

Making Sense of an Incomplete Water Analysis

by Frank DeSilva

The water treatment professional is often required to recommend a treatment scheme to rectify problem water. More often than not, the initial water analysis data that the end user provides is not sufficient to make a valid recommendation. This article provides the items you need to get from your customers in order to make a valid recommendation for resin selection and throughput predictions: the influent conditions and also the effluent requirements.

Author's note: I have gotten into the habit of listing ions in mg/L if they are reported as the ion and in ppm if they are reported as CaCO₃. This is a convention used by Bill Bornak in his book, *Ion Exchange Deionization*.

Information Needs by Application

Cationic applications

(hardness removal, metals removal, radium removal)

- pH
- TDS or conductivity
- hardness (or separate calcium and magnesium numbers)
- iron
- manganese
- all metals of concern if metals removal is the application (copper, lead, cadmium, etc.)
- other cations as needed (radium, for example)

Anionic applications

(sulfate removal, nitrate removal, chromate removal, uranium removal, organics removal, perchlorate removal, fluoride removal, dealkalizers, boron removal)

Technically, the same type of resin will remove all of the constituents listed; however, the determination of which anion resin will actually be the best choice is dependent upon the water analysis parameters that are requested. For instance, a type II strong base anion resin will work well for arsenic removal on high pH/low TDS water, while a hybrid strong base anion resin would work well on a low pH/ high sulfate water.

- pH
- TDS or conductivity
- sulfate
- nitrate
- chloride
- alkalinity (or HCO₃⁻)
- silica (for arsenic applications)

Of course, for the contaminant of concern (arsenic, chromate, uranium, etc.) you'll need to know the influent concentration and also the effluent requirement. It is also useful to know if the iron and manganese concentrations are above 0.5 ppm and 0.25 ppm respectively. If so, the client needs to lower the iron and/or manganese level before introducing water to the anion unit.

Deionizer applications

- pH
- TDS or conductivity
- calcium
- magnesium
- sodium
- potassium (if any)
- sulfate
- chloride
- alkalinity
- silica
- CO₂

Deionizer applications will specify effluent quality in terms of conductivity, resistivity, silica or sodium.

Customer provided information

It's not often that the customer will have all the items you are asking for. TDS or conductivity is easy to test for and you'll usually be able to obtain those numbers. Here's an example of roughing up a water analysis from partial information.

The customer provides us with a water analysis that shows the following:

- Conductivity 550 microsiemens
- hardness 150 ppm
- alkalinity 125 ppm
- chloride 30 mg/L
- silica 15 mg/L
- pH 7

What's missing? The breakdown of the hardness into calcium and magnesium, the sodium, the sulfate and CO₂.

First the cations. If you're trying to get a cationic water analysis together and the customer only has the inlet conductivity of 550 and the hardness of 150 ppm as

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CaCO₃, here are the assumptions you can make.

Take the inlet conductivity and convert it to TDS ppm as CaCO₃ ($550/2.53 = 217.4$ ppm as CaCO₃). By subtracting the hardness of 150 ppm as CaCO₃, you find the sodium level as CaCO₃ ($217.4 - 150 = 67.4$ ppm as CaCO₃).

Since we don't have separate numbers for calcium or magnesium, you can use an old rule of thumb that says that calcium is usually two thirds of the total hardness number and magnesium the remaining third. So, the calcium is 100 ppm as CaCO₃ and magnesium is 50 ppm as CaCO₃.

Cation summary, all as ppm CaCO₃:

- calcium 100 ppm
- magnesium 50 ppm
- sodium 67.4 ppm

Now let's take a look at the anions.

Assume that all the customer had for us is the alkalinity (again a simple test for the customer to do), chloride and silica.

- alkalinity 125 ppm as CaCO₃ (If the water analysis states alkalinity, it is reported as CaCO₃. Sometimes the alkalinity is reported as HCO₃⁻ and so you must convert that to ppm as CaCO₃)
- chloride 30 mg/L
- silica 15 mg/L

The first thing to do is convert the chloride to ppm as CaCO₃ ($30 \times 1.41 = 42.3$ ppm as CaCO₃). Now find out what the sulfate level is by subtracting the chloride as CaCO₃ plus the alkalinity as CaCO₃ from the total cation ($217.4 - (125 + 42.3) = 50.1$). So the sulfate is 50.1 ppm as CaCO₃.

The silica is not incorporated into the ionic balance since it is weakly ionized and does not contribute to the conductivity or TDS.

Table 1 is a summary of what we have calculated, now shown as ppm as CaCO₃:

Cations		Anions	
Calcium	100	Sulfate	50.1
Magnesium	50	Chloride	42.3
Sodium	67.4	Alkalinity	125
Total	217.4		217.4

The total cations and anions should be equal at this point since they all contribute to the electroneutrality of the solution. There may be some potassium present in the cations. However, for our calculations, it is lumped in with the sodium since it is also monovalent. On the other hand, there may be low levels of nitrate present; it is lumped in with the chlorides as a monovalent. (This is for DI calculations only. If we are dealing with a nitrate removal job, we need to know precisely how much nitrate is present.)

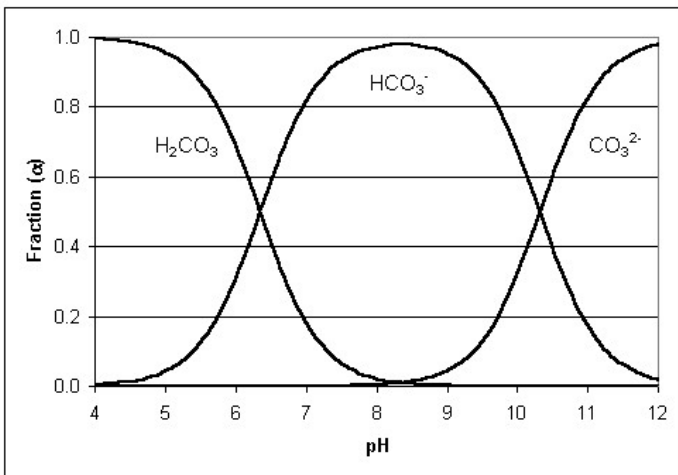
This is not all of the exchangeable anions, however, since we still have the silica and carbon dioxide to contend with. The silica is reported at 15 mg/L as silica. The conversion to CaCO₃ is 0.83 ($15 \times 0.83 = 12.5$ ppm as CaCO₃). Adding that to the total anions, $12.5 + 217.4 = 229.9$ ppm as CaCO₃ as total exchangeable anions (TEA). To be completely thorough, you would want to calculate the CO₂ level to see what its contribution would be to the anion loading.

When discussing the alkalinity measurement of natural waters, the assumption is made that the carbonate/bicarbonate concentration far exceeds the hydroxide concentration and that all of the alkalinity is estimated as due to a combination of carbonate and bicarbonate. The alkalinity concentration reported on the water analysis also does not take into account the dissolved carbon dioxide gas (H₂CO₃). The graphed summary of the carbonate system in Figure 1 can be used to estimate what fraction of the three forms of CO₂ (H₂CO₃, HCO₃⁻, CO₃²⁻) exist at a given pH.

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Figure 1: Fractional Distribution of Carbon Dioxide Species in Water as a Function of pH¹



At a pH of 7, the ratio of CO₂ to M alkalinity (total alkalinity) is 0.16 (0.16 x 125 = 20 ppm CO₂ as CaCO₃). That means that our total exchangeable anions are now 229.9 + 20 = 249.9. To calculate the load in grains per gallon, divide the ppm as CaCO₃ by 17.1. Total cation load therefore equals 217.4/17.1 = 12.7 grains per gallon (gpg). Total anion load equals 249.9/17.1 = 14.6 gpg.

Here's our water summary once again. Provided by customer: conductivity 550 microsiemens; hardness 150 ppm; alkalinity 125 ppm; chloride 30 mg/L as Cl; silica 15 mg/L as SiO₂; pH 7. Table 2 is the calculated analysis (all shown as ppm as CaCO₃).

Cations		Anions	
Calcium	100	Sulfate	50.1
Magnesium	50	Chloride	42.3
Sodium	67.4	Alkalinity	125
		Silica	12.5
		CO ₂	20
Total	217.4		249.9

Of course, any predictive information provided to the customer at this point must clearly show the calculations and assumptions that have been made. The less complete the original water analysis is, the higher the safety factor or engineering factor should be. A typical engineering factor that is used for DI calculations is 0.9 or a 10-percent downgrade for cation or 15 percent for anion, which is applied to the throughput calculations. If we run a projection on the water analysis that we just calculated, you might want to use 0.8 or 0.75 as the safety factor.

About the author

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1. <http://ion.chem.usu.edu/~sbialkow/Classes/3650/Carbonate/Carbonic%20Acid.html>