WATER QUALITY CHEMISTRY: NEEDS AND INTERPRETATION

Too many individuals assume that water quality issues associated with soluble salts are a problem of arid climatic regions. However, this is far from the truth. For example, salt water intrusion in coastal areas resulting from excessive pumping of fresh water is an increasing problem in high rainfall areas, such as Florida and Gulf coast areas and in the Islands of Hawaii. Even in certain humid continental areas the ground water may contain significant levels of soluble salts, which may be associated with underground rock salt deposits. Thus, it is essential that water quality analysis be obtained whenever a new water source is being considered. In addition, periodic monitoring for potential changes in water quality also should be practiced.

Essentially all irrigation water contains some dissolved mineral salts and chemicals. Some of the soluble salts are nutrients and thus beneficial to turfgrass growth, but others may be phytotoxic. The rate at which salts accumulate to undesirable levels in the soil depends on the concentration of soluble salts in the irrigation water, the amount of irrigation water applied annually, and the physical/chemical characteristics of the soil in question. The major salt problems of concern in water quality are the (a) total concentration of soluble salts, (b) sodium (Na), (c) relative proportion of sodium (Na), carbonate (CO_3), and bicarbonate (HCO_3) to calcium (Ca) and magnesium (Mg), and (d) the amount of chloride (Cl) and boron (B).

Salinity. Most water of acceptable quality for turfgrass irrigation contains from 200 to 800 parts per million (ppm) soluble salts. Soluble salt levels above 2,000 ppm are very undesirable and may be directly injurious to turfgrass. If the soil has exceptional permeability and good subsoil drainage characteristics, and depending on the turfgrass species grown (Table 1), irrigation water with salt levels up to 2,000 ppm may be tolerated. Exceptional permeability and good subsoil drainage permit the turf manager to leach excessive soluble salt concentrations from the root zone by periodic, intense irrigations. The USGA Method of high-sand root zone construction fits these criteria very well.

Table 1. The relative tolerances of 18 turfgrass species to soil salinity.

Sensitive (<3 Ds/M)	Moderately Sensitive (3 to 6 dS/m)	Moderately Tolerant (6 to 10 dS/m)	Tolerant (> 10 dS/m)
annual bluegrass colonial bentgrass Kentucky bluegrass rough bluegrass centipedegrass	annual ryegrass creeping bentgrass fine-leaf fescues bahiagrass	perennial ryegrass tall fescue buffalograss, American zoysiagrasses	alkaligrass bermudagrasses

Adapted from M.A. Harivandi, J.D. Butler and L. Wu 1992. Salinity and turfgrass culture. (In *Turfgrass* D.V. Waddington, R.N. Carrow, and R.C. Shearman (eds.) pp. 207-229. Series No. 32, American Society of Agronomy, Madison, Wisconsin, USA.

The total concentration of soluble salts in the soil and the water also is measured as **electrical conductivity** (EC), which is expressed in units as decisiemens per meter (dSm^{-1}) with dSm^{-1} = milli mhos per centimeter (mmhos cm^{-1}). The general equation used to convert electrical conductivity to parts per million is $1dSm^{-1} = 640$ ppm total salts. This type of soil and water quality information may be obtained by submitting representative samples for analyzes to either a reputable laboratory.

A water EC of 0.70 dSm^{-1} (mmhos cm^{-1}) is the approximate upper limit for growing turfgrasses without potential problems that necessitate costly, specialized adjustments in the cultural program. In contrast, soils having an EC_s analysis below 3 dS m^{-1} are considered satisfactory for growing most turfgrasses. Soils with an EC_s of 3 to 10 dS m^{-1} will restrict the growth of many turfgrass species and cultivars, while readings over 10 dS m^{-1} support only a few salt-tolerant turfgrass species (Table 2).

Table 2. Guidelines for the interpretations of water quality for irrigation.

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		none	slight to moderate	severe
Salinity Ec_w	$dS\ m^{-1}$	<0.7	0.7 to 3.0	>3.0
TDS	$mg\ L^{-1}$	<450	450 to 2,000	>2,000
Soil Water Infiltration (Evaluate using EC_w (dSm^{-1}) and SAR together):				
if SAR = 0 to 3 and EC_w =		>0.7	0.7 to 0.2	<0.2
if SAR = 3 to 6 and EC_w =		1.2	1.2 to 0.3	<0.3
if SAR = 6 to 12 and EC_w =		1.9	1.9 to 0.5	<0.5
if SAR = 12 to 20 and EC_w =		2.9	2.9 to 1.3	<1.3
if SAR = 20 to 40 and Ec_w =		5.0	5.0 to 2.9	<2.9
Specific Ion Toxicity:				
• Sodium (Na):				
• root absorption	SAR	<3	3 to 9	>9
• foliar absorption	$meq\ L^{-1}$	<3	>3	
	$mg\ L^{-1}$	<70	>70	
• Chloride (Cl):				
• root absorption	$meq\ L^{-1}$	<2	2 to 10	>10
	$mg\ L^{-1}$	<70	70 to 355	>355
• foliar absorption	$meq\ L^{-1}$	<3	>3	
	$mg\ L^{-1}$	<100	>100	
• Boron (B)	$mg\ L^{-1}$	<1.0	1.0 to 2.0	>2.0
Miscellaneous Effects:				
• Bicarbonate (HCO_3)	$meq\ L^{-1}$	<1.5	1.5 to 8.5	>8.5
(unsightly foliar deposits)	$mg\ L^{-1}$	<90	90 to 500	>500
• pH		normal range	6.5 to 8.4	
• Residual chlorine	$mg\ L^{-1}$	<1.0	1 to 5	>5

Adapted from D.W. Westcot and R.S. Ayers. 1984. Irrigation water quality criteria. (In G.S. Pettygrove and T. Asand (eds). *Irrigation with reclaimed municipal wastewater - A guidance manual*. Report No 84-1 wr. Calif. State Water Resources Control Board, Sacramento, California, USA). and from D.S. Farnham, et al. 1985. *Water quality: Its effects on ornamental plants*. Univ. of Calif. Coop. Ext. Leaflet 2995. Div. of Agric. Nat. Resources, Oakland, California, USA. by A. Harivandi of the University of California, Hayward, California.

Sodium. The presence of sodium (Na) in irrigation water is of great concern in turfgrass culture (Table 2). The rate at which a soil adsorbs sodium from water is known as the **sodium adsorption ratio** (SAR). This ratio is used for classifying the sodium hazard of water sources. Depending on its soluble salt content, water with an SAR above 6 may produce a sodium buildup in certain soils, unless sulfur (S) or gypsum ($Ca\ SO_4 \bullet 2H_2O$) is applied periodically followed by leaching. The effect of sodium in deflocculation of clay soils is particularly critical on intensively trafficked turfgrass areas because of the decrease in aeration, water infiltration, and soil water percolation.

Bicarbonate. Reduced soil permeability also can occur when a water with high bicarbonate (HCO_3) content is used for irrigation. High levels of bicarbonate facilitate calcium precipitation in the soil, i.e. forming calcium carbonate, which in the presence of sodium may cause a significant reduction in soil permeability. In addition to calcium, magnesium and sodium therefore, water also should be analyzed for its bicarbonate content. A good indicator of a potential negative impact from bicarbonate in irrigation water is the **residual sodium carbonate** (RSC). RSC is calculated in meq/L by the formula : $RSC = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$.

When the RSC is less than 1.25, the bicarbonate will have minimal impact on soil permeability. At RSC levels above 2.5 there is considerable danger of soil impermeability occurring. At RSC values between 1.25 and 2.5, other factors, such as both the water and the soil sodium and salt contents will determine the magnitude of the problem.

Chlorides. Chloride (Cl) in irrigation water contributes to its total soluble salt concentration. Excessive concentrations of chlorides may cause turfgrass tip burn and even total kill of the shoots. Concentrations of 355 ppm and higher are considered undesirable for irrigation of some salt-sensitive grasses (Table 2). Turfgrasses tend to be more tolerant to chlorides than is the case for many landscape plants. Fortunately, chloride salts are quite soluble and thus may be leached from well-drained soils if there is a functioning subsurface drainage system.

Boron. Boron (B) is an essential micronutrient for plant growth, but is required in very minimal amounts. It is water soluble and is found in many water sources used for irrigation. Turfgrasses generally are tolerant of boron, but it may become toxic to non-turfgrass plants if the concentration in the irrigation water exceeds 1 to 2 ppm. An additional problem is soil accumulation, since boron may form chemical complexes that are not readily leached from the soil. Most turfgrasses will grow in soils with boron levels as high as 10 ppm.

Interpreting Water Quality Hazards. The best approach is to arrange for a qualified, independent soil and water quality chemist to analyze and properly interpret the water and soil analysis reports.

Water quality problems should be analyzed and solved on an individual basis after an assessment of all related factors. The concentrations of individual constituents must be known before water quality can be properly evaluated. In the case of sodium as well as of several other salts, the indirect effects on the soil and the direct effects on turfgrass growth must be considered. There also is a question of the combined effects from several salts. For example, high concentrations of both sodium and bicarbonates are especially undesirable. Similarly, it is difficult to set precise limits on the maximum acceptable sodium level because its reaction is influenced by the quantity of calcium and magnesium in the soil, and the salt content of the irrigation water.

In most cases marginal irrigation water can be used for golf course irrigation if practices such as (a) acid or gypsum injection or (b) gypsum, sulfur or other chemical amendments are added to the soil.