'Quality' water for your plants

by W. Lee Berndt, Ph.D.

■ Water quality is vital to turf and landscape plants. Four aspects of water govern its quality:

1) the level of dissolved salts;

2) the level of sodium ion relative to other cations;

3) the level of bicarbonate ion relative to cations; and

4) the level of potentially toxic ions like boron.

Lab testing is needed to judge the quality of a water. A better grasp of the lab terms will give more meaning to the test results.

Salinity and Soluble Salts. Some waters have high levels of dissolved salts. Irrigating with these waters adds salts to the soil. As the salts accumulate, they cause plant stress. For example, salt build-up in soil causes the water in plant cells to flow back into the soil. This is called crenation. It causes the plants to wilt when soil water is adequate. As a result, the plant's energy is diverted away from the normal growth process.

Irrigating with water that is high in sodium may destroy the soil's structure.

Table 1. Classification of irrigation water based on the level of soluble salts (EC), and the ratio of sodium to calcium plus magnesium (SAR). EC is measured in units called micromhos per centimeter (µmhos cm^{-1})*.

Class of Water	Designation	EC (µmhos cm-1)	SAR
C1	Low Salinity	< 250	---
C2	Medium Salinity	251-750	---
C3	High Salinity	751-2,250	---
C4	Very High Salinity	> 2,251	---
S1	Low Sodium	---	< 10
S2	Medium Sodium	---	10.1 - 18
S3	High Sodium	---	18.1 - 26
S4	Very High Sodium	---	> 26

* Many labs give the value of EC in millimhos per centimeter (mmhos cm^{-1}), in desci-siemans per meter (dS m^{-1}), or in siemans per meter (S m^{-1}). 750 µmhos cm^{-1} = 0.750 mmhos cm^{-1} = 0.750 dS m^{-1} = 0.075 S m^{-1}.

The EC (electrical conductivity) of a water is measured to find the level of dissolved salt. The EC of a water varies directly with the salt content. EC is measured in units termed micromhos per centimeter (µmhos cm^{-1}). Water with an EC of less than 750 µmhos cm^{-1} is the most suitable for irrigating turf and landscape plants (see Table 1).

Leaching to Control Salts. Leaching a soil with water will help to prevent the build up of salts. Without leaching, the salts gather in direct proportion to the EC of the water. The LR (leaching requirement) is given by the formula: $LR = EC_{iw} \div EC_{dw}$ where EC_{iw} is the EC of the irrigation water and EC_{dw} is the EC of the drainage water percolating from the bottom of the rootzone. In effect, EC_{dw} is the maximum level of salt the plant of interest can tolerate (see Tables 2 and 3).

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Table 2. Approximate salt tolerance of select grasses and landscape plants.

2,000 µmhos cm^{-1}	3,000 µmhos cm^{-1}	4,000 µmhos cm^{-1}	6,000 µmhos cm^{-1}	8,000 µmhos cm^{-1}	> 8,000 µmhos cm^{-1}
Star Jasmine	Pineapple Guava	Kentucky Bluegrass	Glossy Privet	Tall Fescue	Creeping Bentgrass
Oregon Grape	Chinese Holly	Colonial Bentgrass	Yellow Sage	Perennial Ryegrass	Bermudagrass
Photinia	Rose, cv. Grenoble	Red Fescue	Orchid Tree	Chewings Fescue	Zoysiagrass
Pyrenees Cotoneaster	Glossy Abelia	Annual Bluegrass	Southern Magnolia	Blue Gramma	St. Augustinegrass
	Southern Yew	Centipedegrass	Japanese Boxwood	Orchardgrass	Western Wheatgrass
	TulipTree	Meadow Fescue	Indian Hawthorne	Smoothe Brome	Tall Wheatgrass
		Heavenly Bamboo	Spreading Juniper	Weeping Bottlebrush	Alkaligrass**
		Laurustinus	Thorny Elaeagnus	Oleander	Seashore Paspalum**
		Algerian Ivy	Pyracantha	European Fan Palm	Natal Plum
		Chinese Hibiscus	Cherry Plum	Blue Dracaena	Evergreen Pear
		Strawberry Tree	Japanese Black Pine	Spindle Tree	Bougainvillea
		Crape Myrtle	Oriental Arborvitae	Rosemary	Stone Pine
			Xylosma	Aleppo Pine	Ceniza
				Sweet Gum	Brush Cherry
					White Iceplant*

* > 10,000 µmhos cm^{-1}
** > 16,000 µmhos cm^{-1}

Table 3. Leaching requirement (LR) as related to the electrical conductivity (EC) of irrigation water and plant salt tolerance.

EC of Irrigation Water (µmhos cm-1)	Maximum Plant Salt Tolerance 4,000 µmhos cm-1	8,000 µmhos cm-1	12,000 µmhos cm-1
	Extra Leaching Fraction Required (%)		
100	2.5	1.2	0.8
250	6.2	3.1	2.1
750	18.8	9.4	6.2
2,250	56.2	28.1	18.8
5,000	---	62.5	41.7

Example: Assume the plant has a maximum salt tolerance of 4,000 µmhos cm^{-1}, and assume that the EC of the water utilized for irrigation is measured at 2,250 µmhos cm^{-1}. An extra 56.2% more water would need to be applied with each irrigation to continiously leach salts from the rootzone. $LR = EC_{iw} \div EC_{dw}$ where EC_{iw} = EC of the irrigation water to be applied, and EC_{dw} is basically the salt tolerance of the plant of interest.

Table 4. Background information on ions with regard to the quality of irrigation water for turfgrasses.

Ion	Name	mg meq^{-1}	meq mg^{-1}	Acceptable Level for Irrigation Water
Na^+	sodium	22.98	0.0435	SAR of 9-10 or less; SAR_{adj} of 3-6 or less; less than 70 ppm or 3 meq L^{-1}
K^+	potassium	39.10	0.0256	
Mg^{2+}	magnesium	12.16	0.0823	
Ca^{2+}	calcium	20.04	0.0499	
Ni^{2+}	nickel	29.35	0.0340	less than 0.5 ppm or 0.02 meq L^{-1}
Cu^{2+}	copper	31.77	0.0318	less than 2 ppm or 0.06 meq L^{-1}
Zn^{2+}	zinc	32.69	0.0306	less than 5 ppm or 0.15 meq L^{-1}
Cd^{2+}	cadmium	56.20	0.0178	less than 0.005 ppm or 9.0 x 10^{-5} meq L^{-1}
B^{3+}	boron	3.60	0.2778	less than 1-2 ppm or 0.2-0.6 meq L^{-1}
Cl^-	chloride	35.45	0.0282	less than 250 ppm or 7 meq L^{-1}
HCO_3^-	bicarbonate	61.02	0.0164	RSC of less than 1.25; less than 120-180 ppm or 2-3 meq L^{-1}
NO_3^-	nitrate	62.00	0.0161	
CO_3^{2-}	carbonate	30.01	0.0333	
SO_4^{2-}	sulfate	48.03	0.0208	less than 250 ppm or 5.2 meq L^{-1}
PO_4^{3-}	phosphate	31.66	0.0316	

ppm = parts per million = milligrams substance per liter of water (mg L^{-1})
meq = number of milliequivalents of a substance
meq L^{-1} = number of milliequivalents of substance per liter of water
meq mg^{-1} = number of milliequivalents of substance per milligram of substance
mg meq^{-1} = number of milligrams substance per milliequivalent of substance
(ppm)(meq mg^{-1}) = meq L^{-1}
(example: 70 ppm sodium x 0.0435 meq mg^{-1} = 3 meq L^{-1})

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Sodium Ion and the Sodium Hazard. Irrigating with water high in sodium (Na^+) may destroy the soil's structure. As the Na^+ is added to the soil, it adsorbs to the exchange sites.

If Na^+ becomes the dominant cation on the exchange sites, the soil particles tend to repel each other. This is termed dispersion. When a dispersed soil is dried it forms a hard crust. Dispersion hinders the drainage that is vital to plant growth.

Ions in a water can affect plants–even be toxic to them.

The levels of Na^+ and other ions in a water are measured in a variety of ways. The levels are given in units called meq L^{-1} (milliequivalents per liter) or in units called ppm (parts per million) (see Table 4). Once the levels of Na^+, calcium (Ca^{2+}), and magnesium (Mg^{2+}) are known an SAR (sodium adsorption ratio) can be calculated for a water:

$$SAR = \frac{Ma^{2+}}{\sqrt{(Ca^{2+} + Mg^{2+}) \div 2}}$$

The SAR is a term that expresses the relative Na^+ hazard of a water. It is a ratio of the level of Na^+ to the levels of the other major cations. Water that has an SAR value of less than 9-10 is the most suitable for irrigating turf and landscape plants (see Table 1). SAR values greater than 9-10 imply that Na^+ levels are excessive.

Bicarbonate Hazard. Irrigating with a water that has a high level of bicarbonate (HCO_{3-}) may also destroy the structure of the soil. When HCO_{3-} is present in a water it can react with the Ca^{2+} and Mg^{2+} to form carbonate salts. This reaction increases the proportion of Na^+.

The bicarbonate hazard of a water is given by the term RSC (residual sodium carbonate). Once the levels of HCO_{3-} and CO_3^{2-} are known the RSC can be calculated: $RSC=(HCO_{3-}+CO_3^{2+})—(Ca^{2+} + Mg^{2+})$

A water with an RSC of less than 1.25 is safe. A water with an RSC of greater than 2.5 has a high HCO_{3-} hazard. An adjusted value of SAR will also reflect the HCO_{3-} hazard of a water: SAR adj+SAR [1+(8.4—pHc)] where pHc is a calculated value (see Table 5). Water with an SAR_{adj} of less than 6 is safe while water with a value greater than 9 may pose severe problems regarding HCO_{3-}.

Toxic Elements. Certain ions that are present in a water can be directly toxic to plants. Ions in a water that may be toxic to plants include Na^+, Cl^- (chloride), and B^{3+} (boron). Boron is needed for normal growth in very small quantities. Injury can occur to plants if that level is exceeded. Boron can injure lemon trees and American elms when levels in soil water are 0.5 ppm (see Table 6).

Summary. Ions that are in a water will affect the health and vigor of landscape plants. High levels of dissolved salts cause plant stress while high levels of Na^+ and HCO_{3-} affect soil structure. Other ions like B^{3+} can be directly toxic to plants. Routinely test a water that is used to care for plants. The results of water testing can make a difference in your plant care practices.

Table 5. Data necessary to calculate pHc and SAR_{adj}.

Total meq L^{-1}	$pK_2 - pK_c$	pCa^{2+}	$pHCO_3^-$
0.1	---	4.30	4.00
0.5	2.11	3.60	3.30
1	2.13	3.30	3.00
2	2.16	3.00	2.70
4	2.20	2.70	2.40
6	2.23	2.52	2.22
8	2.25	2.40	2.10
10	2.27	2.30	2.00
15	2.32	2.12	1.82
20	2.35	2.00	1.70
25	2.38	1.90	1.60
30	2.40	1.82	1.52
35	2.42	1.76	1.46
40	2.44	1.70	1.40
50	2.47	1.60	1.30

Sample calculation: assume water contains 2.0 meq Ca^{2+} per liter, 1.0 meq Mg^{2+} per liter, 3.0 meq Na^+ per liter, and 5.0 meq HCO_3^- per liter. The total cation concentration is 6 meq per liter. Therefore, $pK_2 - pK_c = 2.23$. The value of pCa^{2+} at 2 meq per liter equals 3.00 and the value of $pHCO_3^-$ at 5.0 meq per liter equals 2.31. The pHc is the sum of these values, or 7.54. The SAR = 2.45. The $SAR_{adj} = 2.45[1+(8.4 - pHc)] = 4.56$.

Table 6. Approximate boron tolerance limits of select grasses and landscape plants.

Sensitive < 0.5 ppm	Sensitive 0.5-1.0 ppm	Semi-sensitive 1.0-2.0 ppm	Semi-tolerant 2.0-4.0 ppm
Oregon Grape	Persimmon	Gladiolus	Bottlebrush
Photinia	Grapefruit	Olive	Date Palm
Xylosma	Avacado	Sweetpea	Carnation
Thorny Elaeagnus	Cherry	Blue Dracaena	California Poppy
Laurustinus	English Walnut	Sunflower	Japanese Boxwood
Wax-leaf Privit	Apple	Marigold	Oleander
Pineapple Guava	Zinnia	Poinsettia	Chinese Hibiscus
Spindle Tree	Pansy	China Aster	Sweetpea
Chinese Holly	Violet	Gardenia	Kentucky Bluegrass
Juniper	Larkspur	Southern Yew	
American Elm	Glossy Abelia	Brush Cherry	**Tolerant**
Yellow Sage	Geranium	Ceniza	**4.0-8.0 ppm**
Lemon	Rosemary	Blue Dracaena	Indian Hawthorne
Blackberry	Orange		Natal Plum
			Oxalis
			Purple Vetch

SOIL: the source of turf life

The savvy landscape manager knows soil is a medium to support ornamental plant life, a vital component of the ecosystem.

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■ To some, it's nothing more than "dirt" that sticks to their shoes when wet. Others think of soil as something to be swept away and discarded or covered. An engineer may view soil as something to be moved during a construction project.

Good, healthy soil is a dynamic living system with many biological, chemical and physical properties. In landscape soils, one of the most important properties that affects plant growth and vigor is aeration.

Aeration is a measure of the rate at which oxygen is able to move through the soil to the plant roots.

Oxygen movement depends on the soil water content. A well aerated soil is composed of about 50 percent solids, 25 percent water and 25 percent air spaces or voids (Fig. 1). Soils which have less than 25 percent air spaces are considered compacted and limit root growth to some degree.

Compaction can be caused by foot and vehicle traffic, soil texture and maintenance procedures conducted on the site such as irrigation, fertilization and mowing. Heavily trafficked areas are subject to compaction, and the turfgrass growing in compacted sites usually becomes thin and non-vigorous (Fig. 2).

Soils most likely to be compacted are those with a heavy clay content. The percentage of clay, sand and silt in a given soil combine to form the soil's texture. A soil testing laboratory can make the most accurate assessment of a soil's texture. Once the percentage of each component is calculated, soil texture is determined by using a textural triangle (Fig. 3). The

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