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Conductivity: Water Quality Assesment

Dr.Abha Mathur
(Professor, Department of Chemistry, Govt. Girls College, Dausa)

Abstract— **Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.**

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through. Discharges to streams can change the conductivity depending on their makeup. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity.

Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Distilled water has conductivity in the range of 0.5 to 3 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

Conductivity is useful as a general measure of stream water quality. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other source of pollution has entered a stream.

I. INTRODUCTION

There are a wide variety of inorganic substances or dissolved solids in water solutions. Common dissolved substances are sodium, chloride, sulphates, calcium, bicarbonate, nitrates, phosphates, iron, and magnesium. All of these materials at certain concentrations are essential for aquatic life and all have the ability to carry an electrical current. These substances affect the flow of materials in and out of the cells of organisms living in the water and they may also be used as energy sources in certain organisms. The dissolved substances in addition serve as parts of the molecules needed for building new cells. In general, water with high concentrations of dissolved solids is considered "salty" while water with low concentrations of dissolved solids is considered "fresh." Salinity is the total of all salts dissolved in water, usually expressed in parts per thousand (ppt) or parts per million (ppm). Most organisms are adapted to a particular level of dissolved solids. The salt content of water affects the distribution of animals and plant species according to the amount of salinity they can tolerate. For this reason it is unexpected to find a largemouth bass in the Gulf of Mexico (35 ppt), or to see a red snapper in the Brazos River.

Fig. 1. Figure: Salinity tolerance range of species

Tolerance of Pollution may cause the levels of dissolved solids to fluctuate, so some organisms may be harmed during these times because their bodies are unable to adjust. Some examples of activities that can pollute the water are: wastewater discharges that are high in salts, brine waters from oil production activities, irrigation, clearing the land near a stream, overuse of fertilizers, spreading of road salt during icy conditions, etc. Salt pollution can be a direct problem for humans when drinking water supplies have levels of salt over 0.5 ppt. Streams with high salinity may be unsuitable for agricultural or industrial use.

Chemical and physical measurements that includes temperature, specific conductivity, pH, dissolved oxygen, and turbidity along with biological index scores are generally determined to ascertain and monitoring the quality of rivers and streams. Biological index scores are based on the diversity and abundance of macro invertebrate species and provide a good way for assessing the overall water quality of streams. This distinction of quality is based on the general environmental setting of the streams and their biological index scores. After observing and analyzing chemical and physical parameters of different streams and rivers, it become apparent that specific conductivity is the parameter that best differentiate the good and bad or fresh and pollution impacted streams. Other chemical and physical parameters, such as pH, DO, turbidity, and temperature are generally not distinct or consistently different.

II. CONDUCTIVITY

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Electrical conductivity of all electrolytic solutions is strongly dependent on temperature. A solution of a higher temperature will present a higher quantity of ions dissociated, therefore a higher concentration of electric charges and as consequence conductivity will rise i.e. warmer the water, the higher the conductivity. For this reason, conductivity is generally reported at certain reference temperature, e.g. conductivity at 25 degrees Celsius. The measurements for different concentrations of salt confirm the linear variation of the conductivity with temperature.

$$\sigma t = \sigma ref \{1 + \alpha (t - tref)\}$$

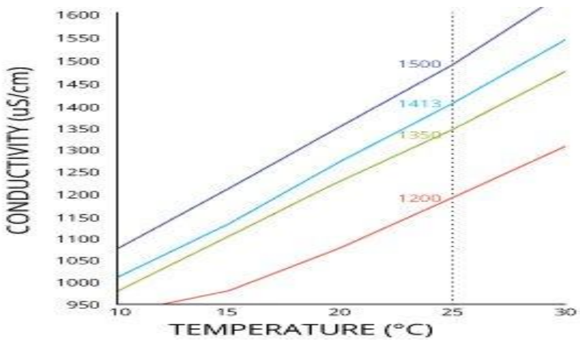

Figure:2 Conductivity temperature relationship

Where σ represents conductivity, δ w the water density, αi the equivalent ionic conductance of ion “i” and ci its concentration Conductivity of very dilute solutions can be calculated by the sum of the conductivity contribution of all ions in the solution

$$\sigma = \delta w \ \Sigma i \ (\alpha i \ ci)$$

Where σ represents conductivity, δ w the water density, αi the equivalent ionic conductance of ion “i” and ci its concentration. If a single ion solution is present, its concentration can also be evaluated from the conductivity measurements. Implicit temperature dependence is included in the equivalent ionic conductance and water density coefficients.

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize or do not dissolve into ionic components when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through. These factors imply that the physical location of the measuring unit is important and that a correlation between them and the measured values must also be considered.

Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity. The basic unit of measurement of conductivity is the mho or Siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimetre (µs/cm). Distilled water has conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µmhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro invertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

In industrial environments, water conductivity measurements are generally used to measure the concentration of ionized chemicals in water. For water quality assessment, conductivity measurement can be non-selective in the sense that it doesn’t distinguish individual concentrations of different ionic chemicals mixed in water. Nevertheless conductivity measurements are of paramount importance in water quality assessment systems since high or low conductivity levels, relatively to its nominal value, can be used to detect environmental changes and pollution events. Generally, high conductivity levels come from industrial pollution or urban runoff. Extended dry periods and low flow conditions also contribute to increase conductivity levels (e.g., measurements of water conductivity in lakes). However, organic compounds, such as oils, tend to lower water conductivity. Industrial discharges also have thermal effects, especially those from power plants that cause temperature changes and reduce dissolved oxygen concentration. And so, temperature is itself a water quality parameter besides being an influence variable that affects conductivity measurements. For estuarine salty water the conductivity temperature coefficient is about 2% per ºC. This means that accurate conductivity measurements imply also temperature measurements to compensate the conductivity for a certain reference temperature (typically 20 ºC or 25 ºC).

III. CONDUCTIVITY MEASUREMENT

Conductivity is used as a general measure of stream water quality. Each stream tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other source of pollution has entered a stream. Conductivity is measured with a probe and a meter. Voltage is applied between two electrodes in a probe immersed in the sample water. The drop in voltage caused by the resistance of the water is used to calculate the conductivity per centimeter. The meter converts the probe measurement to micromhos per centimeter and displays the result for the user.

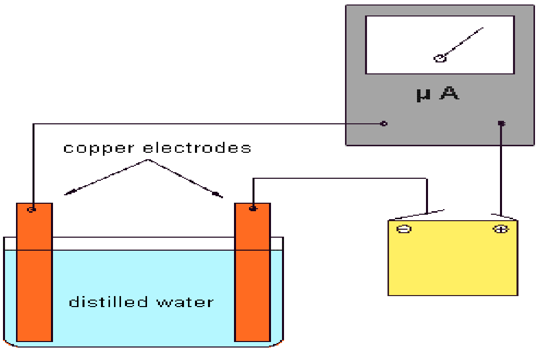

Figure: 3 Conductivity measurement

There are two types of conductivity sensors: electrodes (or contacting sensors) and toroidal or inductive sensors.

Electrode sensors contain two, three, or four electrodes. The conductivity is directly proportional to the cell constant and inversely proportional to the resistance. The proportionality coefficient or cell constant (KC) depends on the geometry of the sensor and must be designed according to the target conductivity range.

$\sigma = KC\ (1/R)$

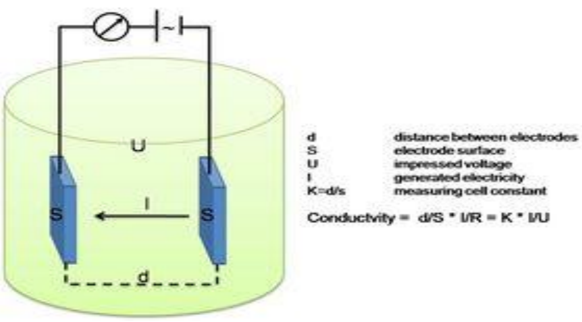

Figure:4 Electrode conductivity principle

Toroidal or inductive sensors usually contain two coils, sealed within a non conductive housing. The first coil induces an electrical current in the water while the second coil detects the magnitude of the induced current, which is proportional to the conductivity of the solution.

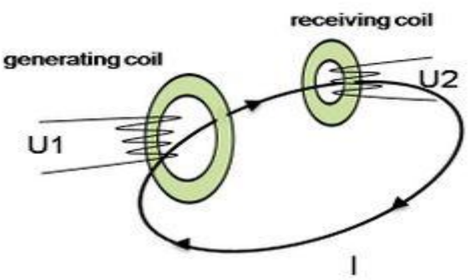

Figure: 5 Inductive conductivity sensor principle

Some conductivity meters can also be used to test for total dissolved solids and salinity. Total dissolved solids (TDS), is defined as the quantity of dissolved material in water, and depends mainly on the solubility of rocks and soils the water contacts. As the level of TDS rises, the conductivity will also increase.

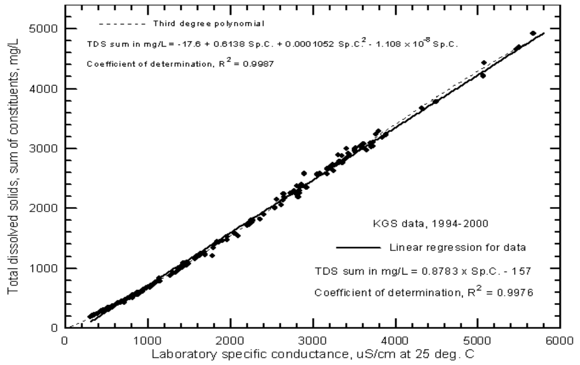

Figure: Conductivity and total dissolved solids

IV. CONCLUSIONS

Data acquired from different streams with poor water quality as judged by their biological index scores show relatively high specific conductivities. In contrast, streams with low specific conductivities have biological index scores indicating good or excellent water quality. No other routinely measured parameter such as temperature, dissolved oxygen, pH and turbidity showed such consistent differences between streams with poor and excellent water quality.

Therefore specific conductivity is a good way to assess the impact of urban pollution in streams and rivers. Conductivity measurements are easy to make. Meters are relatively inexpensive, ranging from small hand held instruments to more sophisticated meters. Such instruments are easy to calibrate, calibration standards are inexpensive, and when once calibrated, most instruments require only periodic (once in week or less) checking. These meters are capable to the harsh environmental conditions in which the sensors are usually exposed. For all these reasons, conductivity measurements are getting importance as a routine part of water quality monitoring programs. Some of the problems associated with water conductivity measurements are sensitivity to external disturbances, polarization and fouling effects, measurement selectivity and measurement dynamic range.

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