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, it 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.

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 (CU-ASL) has a specific set of tests for evaluating irrigation water <http://www.clemson.edu/public/regulatory/ag_svc_lab/irrigation_water/index.html>.

What's In Your Irrigation Water

Table 1 discusses the components of water that CU-ASL tests for in relation to irrigation of plants, not for drinking water or for livestock health. If you have further questions contact your county extension agent <http://www.clemson.edu/extension/county/index.html>.

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:

Table 1. Irrigation water component, its severity range, description of issue, and strategy for managing the problem.

Component	Origin	Severity			Issue	Management
		Not a Problem	**Increasing Problem**	**Severe Problem**		
Phosphate (PO_4^{3-}-P) ppm	Ground & surface waters, fertilizers, landscape runoff, & treated sewage.	< 1.2	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.\n\nFertilizer amounts & scheduling should account for amount contributed by irrigation water.
Potassium (K^+) ppm	Dissolved rock, salts, soil, & fertilizers.	< 20 ppm	20 - 50	> 50 for foliar†	Increase K in plant tissues, can lead to limited plant uptake of other required nutrients.	Distillation, reverse osmosis, or ion exchange methods.
Calcium (Ca^{2+}) ppm	Dissolved rock, limestone, gypsum, salts, soil, & fertilizers.	< 20\n\n< 60	25 – 250\n\n60 - 80	> 250 soil & water ion hazard\n> 100 foliar injury†	Binds with CO_3^{2-} and HCO_3^- to form lime deposits, contributes to "hard water" & salinity.	Water softeners are most commonly used.\n\nCan use other ion exchange methods.
Magnesium (Mg^{2+}) ppm	Dissolved rock, limestone, dolomite, salts, soil, & fertilizers.	< 25 ppm	25 - 35	> 35	Binds with CO_3^{2-} and HCO_3^- to form lime deposits, contributes to "hard water" & salinity.	Water softeners & ion exchange methods.
Zinc (Zn) ppm	Occurs naturally in small amounts.\n\nMay result from industrial pollution.	< 2.0 ppm		> 2.0	Not usually a problem, can give water a milky appearance.\n\nZinc released from corrosion of plumbing systems (copper-zinc alloys), with low pH water.	Source dependent:\n1- reverse osmosis.\n2- other ion exchange methods.\n3- distillation.\n\nIncrease pH of water using sodium carbonate (soda ash).
Copper (Cu) ppm	Occurs naturally in small amounts, also from mining operations, acidic water, & from corroding copper pipes.	< 0.2 ppm	0.2 – 5.0	> 5.0	Not usually a problem, staining & corrosion possible (*see Zn*).\n\nToxicity in some plants at concentrations >1.0 ppm.	Increase pH using sodium carbonate.
Manganese (Mn^{2+}) ppm	Dissolved from shale, & sandstone.\n\nPresent in flooded soils & wetlands with low dissolved oxygen.	< 0.2 ppm		>0.2	Not usually a problem.\n\nExcessive Mn\n1- turns water grayish/black.\n2- can coat leaf surfaces & subsequently reduce photosynthesis.	Precipitation then filtration.\n\nAt low concentrations use a water softener.\n\nKeep soil pH between 6.0 – 7.0, with good drainage.

Table 1 *cotinued.* Irrigation water component, its severity range, description of issue, and strategy for managing the problem.

Component	Origin	Severity			Issue	Management
		Not a Problem	**Increasing Problem**	**Severe Problem**		
Iron (Fe^{2+} or Fe^{3+}) ppm	Iron is dissolved from underlying rocks & soil. Can be present if low pH water passes through iron pipes or equipment.	< 0.3 ppm	0.3 - 5	> 5	Rust forms in the presence of oxygen (in water or air). If salt present, metal will rust faster. Rust causes reddish-brown staining and/or flake off and clog nozzles, filters, and lines. Iron complexes with organic materials & bacteria causing slimes. If Fe >5 ppm, coatings form on leaf surfaces & may reduce photosynthesis.	Iron treatment depends on the type of problem. Common techniques include: 1- aeration then sediment filtration. 2- sediment filtration then a water softener (caution: these usually use sodium). 3- precipitation with potassium permanganate then sediment filtration. 4- chlorination then sediment & carbon filtration.
Sulfur (S) ppm	Rock & soil containing gypsum, iron sulfides, other sulfur compounds. Industrial wastes, sewage, & from coal mining operations.	< 33 ppm	33 - 66	> 66	If calcium is present, scale can form. As part of salinity, can reduce growth and/or cause plant injury.	Reverse osmosis.
Boron (B) ppm	Naturally occurring in groundwater, & 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 toxic. Plant sensitivity ranges.	Boron leaches quickly from sandy soils, not typically a problem. Will accumulate in fine textured soils & pose a greater toxicity threat to sensitive plants.
Sodium (Na$^+$) ppm	Dissolved from rock, salts, & soil. Human induced concentrations from road salt, fertilizers, industrial brines, & 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.

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Chloride (Cl⁻) ppm	From dissolved minerals, & sea water. Human induced concentrations from road salt, fertilizers, industrial wastes and/or sewage.	< 70 ppm 0	70 – 300 0 - 100∫	> 300 for soil & water ion hazard > 100 for foliar injury†	Mobile in the soil. Cl can be taken up by roots & accumulate in leaves causing toxicity.	Blend or change to an alternative water source. Reverse osmosis.
Nitrate (NO₃⁻-N) ppm	From decaying organic material. Major contributions from fertilizers, sewage, & manure applications.	< 50	50 - 100	> 100	High concentrations: succulent plant growth, tissues not as resource efficient, & plants more susceptible to some pests. Nitrogen-rich runoff can cause eutrophication in receiving waters.	Fertilization amounts & scheduling should account for amount supplied by irrigation water. Reverse osmosis.
Total Dissolved Salts (TDS) ppm	Concentration of mineral salts (ex: MgSO₄, MgCl, CaCl, NaHCO₃, NaCl, KCl) dissolved in water. Refer to electrical conductivity in this table.	< 500	500 - 2000	> 2000	The same as total dissolved solids in clear, non-turbid water. High salinity- salt accumulation in fine textured soils, hard for roots to absorb water. Determine if sodium dominant.	Refer to: Electrical conductivity in this table. Permeability and residual sodium chloride in the next section.
Electrical Conductivity (EC) mmhos/cm	Indicator of presence of mineral salts, which originate from the earth's crust. Salts contribud by: fertilizers, organic matter, & treated wastewater.	0.50 - 0.75	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 HCO₃⁻ & CO₃²⁻.	Management will be dependent on the type and degree of the problem. Refer to water permeability in the next section.

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Component	Origin	Severity			Issue	Management
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pH	Measure of hydrogen ion (H^+) concentration. Logarithmic scale 1-14: 1 = acidic 7 = neutral 14 = alkaline. Water pH fluctuates diurnally & seasonally.	Normal range: 6.5 – 8.0		< 6.0 or > 8.0	Regulates plant nutrient & soil elements availability. Indicates a problem exists, continue to evaluate. Alkaline water: high in CO_3^- and HCO_3^{2-} and/or salinity. pH <5.5 or >8.5 can cause corrosion of pipes & equipment.	Inject an acid or base into the irrigation water.
Bicarbonate (HCO_3^-) meq/L	Dissolution of limestone and dolomite, & from atmospheric carbon dioxide.	< 1.5 <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^{2+} & Mg^{2+} to form insoluble precipitates.	Inject acid into irrigation water to lower the pH.
Carbonate (CO_3^{2-}) meq/L	Refer to bicarbonate (HCO_3^-).	< 0.5 meq/L	0.5 – 1.65	> 1.65	Deposits (milky spots) form when reacting with Ca^{2+} & Mg^{2+} to form insoluble precipitates.	Inject acid into irrigation water to lower the pH.
Sodium Absorption Ration (SAR) or Adjusted Residual Sodium (Adj RNa) meq/L	Sodium hazard measured by comparing the concentration of sodium to that of calcium & magnesium.	<10 meq/L*	10 - 18	> 18	High sodium hazard: 1- sodium is disproportionately abundant. 2- soils may disperse reducing porosity 3- salt crust may reduce infiltration 4- harder for roots to absorb water. Fine textured soils more affected than sandy soils.	Blend or change to an alternative water source. Apply a leaching fraction with every irrigation. Inject S or Ca^{2+} into the water. Reverse osmosis. Disrupt soil surface to break any crusts & for aeration. Incorporate deep drainage.

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Residual Sodium Carbonate (RSC) meq/L	Residual sodium carbonate: another method used to assess Na^+ hazard of irrigation water sources.	<1.25	1.25 – 2.50	> 2.50	Bicarbonates and carbonates: high affinity to form insoluble precipitates with Mg^{2+} & Ca^{2+}. When precipitates form, need excess divalent (2^+) cations available to bind with all CO_3^{2-} & HCO_3^- with enough remaining to aggregate soil particles. If inadequate divalent cations available & irrigation water contains Na, the pool of Mg & Ca is used to satisfy the CO_3^{2-} & 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, & decreased water infiltration.	Blend or change to an alternative water source. Apply a leaching fraction with every irrigation. Inject S or Ca^{2+} into the water. Reverse osmosis. Disrupt soil surface to break any crusts and for aeration. Improve deep drainage.

† for turfgrass
‡ for sensitive ornamental plants
* not for clay soils
∫ ornamental plants exhibit a wide range of tolerance

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 or adj RNa (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. When divalent cations (Ca^{2+} and Mg^{2+}) dominate irrigation water, even with the presence of Na^+, the soil aggregates, forming pores, and water infiltrates.

SAR is best used for irrigation waters that are low in HCO_3^- and CO_3^{2-}, at concentrations of <120 and 15 mg/L, respectively. When HCO_3^- and CO_3^{2-} concentrations are higher (such as >120 and 15 mg/L, respectively), adjusted residual sodium (Adj RNa) is best.

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

SAR or Adj RNa	Water permeability problem	
	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

References

Duncan, Ronny R., Robert N. Carrow, and Michael T. Huck. 2008. Turfgrass and Landscape Irrigation Water Quality: Assessment and Management. CRC Press. Boca Raton.

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