Interpreting Irrigation Water Quality Reports

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Water Chemistry

What? Water is not just H_2O? What else could possibly be in there?

As water evaporates and condenses in the atmosphere and falls as rain, it flows overland, seeps through the soil, and moves underground. During this cycling it is processed by humans, animals, plants, and microbes, picking up some compounds, leaving some behind, and acting as a medium to form new ones.

Naturally, mineralogy and weathering influence water chemistry. Water can dissolve minerals in rocks. Chemicals may be released (dissolved) into water as microbes decompose organic material. Plants exude chemicals from their roots to increase availability of minerals in soil pore water. Further, extreme temperatures cause water to expand in rocks breaking them apart and releasing minerals that were once tightly bound.

Humans impact water quality in various ways. Nutrient, pathogenic, and pharmaceutical waste can be introduced from treated and untreated sewage. Metal and chemical waste can be, released as by-products of industry and mining operations. Fungicides, herbicides, and pesticides are applied for agricultural purposes. Urbanization and development expose subsoils that are naturally anaerobic, introduce deicing rock salts, and change landscape use.

Some water sources are influenced more by man-made actions than natural processes. For example, reclaimed stormwater runoff and treated (reclaimed) wastewater are increasingly common irrigation water sources as demand for potable water increases.

Testing Water Sources

Knowing what is in your irrigation water can help in managing your landscape. Far too often, an irrigation water test is used as a diagnostic tool *after* plants are exhibiting some type of stress. However, irrigation water tests should be done when the irrigation system is installed and with some frequency, dependent on the outcome of the initial test, location (are you near the coast?) and the potential for fluctuations in water source quality.

Use opaque plastic containers to collect your water sample. Rinse out the bottle three times with the water you will be sampling before bottling the final sample. Place your name, location, and date on the sample bottle with a permanent marker. Place in a cooler or refrigerator until delivery to the laboratory. Make sure to submit the sample within 24 hours of collection. Clemson University's Agricultural Service Laboratory (ASL) has a specific set of tests for evaluating irrigation water (http://www.clemson.edu/agsrvlb/feedback3.htm).

What's in Your Irrigation Water?

Table 1 discusses the components of water that ASL tests for in relation to ***irrigation of plants*** and not for drinking water or for livestock health. If you have further questions, contact your county extension agent.

Table 1. Irrigation water component, severity range, description and management.

Component	Origin	Severity			Issue	Management
		Not a Problem	Increasing Problem	Severe Problem		
Phosphate (PO_4-P)	Found naturally in ground and surface waters, fertilizers, landscape runoff, and treated sewage.	< 1.2 ppm	1.2 – 2.4	> 2.4	Runoff to water bodies can cause algal blooms followed by a decrease in dissolved oxygen, ultimately resulting in less aquatic life.	Reverse osmosis. Fertilization amounts and scheduling should account for amount attributed from irrigations.
Potassium (K^+)	Originates from dissolved rock, salts, soil and fertilizers.	< 20 ppm	20 - 50	> 50 for foliar injury[†]	Can significantly increase K in plant tissue which may lead to limited plant uptake of other required nutrients.	Distillation, reverse osmosis, or ion exchange methods.
Calcium (Ca^{+2})	Originates from dissolved rock, limestone, gypsum, salts, soil and fertilizers.	< 25 ppm < 60	25 – 250 60 - 100	> 250 for soil and water ion hazard > 100 for foliar injury[†]	Binds with CO_3 and HCO_3 to form lime deposits, contributes to "hard water" and salinity.	Water softeners are most commonly used. Can use other ion exchange methods.
Magnesium (Mg^{+2})	Originates from dissolved rock, limestone, dolomite, salts, soil and fertilizers.	< 20ppm	20 - 40	> 40	Binds with CO_3 and HCO_3 to form lime deposits, contributes to "hard water" and salinity.	Water softeners are most commonly used. Can use other ion exchange methods.
Zinc (Zn)	Occurs naturally in small amounts. May result from industrial pollution.	< 2.0 ppm		> 2.0	Not usually a problem, can gives water a milky appearance. When low pH water is in contact with copper-zinc alloys used in plumbing systems, zinc from corrosion is released.	Source dependent: From natural source: use reverse osmosis, or other ion exchange methods and distillation. From low pH water in contact with metal: increase pH using sodium carbonate (soda ash).
Copper (Cu)	Occurs naturally in small amounts. Can be present from mining operations, acidic water, and from corroding copper pipes.	< 0.2 ppm	0.2 – 5.0	> 5.0	Not usually a problem, can cause staining and have a corrosive effect. Toxicity can occur in some plants at concentrations <1.0 ppm.	Increase pH using sodium carbonate.

Component	Origin	Severity			Issue	Management
		Not a Problem	Increasing Problem	Severe Problem		
Manganese (Mn)	Dissolved from shale, and sandstone. Present in flooded soils, and wetlands with low dissolved oxygen.	< 0.2 ppm		>0.2	Not usually a problem, excessive Mn turns water grayish/black, can coat leaf surfaces and subsequently reducing photosynthesis.	Precipitation followed by filtration. At low concentrations can use a water softener. Keep soil pH between 6.0 – 7.0 and good drainage.
Iron ($Fe^{+2 \text{ or } +3}$)	The fourth most abundant element in the earth's crust (although not commonly found in the free metal form). Iron is dissolved from underlying rocks and soil. Can be present if low pH water passes through iron pipes or equipment.	< 0.3 ppm	0.3 - 5	> 5	In the presence of oxygen (in water or air) rust forms. If salt is present, the metal will rust faster. The rust can cause reddish-brown staining and or flake off and clog nozzles, filters and lines. Iron also complexes with organic materials and bacteria which can cause slimes. When > 5 ppm, coatings form on leaf surfaces and subsequently reduce photosynthesis.	Treatment of iron will depend on the type of problem that exists. The most common techniques include 1-aeration followed by sediment filtration, 2-sediment filtration and using a water softener (caution: these usually use sodium), 3-precipitation with potassium permanganate followed by sediment filtration, and 4-chlorination followed by sediment and carbon filtration.
Sulfate (SO_4^{-2})	Naturally from rock and soil containing gypsum, iron sulfides, other sulfur compounds. Industrial wastes, sewage, and from coal mining operations.	< 100 ppm	100 - 200	> 200	If calcium is present, scale can form. As part of salinity, can reduce growth and or cause plant injury.	Reverse osmosis
Boron (B)	Naturally occurring in groundwater, and from decaying plant material. Industrial pollutants and from agricultural runoff also are sources.	< 1.0 ppm	1.0 – 2.0	> 2.0	Needed in very small amounts by plants. When in excess it is very toxic. Plant sensitivity widely ranges.	Boron is quickly leached from sandy soils, and thus is not typically a problem. Will accumulate in fine textured soils and pose more of a toxicity threat to sensitive plants.

Component	Origin	Severity			Issue	Management
		Not a Problem	Increasing Problem	Severe Problem		
Sodium (Na^+)	Dissolved from rock, salts, and soil. Human induced concentrations from road salt, fertilizers, industrial brines, and reclaimed wastewater.	< 70 ppm < 70	70-200	> 200 for soil and water ion hazard > 70 for foliar injury[‡]	High concentrations can speed up corrosion by other elements. Can also burn foliage. Refer to SAR in this table.	Refer to SAR in this table.
Chloride (Cl^-)	Naturally occurs from dissolved minerals, and sea water. Human induced concentrations from road salt, fertilizers, industrial wastes and or sewage.	< 70 ppm 0	70 – 300 0 - 100[∫]	> 300 for soil and water ion hazard > 100 for foliar injury[†]	Mobile in the soil, Cl can be taken up by roots and accumulate in leaves causing toxicity.	Blend or change to an alternative water source. Reverse osmosis.
Nitrate (NO_3-N)	Naturally occurring in the soil from decaying organic material. Major contributions from fertilizers, sewage, and manure applications.	< 50 ppm	50 - 100	> 100	High concentrations can cause succulent tissue that is not as resource efficient and more susceptible to some pests. Runoff can cause eutrophication in receiving waters.	Fertilization amounts and scheduling should account for amount attributed from irrigations. Reverse osmosis.
Total Dissolved Salts (TDS)	Concentration of mineral salts (ex: $MgSO_4$, MgCl, CaCl, $NaHCO_3$, NaCl, KCl) dissolved in water. Refer to electrical conductivity in this table.	< 500 ppm	500 - 2000	> 2000	The same as total dissolved ***solids*** in clear, non-turbid water. High salinity can result in salt accumulation in fine textured soils, making it hard for roots to absorb water. Must determine if dominated by sodium.	Refer to electrical conductivity in this table, and permeability and residual sodium chloride in the next section.

Component	Origin	Severity			Issue	Management
		Not a Problem	Increasing Problem	Severe Problem		
Electrical Conductivity (EC)	An indicator of the presence of mineral salts, which originate from the earth's crust. Fertilizers, organic matter, and treated wastewater also contribute salts.	0.50 - 0.75 mmhos/cm	0.75 – 3.0	< 0.50 or > 3.0	Use EC as the initial identifying that a problem exists. Further evaluation is needed to determine if the problem is total dissolved salts, sodium, and or HCO_3^- and CO_3^{-2}.	Management will be dependent on the type and degree of the problem. Refer to water permeability in the next section.
pH	Potential of hydrogen. It is the measure of the concentration of hydrogen ions (H+). Measured on a logarithmic scale of 1-14 with 1 = acidic, 7 = neutral, and 14 = alkaline. Water pH fluctuates diurnally and seasonally.	Normal range: 6.5 – 8.0		< 6.0 or > 8.0	Influences availability of plant nutrients and other soil elements. Use as an indicator that a problem exists and continue to evaluate. Alkaline water can indicate water high in CO_3^- and HCO_3^{-2} and or salinity. pH <5.5 or >8.5 can cause corrosion of pipes and equipment.	An acid or base can be injected into the irrigation water.
Bicarbonate (HCO_3^-)	Naturally occurring from dissolution of limestone and dolomite, and from atmospheric carbon dioxide.	< 1.5 meq/L <1.5	1.5 – 3.0 1.5 – 8.5	> 3.0 for soil and water ion hazard > 8.5 for foliar‡	Deposits (milky spots) form when reacting with Ca and Mg to form insoluble precipitates.	Lower the pH by injecting acid into the irrigation water.
Carbonate (CO_3^{-2})	Refer to bicarbonate.	< 0.5 meq/L	0.5 – 1.65	> 1.65	Refer to bicarbonate.	Refer to bicarbonate.
Sodium Absorption Ration (SAR)	Measures the sodium hazard by comparing the concentration of sodium to the concentration of calcium and magnesium.	<10 meq /L*	10 - 18	> 18	High sodium hazard describes that sodium is disproportionately abundant and can cause soils to disperse reducing porosity, and have a salt crust reducing infiltration and causing it harder for roots to absorb water. Fine textured soils are affected more than sands.	Blend or change to an alternative water source. Apply a leaching fraction with every irrigation. Inject S or Ca into the water. Reverse osmosis. Disrupt soil surface to break any crusts and for aeration. Incorporate sand into the soil.

† for turfgrass ‡ for sensitive ornamentals * not for clay soils. ∫ ornaments exhibit a wide range of tolerance.

Other Information that can be Determined from the Analysis

Besides comparing your reported values with those in Table 1 to evaluate your irrigation water, you can make other water quality conclusions by using the values for other calculations:

Water Permeability

Water permeability, also known as infiltration, can decrease under certain salinity and Na conditions. Match up your reported EC (mmhos/cm) and SAR (meq/L) values to Table 2 to determine if a problem may exist. In parts of the South Carolina Midlands and Piedmont regions, pure water problems exist. This is when there are few minerals in the water (as measured by EC). Divalent cations such as Ca^{2+} and Mg^{2+} act as bridges to bind soil particles together forming soil aggregates. When there are few divalent cations, soil porosity is low with few aggregates and water infiltration is difficult (EC = 0.3 dS/m, SAR = 0 - 3 meq/L). Raise the EC over 0.5 dS/m by injecting the water with Ca or Mg.

In the South Carolina Coastal Plains, high sodium concentrations are a more common problem. Sodium, a monovalent cation (Na^+), does not form bridges between soil particles thus limiting soil aggregate formation. It is also bulky in size and does not allow water close to the aggregate. When Na^+ dominates irrigation water, the water soaks in slowly or not at all because the soil is dispersed (has few aggregates) and porosity is low. If Na^+ is present in irrigation water, but divalent cations dominate, the soil aggregates, forming pores, and water infiltrates.

Table 2. Water permeability based off of irrigation water EC and SAR.

	Water permeability problem	
SAR of irrigation water	Unlikely when EC is ***more*** than	Likely when EC is ***less*** than
0 - 3	0.7	0.4
3 - 6	1.2	0.3
6 - 12	1.9	0.5
12 - 20	2.9	1.3
20 - 40	5.0	2.9

Residual Sodium Carbonate

Residual sodium carbonate (RSC) is another term used when assessing irrigation water sources for Na^+ hazard. Carbonates and bicarbonates have a high affinity to and form insoluble precipitates with Mg and Ca. When these precipitates form, it is desirable to have excess divalent cations available to bind with all HCO_3^- and CO_3^{2-} and excess to help aggregate soil particles. If there are not enough divalent cations available, and irrigation water contains Na, the pool of Mg and Ca is used to satisfy the CO_3 and HCO_3 leaving no extra divalent cations to aggregate soil particles. The Na is left to bind with soil particles, leading to soil dispersion, less aggregation, fewer soil pores, and decreased water infiltration.

Although not included in Clemson reports, the RSC (meq / L) can be calculated from the given information.

Step 1: Convert the Ca, and Mg from ppm to meq / L:

$$\text{Ca and Mg (meq / L)} = \frac{[\text{Ca ppm}]}{20} + \frac{[\text{Mg ppm}]}{12.2}$$

Step 2: Sum the reported CO_3 and HCO_3 values (already in meq/L) together and divide by the number in Step 1.

$$\frac{[CO_3] + [HCO_3]}{\text{Ca and Mg (meq/L)}}$$

Step 3: Compare with Table 3:

Table 3. Range of severity for residual sodium carbonate.

	Not a Problem	Increasing Problem	Severe Problem
Residual Sodium Carbonate	<1.25 meq / L	1.25 – 2.50	> 2.50