Management of Saline Irrigation Water

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Salinity problems associated with poor quality irrigation water are becoming more prevalent, not only in western states, but across the country as fresh water sources become more scarce. Secondary water sources, such as effluent, are increasingly being used for turfgrass irrigation due to increased urban demand for potable water. Some western states, including Arizona, require the use of effluent for turfgrass irrigation when available.

Salt problems can originate from salty soils, typically found in western states where evaporation exceeds rainfall. But often, good soils become salty, or loose their structure and drainage, by irrigating with low quality water and using incorrect irrigation practices. Managing effluent or other saline irrigation water sources can be a complicated process affected by a number of factors, including the total salinity of the irrigation water, type of saline ions present in the water and soil, soil texture, and turfgrass species and cultivar used (I'll cover the turfgrass factor in a subsequent article).

Water salinity level

Total salinity of water is measured by the electrical conductivity (ECw). You might find total salinity expressed as: decisiemans per meter (dS/m), millimhos per centimeter (mmhos/cm), or micromhos per centimeter (µmhos/cm). The first two units (dS/m and mmhos/cm) are identical: dS/m is the contemporary usage. Micromhos/cm (µmhos/cm) is 1000 times smaller than dS/m.

The other method of reporting salinity is on a concentration basis, in parts per million (ppm) or total dissolved solids (TDSmg/L). These two units are the same: 1 mg of saline ion per liter water is actually 1 part per million. However, water testing labs don't actually measure the concentrations of saline ions to come up with values for ppm or TDS - it's too expensive. Instead, water salinity is measured by conductance (dS/m), and converted to ppm by using a correction factor, typically 640. The problem is that this conversion factor can vary widely (from 400 to 1,000), depending on the various types of ions present in the water. Therefore, dS/m is more exact, while ppm and TDS values are estimates.

Summary of Salinity Units

dS/m = mmhos/cm
µmhos/cm X 1000 = dS/m

and:
ppm = TDSmg/L
ppm X 640 ª dS/m
≠ (approximately!)

The U.S. Salinity Laboratory has classified the salinity hazard of irrigation waters in the table below.

Salinity Level

Units	No Problem	Moderate	Severe Problem
dS/m	<0.75	0.75 -3.0	>3.0
ppm	<480	480 - 1920	>1920

Waters having ECw less than 0.75 dS/m are considered good quality, from 0.75 to 3.0 medium quality, and waters with ECw greater than 3.0 are low quality, and usually not recommended for irrigation without careful management.

Leaching soils

Leaching of salts out of the root zone is critical when using low quality water sources for irrigation. Plants transpire pure water, leaving behind the salts, which accumulate in the soil profile. That's why a soil can gradually become much more saline than the water used to irrigate it. The soil must have adequate permeability to allow for deep leaching (at least 5-6 feet). If water doesn't drain below this depth, subsurface drainage tiles may be necessary to prevent the development of a high water table, which can salinize a soil by capillary rise of drainage water to the soil surface.

The "Leaching Requirement" of a soil is

the excess amount of irrigation water, above what the turfgrass uses as ET (evapotranspiration) that must be applied to flush out excess salinity. The idea is to maintain the soil salinity at a fairly constant, acceptable salinity level. The leaching fraction is the minimum amount of water needed to maintain the soil at a given salinity level. Therefore, it's not a single leaching event, but a continuing process.

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The following formula is used to calculate leaching fraction:

LF (Leaching Fraction) = ECiw ECdw

where ECiw is the EC of the irrigation water, and ECdw is the EC of the drainage water (equal to the EC, or salinity level, which your turfgrass can tolerate).

Here's an example. If you are irrigating an overseeded perennial ryegrass fairway which can tolerate a soil salinity of 4-8 with effluent water having an ECiw of 2, then ECiw = 2, and ECdw = 4-8 (let's use 6), then:

LF = 2/6 = 33%

Your leaching requirement is 33%, meaning that you need to apply 33% more water than what the turf uses [ET + (ET X .33)] in order to maintain the soil salinity at an acceptable level (in this case 6 dS/m).

Maintaining proper ion balance

As long as you can maintain a soil permeability adequate to meet your leaching requirements, you can use fairly salty water to irrigate turfgrass. For example, bermudagrass can tolerate soil salinity of 10 to 16. The problem is that soil structure can be broken down, with subsequent loss of permeability when using salty irrigation water, due to the effects of sodium or carbonates.

When permeability is lost, meeting your prescribed leaching fraction becomes more difficult. Slower drainage results in wet soils, which are susceptible to compaction, and even further reductions in soil permeability - a vicious cycle results. Finally, salt builds up to the point where the turf is damaged or lost.

Why does this happen? The sodium (Na+) ion, a primary component of most saline water, destroys soil structure by dispersing clay and silt particles, which are normally bound together as soil aggregates. However, calcium (Ca2+) and magnesium (Mg2+) ions, due to their high charge densities, counteract the dispersive effects of Na+ on soil particles, thereby maintaining soil structure. The most important factor for maintaining soil structure and good drainage is not just the Na+ content of the water, but the balance of Ca2+ and Mg2+ relative to Na+.

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The ratio of these three ions, which determines the permeability hazard of irrigation water, is expressed as the sodium adsorption ratio (SAR):

SAR = Na _ Ca+Mg/2

In this ratio, ion concentrations are in miliequivalents per liter (meq/L). To convert ppm (often given in soil/water reports) to meq/L, use this formula:

meq/L = ppm ∏ equivalent weight
Equivalent weights are:
Na+ = 23
Ca2+ = 20
Mg2+ = 12.2

According to the U.S. Salinity Laboratory, irrigation water having SAR values greater than 9 may cause permeability problems in finer textured soils. However, coarse soils can tolerate higher levels. Sands, including USGA specification greens, can usually tolerate water with a SAR up to 15 with few problems. Waters with SAR's above 15 are generally not suitable for irrigation without prior treatment.

Sodium is a major component of saline irrigation waters, and therefore many such waters have unfavorable SAR's. To combat this, various soil and water amendments can be used. Gypsum ($CaSO_4$), a Ca^{2+} salt, is incorporated into soils adversely affected by Na^+ (sodic soils). Gypsum reacts with Na^+ to form $NaSO_4$, which is then readily leached out of the soil profile. The free Ca^{2+} can then bind to soil particles, thereby improving soil structure. The reaction of gypsum is:

2 Na—soil + $CaSO_4$ Æ Ca—soil + Na_2SO_4

However, because of gypsum's low solubility, it is usually incorporated into the soil, or in the case of turfgrass, spread over the turf. It is best to do this during a cultivation operation to facilitate incorporation into the soil. The gypsum requirement (GR), in tons per acre, needed to remove soil Na^+ is calculated by: $GR = 1.72 \times Na^+$, where Na^+ is in meq per 100 grams of soil (given in soil analysis reports). For example, if the soil exchangeable Na^+ is measured to be 8 meq/100 g, you would need $8 \times 1.72 = 13.7$, or 7 tons of gypsum per acre to totally neutralize the exchangeable soil Na^+. Gypsum should be applied at approximately 1 ton/acre (ª50 lbs./1000 ft^2), with 2 or 3 applications possible per year.

Sulfur (S) can also be used to remove soil Na^+. First, S reacts oxygen to form sulfuric acid, which then reacts with $CaCO_3$ (calcium carbonate) to form gypsum:

S + O_2 + H_2O Æ H_2SO_4
H_2SO_4 + $CaCO_3$ Æ $CaSO_4$ + CO_2 + H_2O

Gypsum then reacts with soil Na^+, removing it. Sulfur is about 5.6 times more efficient in removing Na^+. In the above example, you would only need $7/5.6 = 1.25$ tons per acre. However, sulfur is about twice as slow as gypsum. Also, you need an alkaline soil, with plenty of $CaCO_3$ present, typical for western soils. Finally, sulfur can burn turf. Sulfur should not be applied to turf above 5 lbs/1000 ft., unless the surface soil is high in free $CaCO_3$.

The acid injection option

Sulfur and gypsum are not soluble, so must be applied to the soil or turf. For this reason, many turf managers are using "acid injection", or injecting sulfuric acid into their irrigation water. The strategy here is to continually inject sulfuric acid into the irrigation water to provide the soil with enough S to prevent a Na buildup in the soil. Sulfuric acid injection cannot rejuvenate a soil that is already sodic (Na^+ affected). Instead, it is a merely a preventive measure. Also note that sulfuric doesn't directly remove Na^+ from the water, it is just providing the soil with S, which binds and removes Na^+ in the soil. However, one added benefit of acid injection is to remove carbonates.

Carbonates (CO_3^-), which are present in some irrigation waters, can cause Na^+ problems indirectly, by precipitating soil Ca^{2+} and Mg^{2+} as limestone or dolomite, thereby shifting the balance in favor of Na^+:

CO_3^- (or HCO_3^-) + Ca^{2+} (or Mg^{2+}) Æ $CaCO_3$ (or $MgCO_3$)

Other management practices, such as encouraging good drainage by installation of subsurface tiles and by periodic core aerification, returning organic matter (in the form of clippings) to the soil, blending poor quality irrigation water with good quality water, and using salt tolerant turfgrasses are important. Managing saline water and soil is complex, and there are no "quick fix" miracle products available. Knowledge of the factors related to soil and water salinity, coupled with good management practices used on a continuing basis are essential for long-term success.

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