EC – Electrical Conductivity

Introduction

The electrical conductivity (EC) of a solution is a measure of its ability to carry an electric current; the more dissolved ionic solutes in a water, the greater its electrical conductivity. Electrical conductivity (S) is the reciprocal of electrical resistance (Ω):

$$S = \Omega^{-1}$$

Electrical conductivity is normally expressed in units of mS m^{-1}. Conductivity can be regarded as a crude indicator of water quality for many purposes, since it is related to the sum of all ionised solutes or total dissolved solid (TDS) content. The relationship between conductivity and TDS is not directly linear, however, since the conductive mobility of ionic species is variable. Univalent cations such as Na^+ are more mobile than multivalent ions such as Ca^{2+} and Al^{3+}. Similarly, univalent anions such as Cl^- are more mobile than multivalent ions such as SO_4^{2-} and CO_3^{2-}, which are in turn more mobile than charged humic substances. Thus, stream water with Na^+ and Cl^- as its dominant dissolved species will have a higher conductivity than one dominated by Ca^{2+} and SO_4^{2-}, if the pH and electrolyte strength are the same. However, as a rough approximation, the relationship between EC and TDS commonly used is:

$$TDS(mgl^{-1}) = EC(\mu Scm^{-1})x0.67$$

Since the movement of ions under an electrostatic potential increases with increasing temperature, EC values are temperature dependent. Most EC data are corrected to 25°C and the values are then technically referred to as specific electrical conductivity (SEC). An arbitrary constant is commonly used for temperature compensation assuming that the relationship between EC and temperature is linear; for example, a 2% increase in EC per 1°C (Hayashi 2004).

Electrical conductivity is widely used for monitoring the mixing of fresh and saline water, for separating stream hydrographs and for geophysical mapping of contaminated groundwater (Hayashi 2004). Distilled water should typically have an EC of less than 0.3 µS cm^{-1}. For groundwater, EC values greater than 500 µS cm^{-1} indicate that the water may be polluted, although values as high as 2000 µS cm^{-1} may be acceptable for irrigation water. In Europe, the EC of drinking water should be no more than 2500 µS cm^{-1} (European Commission 1998); water with a higher TDS may have water quality problems and be unpleasant to drink.

Table 25 compares the median concentrations of EC in the FOREGS samples and in the Barents region.

Table 25. Median concentrations of EC in the FOREGS water samples and in the Barents region.

Electric conductivity (EC)	*Origin – Source*	*Number of samples*	*Size fraction mm*	*Extraction*	*Median*
Water	**FOREGS**	**768**			**30.0 mS m^{-1}**
Water[1)]	Barents region	1357			8.7 mS m^{-1}

[1)]Salminen *et al.* 2004.

EC in stream water

EC values in stream water range over three orders of magnitude, from <3 to 829 mS m^{-1} (excluding an outlier of 1710 mS m^{-1}), with a median value of 30 mS m^{-1} (equivalent to 300 µS/cm).

Lowest conductivities in stream water (<19 mS m^{-1}) are found throughout Fennoscandia, northern Britain and Wales, north-west Iberian Peninsula, in Corsica and over the Massif Central and central Alps. These lowest values are predominantly associated with metamorphic and acid igneous rocks, and high-rainfall upland areas.

Highest conductivities in stream water (>80 mS m^{-1}) are found in Lithuania, south-east Britain, southern Iberian Peninsula (climatic conditions favour evapotranspiration; high metal and sulphate concentration related to diverse mineralisation in the Iberian Pyrite Belt and Sierra Morena; intensive agriculture with fertiliser use, superimposed on a calcareous lithology with evaporites in eastern Spain), Sardinia, Sicily and parts of mainland Italy, and Hungary. In the Mediterranean environments, the high conductivities are most likely related to high evapotranspiration, evaporitic deposits and intensive agriculture. In Britain, parts of southern Italy and over the Pannonian basin in Hungary and eastern Croatia, the highest conductivities relate to higher bicarbonate content derived from limestone rocks, evaporite deposits (notably within the Permo-Trias) and agricultural influences. In Lithuania it is partly related to field observation errors. Irrigation and evaporation effects are also likely to contribute to the high values within Hungary. A highly anomalous EC value in southern Denmark is probably related to high chloride content. The high values in northern Germany and partly Poland are most probably caused by agricultural pollution from the use of manure and fertilizers. The point EC anomaly in southern Germany (east of Stuttgart) is related to anthropogenic sources.

Electrical conductivity is proportional to the sum of cations and anions, and roughly equivalent to total dissolved solids (TDS) in water. The patterns described above are, therefore, very similar to those outlined by the scores on the second principal component (see Annex 4) of Major-ions and related elements, and to the more than two dozen elements and species loaded on it. To summarise the pattern of European north-south zonality, there is a belt with high values in the south, then a belt of low values (mainly high relief areas) in patches from north-west Iberia to the Alps, a belt of high values in central Europe, and finally a belt with the lowest values in Fennoscandia, northern Britain and Ireland. This pattern is a consequence of climate, topography, vegetation, and only subordinately geological factors.

The maps of major cations and anions permit to delimit in stream water the distribution of major hydrochemical water types. The highest mineralised stream water types are also the most diverse ones, and occur in the Mediterranean area in the south of Spain, they are CaMgNa-chloride-sulphate-bicarbonate stream water types. In neighbouring southern Portugal, there occurs the Na(K)Mg-chloride stream water type, and in eastern Spain the MgCa-bicarbonate-sulphate stream water. In Italy, there occurs the NaKMg(Ca)-bicarbonate-chloride-sulphate and high fluoride water type, characterising the alkaline volcanism. Similarly complex are also the stream water types on Sardinia and Sicily. Greece is characterised by Mg(Ca)-bicarbonate-(sulphate) stream water.

The belt of low values from the north-west Iberia Peninsula to the Alps is characterised by very low concentrations of practically all elements in stream water, and is evidently produced by dilution owing to high rainfall, and by the predominance of surface water in topographically higher regions before infiltration occurred.

The main part of central Europe is covered by K-Na–chloride stream water with sulphate, in eastern England, and in an area from Belgium and the Netherlands across Germany, western Poland, Czechia, Slovakia to Hungary. Parallel to this pattern or superposed on it are CaMg-bicarbonate-sulphate-fluoride stream water: eastern England, the Baltic states, Hungary (very high along the border with Croatia). Ca-bicarbonate stream water is found in west Ireland, south-west France and most of the Paris Basin, north Germany and west Poland (with sulphate, chloride and fluoride). The Mg-bicarbonate stream water type is typical for east-central England and southern Germany. In eastern Sweden and southern Finland, high fluoride stream water, with moderate alkalis and earth alkalis, is found. Nitrate stream water extends across all of central Europe, and in smaller parts of southern Europe.

The northern belt with low ionic concentrations and low TDS shows the highest DOC and high concentrations of the REEs and associated elements, apparently bound to organic matter.