

3 THE CHEMISTRY OF GROUND WATER



GROUNDWATER CHEMISTRY

KEY TERMS

Groundwater salinity:

A measure of the concentration of dissolved salts in the groundwater generally in milligrams per litre (mg/L).

If you have spent time away from home in a different city or town, you may have noticed that the drinking water tastes different or that it might be difficult to get your skin or hair really soapy in the shower. This is because of the chemistry of the water.

Our water supplies are not just H₂O - hydrogen and oxygen. There are other chemical elements dissolved in the water that can change the chemistry of the water.

The chemical elements dissolved in water are present as ions. An ion that has a positive charge is known as a cation. Ions with a negative charge are called anions.

The most common cations found dissolved in water are sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺) and magnesium (Mg²⁺). The most common anions in groundwater are chloride (Cl⁻), sulfate (SO₄²⁻), carbon in the form of hydrogen carbonate (HCO₃⁻) and carbonate (CO₃²⁻), and nitrate (NO₃⁻).

All of these ions together account for the TDS or Total Dissolved Solids that can be measured in groundwater. This will be discussed later in the water quality section.

When we use water we expect not to get sick from drinking it. Farmers expect their crops to grow when they add water and people who use water in industry expect it not to corrode or destroy their machinery.

The way in which groundwater is used depends on its quality. The amount of dissolved minerals, metals and salts determines this quality. Potable is a term used to describe water, which is fit for human consumption.

There can be many different chemical elements in groundwater. The most commonly used "measure" of groundwater quality is its salinity, that is the concentration of dissolved solids in the water. The two main ways salinity of groundwater is measured is:

- TDS (total dissolved solids) measures the amount of inorganic salts and organic matter present in water. This is represented as a concentration, usually milligrams per litre (mg/l).
- EC (Electrical Conductivity) measures the ability of water to conduct electricity. Salty water is a better conductor of electricity than fresh water. This is represented by electrical conductivity, or EC units generally reported as micro Siemens per cm (µS/cm). Measuring the electrical conductivity of water. Then a return is generally easy, as there are hand held meters that can measure it at the source. It is possible to estimate the TDS of water based on its EC reading. Although this relationship varies, in general if you multiple the EC by 0.6, it will approximate the salinity in mg/l.

$$\text{EC } (\mu\text{S}/\text{cm}) * 0.6 = \text{TDS } (\text{mg/L})$$

The salinity is only a measure of the total concentration of chemical elements – it tells you nothing of the specific chemicals. As a general rule, it is a good guide for quality.

Where does the salt come from?

Much of the salt in groundwater comes from rainwater. Rain water contains very low concentrations of salt. However, soil and plant processes store or use the water, concentrating the small concentrations of salt. A study in Western Australia of the rainfall chemistry at 65 locations, that the concentration of salt in rainwater ranged between less than 1mg/L to nearly 50 mg/L.



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GROUNDWATER QUALITY

KEY TERMS

Beneficial Use:

The use to which untreated groundwater can be used based on its salt content.

Groundwater chemistry as an indicator of suitability of use

The most common parameter used to describe groundwater quality and its potential uses is salinity. The “saltier” the groundwater gets, the fewer uses it can be put to. A general guide matching salinity with uses is given in Table 3.1.

For drinking water, it is preferable for the water to have as low a salinity as possible. Generally the preference (based on taste) for the salinity to be less than 500mg/l. It is safe to drink at higher concentrations of salt (up to 1000 mg/l), but becomes less preferable as it develops a more distinct “taste”.

For use in irrigated agriculture, it is preferable for the salinity to be less than 3000 mg/l. Different crops have different “tolerances” for the salinity of water. Even 3000 mg/L is too salty for many crops.

Stock (sheep, cows, horses) can generally drink water up to 7,000 mg/l, and even higher under some circumstances. Groundwater is an important source of stock water in many parts of rural Australia where surface water is unreliable.

Industrial uses of water can tolerate much higher salinities depending on the use. In many cases, industrial processes require low salinity water to minimize corrosion. However, basic processes such as mining processing, cooling water and wash-down water can use much higher salinities. At very high salinities, the salts in the groundwater may have a high value themselves. The water is processed to extract these salts.

Total Dissolved Solids (TDS) - mg/L	Electrical Conductivity (EC) - μ S/cm	Use
100–500	160–800	Drinking water (preferred), irrigation, stock water, industrial
501–1000	801–1600	Drinking water (acceptable), irrigation, stock water, industrial
1001–3000	1601–4800	Irrigation, stock water, industrial
3001–7000	4801–11200	Stock water (sheep, cattle), industrial
7001–14000	11201–22400	Limited stock water (sheep), industrial
→14000	→22400	Limited industrial

Table 3.1 GENERAL USES OF WATER FOR DIFFERENT SALINITIES

Source: Derived from the State Groundwater Protection Policy, Groundwaters of Victoria (Environment Protection Authority, Victoria 1998).



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Groundwater chemistry to inform groundwater processes

The chemical composition of the groundwater can help to understand the sources of water in the ground, how it is reacting with the soil and rock it moves through, how old it is and where it is flowing to and from. This can help hydrogeologists understand how best to manage groundwater.

In addition to the major anions and cations, there are a range of minor chemical components such as minor Ions (Sr^{2+} , Br^- , F^-) and trace Metals (e.g. Cu, Pb, Cd, Cr, Hg,...).

The primary natural sources of the chemical elements are from:

- Atmosphere – rainfall salts, gases, aerosols..
- Soil - (Bio)geochemical reactions of water with soil and rock materials..
- Mixing - leakage between aquifers, or intrusion of surface water.

There are also introduced chemicals from human activities. These are addressed more fully in the Chapter on groundwater contamination.

As the groundwater moves through the ground, its chemistry can be changed through:

- Evapotranspiration
- Dissolution and precipitation of soluble minerals
- Acid-base reactions (e.g. CO_2 with carbonates)
- Weathering of aluminosilicate minerals by weak acids (CO_2 & organic matter)
- Ion exchange and sorption
- Oxidation-reduction reactions involving chemical compounds containing O, C, N, S, Fe etc. These processes leave “finger prints” – the chemistry of the groundwater tells the story of where the water has come from and what has happened to it along the way.

One of the common techniques for understanding the “groundwater journey” is discussed below.

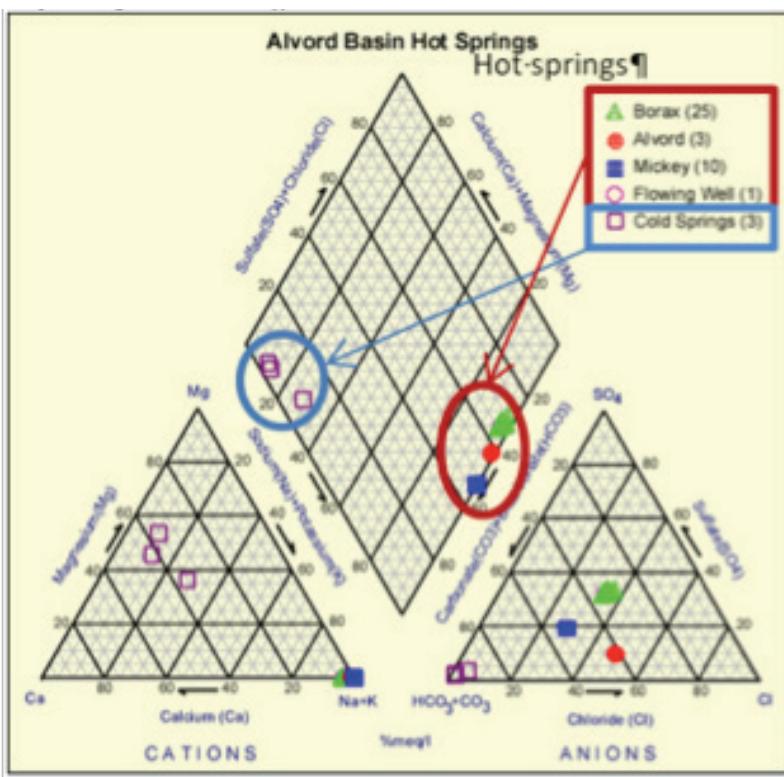


FIGURE 3.1 PIPER DIAGRAM ALVORD HOT SPRINGS USA

Source: <http://www.uweb.uidaho.edu/biogeochemistry/geochemistry.html>



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Major anion / cation ratios:

The ratios of anions and cations can provide information on mixing and reactions within groundwater. Plotting the chemistry ratios for a range of groundwater samples from different locations can identify groundwater with different sources and common characteristic that may be related to the reactions with soil and rock or the role of evaporative processes. A common approach to plotting anion and cation ratios is the use of a Piper Diagram (Figure 3.1).

The plot above shows the chemical composition of hot springs and cold springs in the same area. The ratios demonstrate that the groundwater discharging from the hot springs has a different source to the cold springs. This is illustrated by the two “populations” of analysis having significantly different cation / anion relationships. There is also no evidence of mixing between the two sources. If there were, then it would be expected to see additional points between the two populations.



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