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PLANT MATERIALS TECHNICAL NOTE

DETERMINING THE SUITABILITY OF SALT-AFFECTED WATER AND SOIL FOR TREE AND SHRUB PLANTINGS

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INTRODUCTION

The usefulness or suitability of a water source for irrigating trees and shrubs is typically described in terms of one or more "quality" criteria. Water quality is not an absolute term, and depends on the specific use for which the water is intended. Determining suitability typically involves comparing analytical results to published water quality criteria and studies applicable to the intended use. Interpreting water quality data and then predicting the suitability of that water for irrigating tree and shrub plantings is difficult, especially given the potentially long life span of woody plants. Water, soil, and plant interactions are complex, varying with the specific crop, soil characteristics, local climate, and management practices. Although it is relatively easy to classify irrigation water as "suitable" or "non-suitable" for most crops on a specific soil, suitability becomes more subjective when predicting the effect of marginal quality irrigation water on undefined soils. **In order to make meaningful water quality interpretations, it is necessary to consider both water and soil quality factors simultaneously.** Land managers must often rely on local experience and anecdotal information when making water suitability decisions. When using marginal quality water it may be necessary to initiate corrective actions before planting, as well as monitor plant health and/or apply additional management practices over time. This technical note describes tests, standards, and interpretations for determining irrigation water quality for tree and shrub plantings in the context of soil quality. The focus of this technical note is salt-affected water and soils since these conditions frequently limit woody plant survival and growth in the northern Great Plains and Intermountain West. The term "salts" may be broadly interpreted. For our purposes, we will define salts as chemical compounds dissolved in water to form ionic solutions, e.g., sodium chloride, calcium sulfate, and potassium nitrate.

For a list of analytical services, access *Soil, Plant and Water Analytical Laboratories for Montana Agriculture* at: http://www.montana.edu/wwwpb/pubs/eb150.pdf.

IRRIGATION WATER QUALITY

In many parts of the arid and semi-arid West, it is necessary to provide supplemental water to trees and shrubs to enhance their survival and growth. The quality or characteristics of this water can dramatically influence plant survival and growth. High concentrations of dissolved salts in irrigation water and soil are common and frequently injurious to woody plants. Listed below are tests and standards for determining the suitability of a water source for irrigating tree and shrub plantings. For examples of analytical reports and their interpretation, see *Testing and Interpreting Salt-Affected Water for Tree and Shrub Plantings*, Plant Materials Technical Note, MT-61 at: http://www.mt.nrcs.usda.gov/technical/ecs/plants/technotes/.

IRRIGATION WATER TESTING

Ground and surface water to be used for irrigation should be sampled before application and analyzed to determine its suitability for tree and shrub irrigation. Additionally, water quality should be tested over the course of the irrigation season. Water quality testing should include the following parameters: salinity (Electrical Conductivity [EC_w]) or Total Dissolved Salts [TDS], sodicity (Sodium Absorption Ratio [SAR] and perhaps Soluble Sodium Percent [SSP_w]), specific ion toxicity (particularly sodium [Na^+], chlorides [Cl^-] and boron [B]), pH, and alkalinity (carbonates (CO_3^{--}) and bi-carbonates (HCO_3^-) as measured by Residual Sodium Carbonate [RSC_w]). TABLE 1 lists common tests for salt-affected water and unit measures.

TABLE 1. Common Analytical Tests, Units, and Potentially Use-Restrictions for Water to be Used for Irrigating Tree and Shrub Plantings[1]

Potential Irrigation Problem			Units	Degree of Restriction on Use		
				None	**Slight to Moderate**	**Severe**
SALINITY (affects crop water availability)[2]	**EC_w** or		dS/m	<0.7	0.7 - 3.0	>3.0
	TDS		mg/l	<450	450-2000	>2000
INFILTRATION (affects <u>infiltration rate</u> of water into the soil based on SAR_w and EC_w together)[3]	If the **SAR_w** = 0 - 3 and the **EC_w** in dS/m =			>0.7	0.7 - 0.2	<0.2
	If the **SAR_w** = 3 - 6 and the **EC_w** in dS/m =			>1.2 [4]	1.2 - 0.3	<0.3
	If the **SAR_w** = 6 - 12 and the **EC_w** in dS/m =			>1.9 [4]	1.9 - 0.5	<0.5
	If the **SAR_w** = 12 - 20 and the **EC_w** in dS/m =			>2.9 [4]	2.9 - 1.3	<1.3
	If the **SAR_w** = 20 - 40 and the **EC_w** in dS/m =			>5.0 [4]	5.0 - 2.9	<2.9
SPECIFIC ION TOXICITY (affects sensitive crops)	**Sodium (Na)**[5]	surface irrigation (SAR)		<3	3 - 9	>9
		sprinkler irrigation	meq/l	<3	>3	
		sprinkler irrigation	mg/l	<69	>69	
	Chloride (Cl)[5]	surface irrigation	meq/l	<4	4 - 10	>10
		sprinkler irrigation	meq/l	<3	>3	
		sprinkler irrigation	mg/l	<106	>106	
	Boron (B)		mg/l	<0.7	0.7 - 2.0[7]	>2.0[7]
MISCELLANEOUS EFFECTS (affects susceptible crops)	**Nitrogen ($N0_3$-N)**[6]		mg/l	<5	5 - 30	>30
	Carbonates ($HC0_3$ and CO_3)	(overhead sprinkling only)	meq/l	<1.5	1.5 - 8.5	>8.5
		(overhead sprinkling only)	mg/l	<92	92 - 519	>519
	Residual Sodium Carbonate (RSC) (affects infiltration rate of water)		meq/l	<1.25	1.25 - 2.5	>2.5
	pH			**Normal Range 6.5 - 8.4**		

[1]Adapted from University of California Committee of Consultants 1974, and Ayers and Westcot, 1994 (modified).

[2]EC_w means electrical conductivity measured in deciSiemens per meter (dS/m) at 25°C or millimhos per centimeter (mmhos/cm). Units are equivalent. EC varies with temperature. EC standardized to 25°C is often referred to as Specific Conductance (SC).

[3]SAR means sodium adsorption rate. Evaluate potential infiltration problems by SAR as modified by EC_w based on Rhoades 1977, and Oster and Schroer 1979.

[4]Although the "degree of restriction of use" some combinations of water SAR and EC are listed as "none" and "slight to moderate" <u>relative to soil infiltration</u>, EC_w values above 0.7 dS/m may result in a buildup of soil salinity over time. EC_w values of 1 dS/m or greater will likely require management practices to prevent salt accumulation, and EC_w values greater than ~2 dS/m should be used only for short durations, especially on heavy textured soils.

[5]Most woody plants are sensitive to sodium and chloride applied via surface irrigation. With overhead sprinklers and low humidity (<30%), sodium and chloride may be absorbed through the leaves of sensitive crops.

[6]NO_3-N means nitrate nitrogen reported in terms of elemental nitrogen (NH_4-N and Organic-N should be included when wastewater is being tested.

[7]Value amended, based on Montana Irrigation Manual values.

Degrees of restriction severity are somewhat arbitrary as changes occur gradually. All use restrictions in TABLE 1 are guideline values; the user should allow 10 to 20 percent variation above or below a guideline value when making interpretations. The restrictions on use in

TABLE 1 are based on several assumptions including; soil texture ranging from sandy-loam to clay-loam with good internal drainage; low rainfall; no shallow water table; normal irrigation methods are used relative to the delivery, frequency, amount, and leaching fraction; water use by the crop; and salt distribution within the soil profile (see *Water Quality for Agriculture* (in References) for more information). In TABLE 1, the degree of restriction on use "none" indicates full production capability without special management practices. "Slight to moderate" restrictions indicate that species choice may be limited and/or specialized management will probably be necessary to achieve full production. "Severe" restriction on use indicates an increasing need for specialized management, although it does not necessarily indicate a complete lack of suitability for use.

Sprinkler versus Surface Applied Irrigation Water. Water quality use restrictions may be more limiting when irrigation water is applied by sprinkler systems (see TABLE 1) rather than by surface irrigation methods. Acceptable concentrations of specific ions in surface applied irrigation water may cause plant injury when applied directly to foliage. Frequent, low volume applications of salty water can, however, result in salt accumulation in the root zone, especially on heavy-textured (clay) soils. Potentially damaging ions include Na^+, Cl^-, and HCO_3^- and CO_3^{--}. It is important to note that tests results may be reported in various units of measure. APPENDIX 1 lists unit conversion factors that may be useful when interpreting water quality. Total salinity measurements are based on the following relationships:

[1 dS/m = 0.1 S/m = 1000 µS/cm =1 mmhos/cm = 1000 µmhos/cm] (Camberato 2001)

Water Na^+ hazard is expressed as either the SAR_w (no units) or as percentage Na^+, so it is not included in Appendix 1.

1. **Irrigation Water Salinity.** Salinity is an indicator of the total amount of soluble ions (salt) in solution in a given water sample. High soil water salinity can cause a "physiological drought" for plants by creating osmotic potentials so high that roots cannot extract soil water even though the soil appears moist or even saturated. Salinity tests indicate the total salt level in the water sample, but will not identify which salts or ions comprise that salinity. Salinity is be measured <u>indirectly</u> by an Electrical Conductivity (EC_w) test using an electric current to determine the amount of salts in solution. EC_w is reported in various units, including deciSiemens per meter (dS/m), Siemens per meter (S/m), microSiemens per centimeter (µS/cm), millimhos per centimeter (mmhos/cm), or micromhos per centimeter (µmhos/cm). Salinity is also measured <u>directly</u> via a Total Dissolved Solids (TDS_w) test, and are reported in milligrams/l (mg/l) or parts per million (ppm). **As a result, it is easy to mistakenly compare different units of measure when referencing tables of standards or limits. Only compare identical or equal units of measure.** You can convert EC_w readings (in mmhos/cm or dS/m) to TDS (mg/l or ppm) by multiplying the EC_w value by 640. This conversion is an approximation; the conversion factor actually varies between 550 and 800 depending on the EC_w value (see TABLE 1 for potential water use restrictions as a function of irrigation water salinity). The tolerable level of irrigation water salinity also varies with soil texture, with plants growing on coarse-textured or "light" soils (sands/loamy sands) tolerating more water salinity than plants growing on fine- textured or "heavy" soils (clay/sandy clay/silty clay) (see the *Montana Irrigation Manual* or *Irrigation Water Quality for Montana* (1983) MT 198373A [in References] for more information).

NOTE: Using water with an EC_w as low as 1 dS/m can result in unacceptably high soil salinity levels with long-term, repeated use. As water evaporates or is used by plants, the salts from the water, as well as the soil, precipitate in the profile and can become concentrated over time if not leached. Consider tree and shrub salinity tolerance, as well as anticipated management practices, when designing irrigation systems and schedules with marginal quality water.

As irrigation water quality values approach "severe", it is suggested that small scale trials be conducted to determine plant response before initiating attempts at large scale production.

2. **Irrigation Water Sodicity (Sodium).** The concentration of Na^+ in the source water is an important factor in the evaluation of irrigation water suitability because Na^+ strongly influences water infiltration and soil aeration. High irrigation water Na^+ tends to reduce soil aeration, a critical tree and shrub survival parameter, by causing clays and organic matter to disperse. This dispersal reduces soil structure and clogs soil pores, thereby reducing soil aeration and water infiltration. This condition is exacerbated on soils low in Ca^{++} and magnesium Mg^{++}. The Sodium Adsorption Ratio (SAR_w) indicates the amount of Na^+ in a water (or soil) sample relative to Ca^{++} and Mg^{++}.

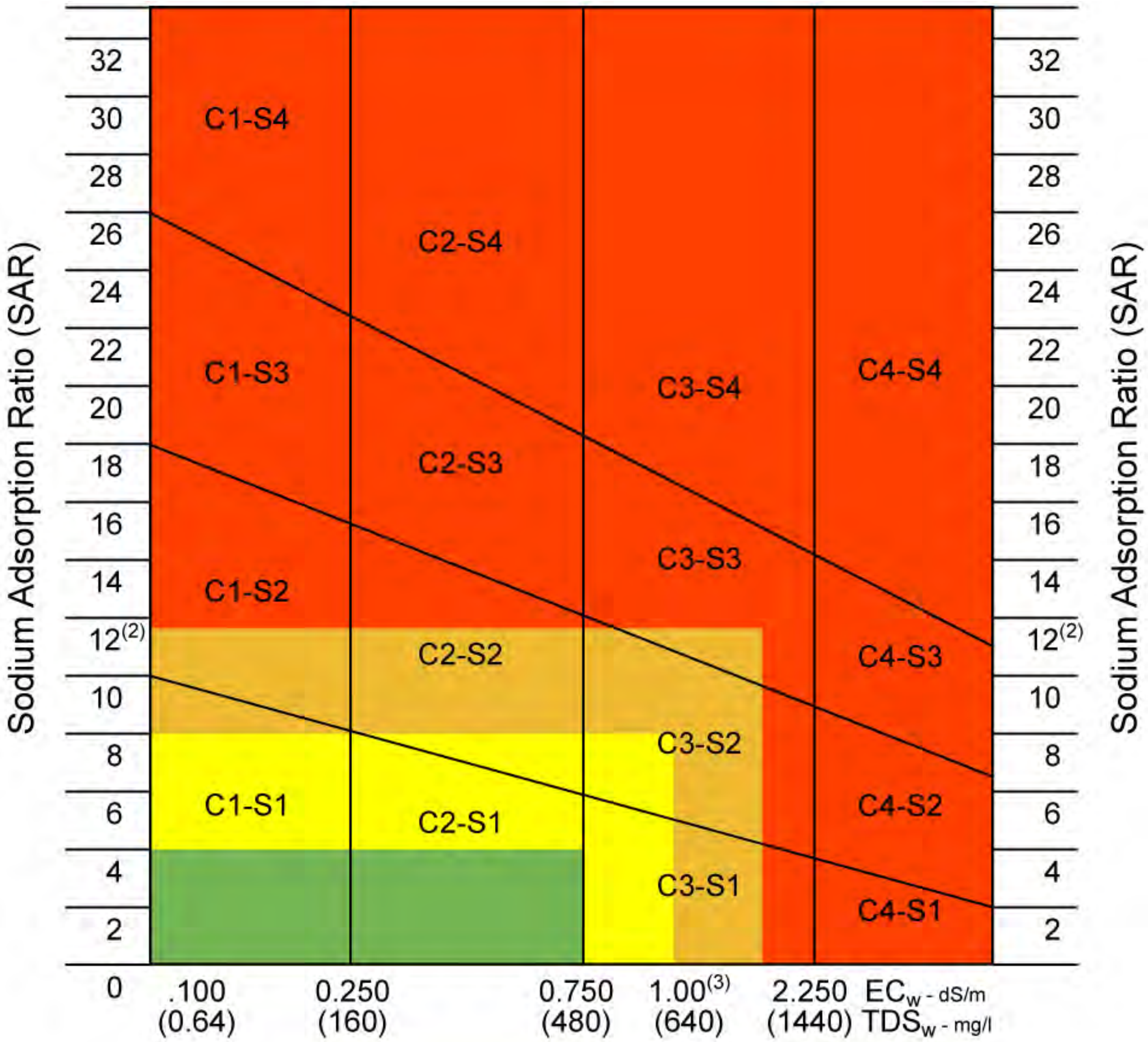
a. **Sodium Adsorption Ratio (SAR_w)** – SAR_w calculates the ratio of Na^+ in solution relative to Ca^{++} and Mg^{++} ions and is expressed by the equation:

$$SAR_w = \frac{Na^+}{\sqrt{\frac{(Ca^{++} + Mg^{++})}{2}}}$$

where Na^+, Ca^{++}, and Mg^{++} are expressed in milliequivalents per liter (meq/l) or millimoles per liter (mmol/l). Equivalent weights are calculated by taking the atomic weight of an ion and dividing it by the charge value of that ion. APPENDIX 2 lists specific ions, their charge (valence), atomic weight, and equivalent weight. Similarly, the concentration of an ion is milligrams per liter (mg/l) or parts per million (ppm) can be converted to milliequivalents per liter (meq/l) by dividing the mg/l or ppm value by the equivalent weights (the atomic weight of the ion divided by its charge). See APPENDIX 3 for multiplication factors for converting between meq/l and ppm for the major salt ions.

It should be noted that when irrigation water contains a significant amount of bicarbonate, the Adjusted Sodium Adsorption Ratio (SAR_{adj}) is used. See *Saline and Sodic Soils in Montana* (1982) 2B1272 (in References) or the *Montana Irrigation Manual* for more information. It is important to note the relationship between SAR_w and EC_w as an indicator of irrigation water quality through their effect on water infiltration. Although it seems counter intuitive, for a given SAR_w, water infiltration tends to be better as the EC_w increases (see TABLE 1). **Although infiltration may be acceptable when SAR and EC_w values are both high, high salinity may inhibit plant growth. Furthermore, it is relatively rare in Montana to have reduced infiltration when both the SAR_w and EC_w are low.** CHART 1 depicts the interaction of irrigation water salinity and Na^+ hazards on potential usefulness for woody plant irrigation. As a rule of thumb, if the SAR is >10 times the EC_w, poor infiltration is likely to occur (see APPENDIX 4 for explanations of the classification system). To use the chart, locate your water EC_w or TDS_w on the horizontal (X) axis. Then find your water SAR_w on the vertical (Y) axis. Draw imaginary lines perpendicular from each axis value. The point where the two lines meet identifies the use category. Suitability depends on irrigation water management, soil type, and plant species selection.

CHART 1. Potential Use Restrictions Based on the Relationship between Water SAR_w and EC_w as They Affect Soil Infiltration and Potential Salinity Buildup over Time When Surface Applied. [1]

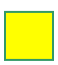


[1]Based on USDA Agriculture Handbook 60, (modified).

[2]SAR >12 require EC_w values for acceptable infiltration so high that they would create a salinity hazard.

[3]Increasing long-term salinity buildup risk above ~1 dS/m; serious risk above 2 dS/m.

Water salinity levels generally acceptable for all trees and shrubs. Sodium may increase over time in the soil to an injurious level for some sensitive species, especially on poorly drained, heavy textured soils.



Water salinity in C3 category acceptable on well-drained soils but problematic on clays. May eventually lead to a soil salinity buildup that could be injurious to woody plants. S2 category sodium levels could pose a hazard on fine-textured soils. Using saline and sodium tolerant species is recommended in C3 and S2 categories.

Salinity and sodicity levels too high for all but the most salt and sodium tolerant species even when special management is applied. Water treatment and specialized management needed in most cases.

Unsuitable for trees and shrubs without treatment.

b. **Soluble Sodium Percentage (SSP)** – SSP is another measure of irrigation water Na^+ hazard. SSP is the ratio of Na^+ in epm (equivalents per million) in water to the total cation epm multiplied by 100. Irrigation water with an SSP greater than 60% may result in Na^+ accumulation and possibly a deterioration of soil structure, infiltration, and aeration.

3. **Toxicity from Specific Ions in Irrigation Water.** Certain ions alone, either because of their direct toxicity to plants or through their effect on water and soil chemistry, can be indicators of irrigation water quality. Substances sometimes found in concentrations in water that are toxic to trees and shrubs include Na^+, Cl^-, and B. Use the values in TABLE 1 as approximate guidelines for determining potential use limitations.

4. **Irrigation Water Carbonate Level.** Bicarbonates (HCO_3^-) and carbonates (CO_3^{--}) in high pH irrigation water can worsen the soil Na^+ hazard by causing Ca^{++} and Mg^{++} to precipitate, thereby becoming unavailable to counteract the negative effects of Na^+. Irrigation water carbonates (both HCO_3^- and CO_3^{--}) is measured by two methods. The first method directly measures the total carbonate level, and is used when irrigation water Ca^{++} and Mg^{++} are low. Problems with calcium carbonate ($CaCO_3$) precipitation begin at approximately 1.5 meq/l and are considered severe above 8.5 meq/l. When water concentrations of Ca^{++} and Mg^{++} are high, the second method, Residual Sodium Carbonate equation (RSC), is used. High levels of Ca^{++} and Mg^{++} can offset the negative effects of high carbonates on water infiltration (see TABLE 1). Over time, the repeated use of irrigation water with a high RSC value can lead to soil alkalinity or create a sodic soil if the water contains an appreciable amount of Na^+ (SAR > ~4). If RSC values are high (> ~2) while SAR_w values are low (< ~4), it is unlikely that infiltration problems will occur, although soil pH is still likely to rise to a detrimental level. As a general rule, RSC values less than or equal to 1.25 meq/l are safe for irrigation; 1.25 to 2.5 are marginal; and greater than 2.5 are unsuitable.

5. **Irrigation Water pH.** Irrigation water pH, in conjunction with soil pH, has its primary effect on plant survival and growth via the availability of essential plant nutrients, although it also influences many physical and biological properties of soil. As alkaline irrigation water raises the soil pH, the availability of certain micronutrients, particularly iron (Fe) and manganese (Mn), is reduced. Inter-veinal chlorosis is a common symptom of Fe deficiency and many species of woody plants are susceptible to low plant-available Fe including Amur maple (*Acer ginnala*), members of the mountain ash genus (*Sorbus* sp.), quaking aspen (*Populus tremuloides*), members of the spirea genus (*Spiraea*), and other species found growing naturally on lower pH (acidic) soils. Irrigation water pH within the 6.5 to 8.4 range is considered acceptable for most plants. Reducing high soil pH caused by application of high pH water is typically accomplished by applying acidifying fertilizers to the soil, often in conjunction with supplemental chelated Fe and Mn if inter-veinal chlorosis is noted.

SOIL QUALITY

Essentially the same parameters used to describe water quality are used to assess soil quality including salinity level, Na^+ concentration relative to other ions, specific ion concentration or toxicity, and miscellaneous effects. In many cases water and soil quality analyses are the same, although acceptable use limits and potential hazards for each may vary. In order for water quality interpretations to be meaningful for a given plant species and management strategy, it will be necessary to have soil quality data for the site in question. For examples of analytical reports and their interpretation, see *Testing and Interpreting Salt-Affected Soil for Tree and Shrub Plantings*, Plant Materials Technical Note, MT-60 at: http://www.mt.nrcs.usda.gov/technical/ecs/plants/technotes/.

When total soluble salts, Na^+ levels and ratios, or specific ion levels are in question, either in irrigation water or in soil, soil testing should include all of the following tests:

1. **Soil Salinity** – Soil salinity, like irrigation water salinity, is measured by the Electrical Conductivity (EC) test. The EC may be measured by the saturated paste extract or soil:water dilution methods. Although the two tests produce results expressed by the same units of measure, the values are <u>not</u> comparable. Soils are classified into five categories based on the concentration of ions present in a representative sample as measured by EC (see TABLE 2). Calcium (Ca^{++}), magnesium (Mg^{++}), and Na^+ are the most common ionic salt components found in Montana soils.

TABLE 2. Soil Salinity Classes and EC Values Based on Saturated Paste Versus 1:2 Dilution Methods

Salinity Class	EC by Saturated Paste dS/m or mmhos/cm	~EC 1:2 Dilution Method For Clay Loam Soils	Potential Tree and Shrub Use Restrictions
Non-Saline	<2	0.15 - 0.25	none
Very Slightly Saline	2 to <4	> 0.25 - 0.30	limited
Slightly Saline	4 to <8	> 0.30 - 0.50	moderate to severe
Moderately Saline	8 to <16	> 0.50 - 1.00	severe
Strongly Saline	≥16	> 1.00	extremely high

Actual quantitative field testing of woody plant soil salinity tolerance is limited. Most woody plants adapted to climatic conditions in the northern Great Plains and Intermountain West survive and grow well on non-saline to very slightly saline soils. The number of woody species that will reach their full growth potential on soils with ECs ≥8 dS/m is very limited. A number of species will survive but grow at a reduced rate and vigor on soils with ECs between 6 and 10 dS/m. For approximations of tree and shrub soil salinity tolerances, see HortNote No. 6, *Selecting Plant Species for Salt-Affected Soils* at:
http://www.mt.nrcs.usda.gov/technical/ecs/plants/pmpubs/index.html#hortnotes. Also, see Montana Field Office Technical Guide (eFOTG), Section II, Windbreak Interpretations, Conservation Tree/Shrub Suitability Groups (CTSG), for a list of tree and shrub species adapted to salt-affected soils (see References).

The effect of irrigation water on soil salinity varies widely based on the water salinity level, concentration and ratio of the specific ions involved, method of irrigation, soil drainage properties, duration and frequency of irrigation, and other management factors. The long-term maintenance of soil salinity at or below a given level often requires using irrigation water significantly lower in salinity than the soil. As we approach irrigation water salinity levels comparable to the soil, additional management practices such as leaching, improved soil drainage, and other techniques will be needed. As noted earlier, leaching with salt-affected water will benefit a well-drained soil more than a poorly drained soil.

NOTE: There are multiple methods of measuring soil salinity. The values produced by various techniques may not be compatible, even when the units are identical. As an example, both the saturated paste and soil:water dilution ratio techniques report results as an EC value, even though the two values are not comparable. Additionally, field and laboratory equipment may need to be calibrated before a meaningful soil salinity value is produced. Always verify that soil salinity data has been presented as a saturated paste EC or TDS value before interpreting the results.

2. **Soil Sodium Levels.** As with irrigation water, the amount of Na^+ in the soil is an important factor in determining its suitability for supporting trees and shrubs because Na^+ strongly influences water infiltration and soil aeration.

a. **Soil Sodium Adsorption Ratio** – Like irrigation water, soil Na^+ is best described by the SAR, an indication of the amount of extractable Na^+ relative to Ca^{++} and Mg^{++}. Soil SAR indicates the likelihood of reduced soil permeability (water infiltration) and aeration, especially on heavy-textured soils. A soil SAR >13 suggests a likelihood of reduced soil permeability and decreased plant survival and growth.

b. **Exchangeable Sodium Percentage** – Another useful indicator of potential soil Na^+ hazards is Exchangeable Sodium Percentage (ESP). ESP measures the amount of soil exchange capacity occupied by Na+ and is calculated by the formula:

$$ESP = \frac{\text{exchangeable sodium (meq/100 g or cmol/kg)}}{\text{cation exchange capacity (meq/100 g or cmol/kg)}} \times 100$$

One milliequivalent per 100 grams (meq/100 g) of soil equals 1 centimole per kilogram (cmol/kg) of soil. An ESP >15% indicates that soil Na^+ will probably limit permeability.

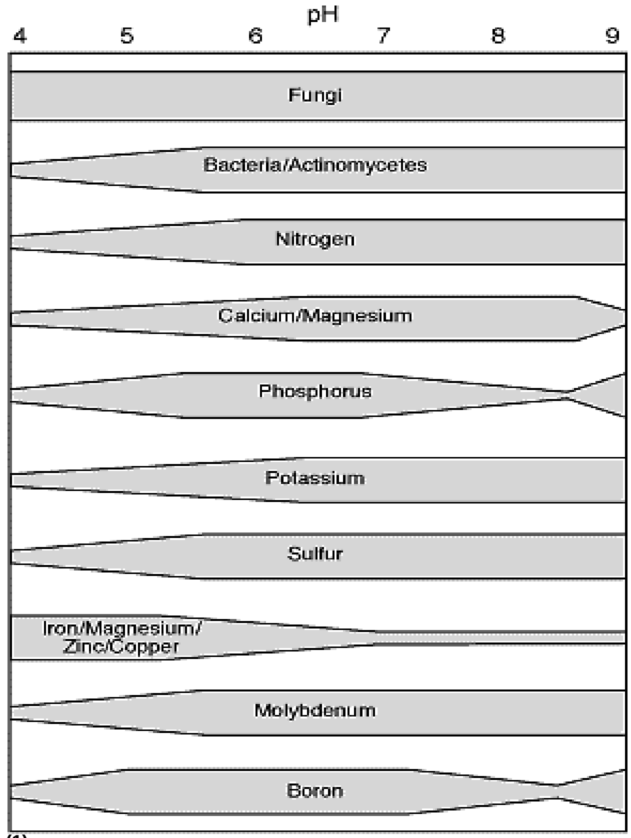
In some cases, excessive Mg^{++} may also cause reduced water infiltration.

3. **Soil pH** – Soil pH, although not a salt test, is often tested in a comprehensive soil analysis. It measures the hydrogen ion concentration in soil solution - an important indication of the chemical status of the soil. Since soluble salts affect soil pH and vice versa, it is often included in evaluations and discussions of soil saltiness. A main implication of changing the soil pH is plant nutrient availability, which is often a secondary response to microbial activity levels responding to changing soil pH. The availability of certain nutrients in soil solution begins to decrease above pH ~5.5 (Fe, Mn, zinc [Zn], copper [Cu], cobalt [Co]), above ~7.0 (phosphorus [P], B), and above 8.5 (Ca^{++}, Mg^{++}) (see CHART 2). The soil pH scale ranges from 0 to 14, with <7 considered acidic, 7 neutral, and >7 alkaline or basic (see TABLE 3). Each whole number represents a ten-fold change in both H concentration and OH, or a 100-fold change in the concentration of H relative to OH (since there is an inverse relationship between the two: as one increases the other proportionally decreases). Most arable soils in our region have a pH in the range of 7 to 9. Soil pH measuring 6.1 to 7.0 is considered ideal for most trees and shrubs, although various species will survive in a range from 5.5 to 8.0+. Listed in TABLE 3 are soil pH classes. It is more likely that a naturally salt-affected soil will have a high, rather than low, soil pH. Although it is possible to amend soil and water with acidifying products including ammonium sulfate and other sulfur containing products to decrease soil pH, it is often necessary to re-apply these substances in order to sustain the effect.

TABLE 3. Soil pH Classes

pH Class	pH
Ultra Acid	<3.5
Extremely Acid	3.5-4.4
Very Strongly Acid	4.5-5.0
Strongly Acid	5.1-5.5
Moderately Acid	5.6-6.0
Slightly Acid	6.1-6.5
Neutral	6.6-7.3
Slightly Alkaline	7.4-7.8
Moderately Alkaline	7.9-8.4
Strongly Alkaline	8.5-9.0
Very Strongly Alkaline	>9.0

CHART 2. Relationship between Soil pH and Plant Nutrient Availability in Soil Solution[1]

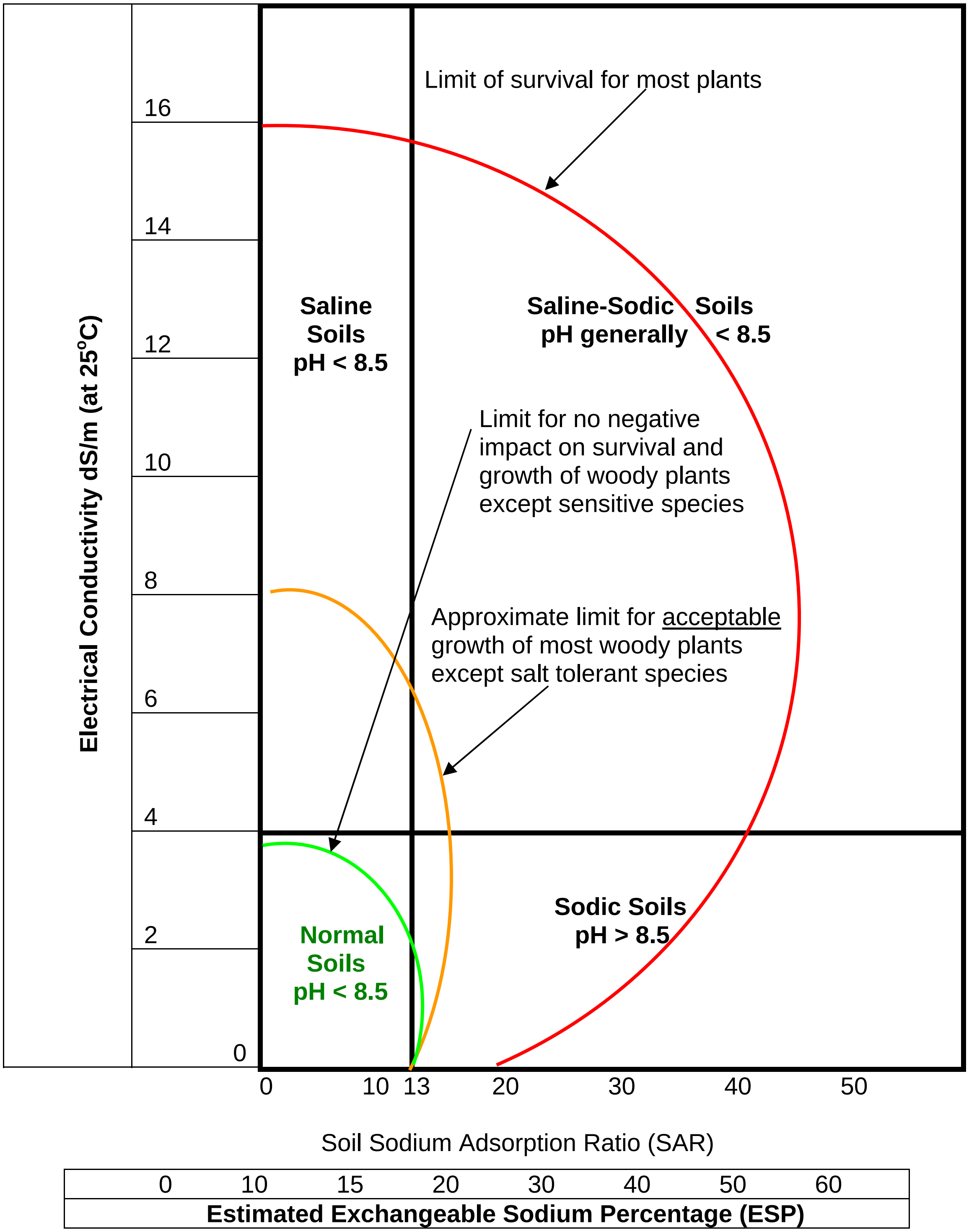


(1) From University of Minnesota Extension Service, BU-01731, Revised 2004.

4. **Soil Texture Classification** – Although soil texture is not a salinity measure, it is often included with salt tests because texture greatly influences how salty soil can be managed. Soil texture indicates the relative amount of sand, silt, and clay particles in a soil sample. The proportions of these three particle sizes influences several soil properties, including water infiltration, percolation, soil aeration, moisture holding capacity, and others. Soils with a high percentage of small clay particles are called “heavy-textured” and are characterized by slow water infiltration into the soil, slow water percolation through the soil, low soil aeration, and a tendency for the soil to hold moisture with great tension. Soils with a high percentage of large sand particles are called “light-textured” and are characterized by rapid water infiltration and percolation, high soil aeration, but low water holding capacity. Light soils (sands and loamy sands) lend themselves to management practices designed to reduce soil salinity by leaching salts from the soil with applications of excess, low-salt irrigation water. Heavy soils (silty clay, sandy clay, clay) are generally more difficult to manage for salinity than soils classified as sandy or loamy. Medium-textured soils (sandy loams, loams, sandy clay loam, clay loam, silt, silt loam, silty clay loam) fall somewhere between light- and heavy-textured soils in terms of their properties and management.

CHART 3 graphically illustrates the relationship between soil EC, SAR, ESP and pH relative to soil classification, as well as plant performance.

CHART 3. Relationship between Soil EC and SAR or ESP on woody plant survival and growth[1]



[1]Based on Brady and Weil, 1999. The Nature and Property of Soils, Twelfth Edition (modified).

MANAGEMENT PRACTICES

Although not within the scope of this paper, it should be noted that specific management practices can offset the effects of elevated water and soil salinity, allowing the use of some marginal quality water to sustain trees and shrubs. The effectiveness of these practices and treatments varies widely depending on the water quality limitations, the growing site, and the plant species. Some potential salt management practices include the installation of soil drainage systems, deep ripping of impervious soil layers (pans), mulching, installing weed-control fabric, diluting elevated salinity water with reduced salinity water, periodic flushing of the soil profile with reduced salinity water, using excess irrigation for leaching salts from the root zone (using irrigation water with an EC_w <2 dS/m; TDS <1280 ppm), minimizing the use of sprinklers in some cases, using flood, properly placed drip, soaker, and bubbler irrigation to flush salts, adjusting the irrigation schedule (especially increasing irrigation frequency on well-drained soils), amending high Na^+, poorly-drained soils with gypsum, elemental sulfur or sulfuric acid, amending high Na^+ water with gypsum, and the selection of salt-tolerant tree and shrub species.

SUMMARY

In review, it is important to test and evaluate irrigation water and soil independently, as well as to consider the potential negative effects when both substrates are combined to create the soil/water matrix. The specific testing steps and interpretations include:

1. Analysis and evaluation of the common ions and carbonate concentrations, and hydrogen ion content (pH) in the irrigation water source for the planned irrigation use. Interpret the suitability of water for the type of irrigation as described in Irrigation Water Quality section of this Technical Note and in other references as appropriate. Consider primary and secondary impacts to soil and plants.

2. Analysis and evaluation of the common ions and carbonate concentrations, hydrogen ion (pH) content, and textural classification of the soils in the proposed planting area. Interpret the suitability of the soil for the type of irrigation and woody species as described in Soil Quality section of this technical note and in other references as appropriate.

3. Evaluate the combined impact of common ions, carbonate, pH, and soil texture on the suitability of the proposed planting. Potential management decisions in selecting an alternative may involve the client's expectation of success or performance and their aversion to risk. Consult Chart 1 and other references as appropriate to evaluate interactive soil-water interactions.

REFERENCES

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Graphics by Mary Myers, Public Affairs Specialist, USDA-NRCS, Bozeman, Montana.

APPENDIX 1. Water Quality Tests, Units of Measure, and Conversions

Test	Units of Measurement	Symbol	Multiply by	To Convert to	Symbol
Water Salinity					
a. electrical conductivity (EC_w)	millimhos per centimeter	mmhos/cm	1	deciSiemens per meter	dS/m
	millimhos per centimeter	mmhos/cm	1000	micromhos per centimeter	µmhos/cm
	Siemens per meter	S/m	10	deciSiemens per meter	dS/m
	microSiemens per centimeter	µS/cm	1	micromhos per centimeter	µmhos/cm
b. total dissolved salts (TDS)	milligrams per liter	mg/l	1	parts per million	ppm
	percent	%	10,000	parts per million	ppm
	percent	%	10,000	milligrams per liter	mg/l
To approximate TDS, multiply EC_w X 640 if the EC value <5 dS/m					
To approximate TDS, multiply EC_w X 800 if the EC value >5 dS/m					
Specific Ion Toxicity	milliequivalents per liter	meq/l	see A.		
A. Meq/l equals mg/l divided by the equivalent weight where equivalent weight equals atomic weight divided by atomic charge.					

APPENDIX 2. Specific Ion Charges, Atomic Weights, and Equivalent Weights

Ion	Symbol	Charge (Valence)	Atomic Weight	Equivalent Weight
calcium	Ca^{++}	+2	40.1	20.05
magnesium	Mg^{++}	+2	24.3	12.15
sodium	Na^{+}	+1	23.0	23.00
chloride	Cl^{-}	-1	35.3	35.30
sulfate	SO_4^{--}	-2	96.1	48.00
carbonate	CO_3^{--}	-1	60.0	30.00
bicarbonate	$HCO3^{-}$	-1	61.0	61.00

APPENDIX 3. Multiplication Factors for Converting between ppm and meq/l

Salt Ion	**ppm→meq/l** Multiply ppm value by:	**meq/l→ppm** Multiply meq/l by:
calcium (Ca^{++})	0.050	20
magnesium (Mg^{++})	0.083	12
sodium (Na^{+})	0.043	23
chloride (Cl^{-})	0.029	35
sulfate (SO_4^{--})	0.021	48
carbonate (CO_3^{--})	0.033	30
bicarbonate (HCO_3^{-})	0.016	61

APPENDIX 4. Classification of Irrigation Waters, USDA Agriculture Handbook 60

Low Salinity Water (C1) can be used for irrigation of most crops with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium Salinity Water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate \salt tolerance can be grown in most cases without special practices for salinity control.

High Salinity Water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants with good salt tolerance should be selected.

Very High Salinity Water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Low Sodium Water (S1) can be used for irrigation on most soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stonefruit trees and avocados may accumulate injurious concentrations of sodium.

APPENDIX 4. Classification of Irrigation Waters, USDA Agriculture Handbook 60 -- continued

Medium Sodium Water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured soils or organic soils with good permeability.

High Sodium Water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management – good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very High Sodium Water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may take the use of these waters feasible.

Sometimes the irrigation water may dissolve sufficient calcium from the calcareous soils to decrease the sodium hazard appreciably, and this should be taken into account in the use of C1-S3 and C1-S4 waters. For calcareous soils with high pH values or non-calcareous soils, the sodium status of water in classes C1-S3, C1-S4, and C2-S4 may be improved by the addition of gypsum to the water. Similarly, it may be beneficial to add gypsum to the soil periodically when C2-S3 and C3-S2 waters are used.

Source: Agriculture Handbook 60, U.S. Department of Agriculture.

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