The electrodes should be well rinsed with distilled water after use to avoid mineral deposit accumulation.
3. The electrodes should periodically be cleaned with alcohol.

Standard Solution

1. The standard should be stored in a tightly capped container in the refrigerator. Making a seal with masking tape will reduce evaporation.
2. Write the date that the standard was purchased on the bottle. Standards should be discarded after one year.
3. Never pour used standard back into the bottle.

Questions for Further Investigation

Would the conductivity of the water at your site to go up or down after a heavy rain? Why?

Would you expect the conductivity to be greater in a high mountain stream that receives fresh snowmelt or in a lake at lower elevations?

Why do you think water with high levels of TDS is harmful to plants?

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