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G77-328 Irrigation Water Quality Criteria

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NebGuide

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Irrigation Water Quality Criteria

This NebGuide is intended to provide guidelines to help understand and interpret chemical water quality test results.

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All well and stream waters contain dissolved minerals. The amounts and kinds of minerals vary from one location to another and may vary with time. When irrigation water is applied, the mineral salts are left in the soil after the crop has used the water. Most of these mineral salts are beneficial to crop growth and soil condition, but in some cases they may be harmful. Irrigation water quality problems may be caused by (1) total mineral salts accumulating so that crops no longer produce well, (2) development of sodic soils (slick spots) or (3) accumulation of toxic levels of elements such as boron.

Fortunately most irrigation water in Nebraska is of good quality. There are exceptions. This NebGuide is intended to provide guidelines to help understand and interpret chemical water quality test results.

There are four basic criteria for evaluating irrigation water quality:

1. Total soluble salt content (salinity hazard).

2. Relative proportion of sodium cations (Na^+) to other cations (sodium hazard - soil permeability effects).

3. Carbonate ($CO_3^=$) and bicarbonate (HCO_3^-) anion concentration as related to calcium (Ca^{++}) plus magnesium (Mg^{++}) concentration (alkalinity).

4. Concentration of elements that may be toxic (toxicity).

The first two criteria are of major concern because water high in salinity and/or sodium causes most problems to irrigators in Nebraska. Several non-water factors must be considered in deciding the usefulness of water for a specific situation. These include soil texture and structure, internal soil drainage, gypsum and lime content of the soil, salt and sodium tolerance of the crop, and irrigation method and management.

Salinity Hazard

Excess salt increases the osmotic pressure of the soil water and produces conditions that keep the roots from absorbing water. This results in a physiological drought condition. Even though the field appears to have plenty of moisture, the plants may wilt because the roots do not absorb enough water to replace water lost from transpiration.

The total dissolved solids (TDS) content or the amount of soluble salts in the water is generally estimated by determining its electrical conductivity. The electrical conductivity (EC_w) is reported in millimhos per centimeter. *Table I* presents the basic guidelines for water use relative to its salt content or conductivity value in millimhos/cm. If TDS is reported in ppm it can be converted to EC_w by dividing ppm TDS by 640.

Table I. Salinity of Irrigation Water	
	Dissolved Salt Content
Hazard	**EC_w (millimhos/cm)**
Water for which no detrimental effects will usually be noticed. Little chance for increased salinity to develop.	<0.75
Water which may have detrimental effects on sensitive crops.[1] Moderate leaching required to reduce salt accumulations.	0.75 - 1.50
Water that may have adverse effects on many crops and require careful management practices. Salinity increases will result unless adequately leached.	1.50 - 3.0
Water that can be used only for salt tolerant plants[2] on permeable soils with careful management practices and only occasionally for more sensitive crops. A high leaching requirement is necessary. Soil should be tested for salinity increases yearly.	3.0 - 7.5
[1]Field beans, lettuce, bell pepper, onion, carrots, string beans [2]Sugarbeets, wheat, barley	

As the water content of the soil decreases due to crop use, the water films surrounding the soil particles become thinner. The salt content of the soil water increases rapidly during the drying process. For this reason, irrigation water with a conductivity of 1 mmho/cm may produce a conductivity of 2 mmho/cm or more in soil solution as the soil dries. As additional irrigation water is applied the salt from the previous irrigation is redissolved. Some of the salt moves deeper with the wetting front, resulting in salt accumulation in the lower part of the root zone unless more water is applied than is used by the crop.

Sodium Hazard (Soil Permeability Effects)

The main problem with high sodium concentration is its effect on soil permeability and water infiltration. Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruit trees. The sodium hazard of irrigation water is estimated by the sodium absorption ratio (SAR). This is the proportion of sodium to calcium plus magnesium in the water.

Water with an SAR greater than 9 should not be used even if the total salt content is relatively low. Continued use of water having a high SAR leads to a breakdown in the physical structure of the soil. The sodium replaces calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles. This dispersion results in breakdown of soil aggregates and causes the soil to become hard and compact when dry and increasingly impervious to water penetration. The permeability of sandy soils may not deteriorate as readily as heavier soils when irrigationd with high SAR water, but a potential problem does exist.

Waters with SAR's in the range 0 to 6 can generally be used on all soils with little problem of a sodium buildup. When SAR's range from 6 to 9, chances for soil permeability problems increase. Soils should be sampled and tested every 1 or 2 years to determine whether the water is causing a sodium increase.

With higher salinity irrigation water, even lower SAR water should be used. The sodium hazard of irrigation water is also dependent upon the total salt concentration. Higher salinity waters contain more sodium in an acre-foot of water at a given SAR than lower salinity water at the same SAR. Consequently, the potential for developing an impermeable soil is greater for the high salinity, high SAR waters. High salinity water (EC_w1.50-3.00) with SAR's above 4 needs to be carefully managed. Yearly soil testing is recommended to assess possible sodium problems.

Carbonate and Bicarbonate Ion Concentration

High carbonate ($CO_3^{=}$) and bicarbonate (HCO_3^{-}) in water essentially increases the sodium hazard of the water to a level greater than that indicated by the SAR. High $CO_3^{=}$ and HCO_3^{-} tend to precipitate calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) when the soil solution concentrates during soil drying. The concentrations of calcium and magnesium in soil solution are reduced relative to sodium and the SAR of the soil solution tends to increase.

An adjusted SAR value may be calculated for water high in carbonate and bicarbonate if the soil being irrigationd contains free lime (calcareous soil). The adjusted SAR is calculated for the surface soil and, if a leaching fraction is assumed, can be calculated for the subsoil at the bottom of the root zone. These calculations can best be made by the laboratory that does the testing. Using these two values allows estimation of the sodium buildup in the soil from continued use of the water. The adjusted SAR, and knowledge of soil properties help determine management practices when using high bicarbonate water.

Toxic Elements

Some elements in irrigation water may be directly toxic to crops. Establishing toxicity limits in water is complicated by reactions which take place once the water is applied to the soil. When an element is added to the soil from irrigation, it may be inactivated by chemical reactions or it may build up in the soil until it reaches a toxic level. An element at a given concentration in water may be immediately toxic

to a crop because of foliar effects if sprinkler irrigation is used. If furrow irrigation is used, it may require a number of years for the element to accumulate to toxic levels, or it may be immobilized in the soil and never reach toxic levels.

At present the content of toxic elements in well water in Nebraska has not been found high enough to expect toxicity problems except for rare cases from boron. Excessive levels of boron are nearly always associated with deep ground water which also has a high salinity hazard. Irrigation waters containing more than 1.0 ppm boron (B) may cause accumulation of toxic levels for sensitive crops.

Management Practices for Irrigating With Saline or Sodic Water

If poor-quality water is used for irrigation, one or more of the following practices may be necessary to avoid soil problems which will limit crop yields.

1. Provide adequate internal drainage. If barriers restrict movement of water through the root zone, water with either a moderate sodium hazard (SAR>6) or salinity hazard (EC_w>1.5) should not be used unless drainage can be provided.
2. Meet the necessary leaching requirement (over- irrigation) depending on crop and EC_w of water. A leaching requirement can be calculated from water test results and tolerance levels for specific crops. This is necessary to avoid buildup of salt in the soil solution to levels that will limit crop yields. Effective rainfall can be considered part of the leaching requirement.
3. Maintain higher available water in the soil. The soil should not be allowed to become more than moderately dry, since the crop cannot remove all the normally available water due to the higher salt content.
4. Monitor salt and sodium with saline-alkali soil tests every 1 to 2 years. Development of a sodium hazard usually takes time. Soil tests for SAR of saturation extract or percent exchangeable sodium can detect changes before permanent damage occurs. Proper management can maintain SAR and salinity values at a steady state below the danger level. Soil samples should be taken to represent the top foot and the second foot. Occasionally samples should be taken down to four feet.
5. Add soluble calcium such as gypsum (calcium sulfate) to decrease the SAR to a safe value. Gypsum can be metered into the water at the required rate, or in some cases it can be broadcast annually over the field. If broadcast, apply directly ahead of irrigation or thoroughly incorporate into the tillage layer to avoid crusting problems. If the soil contains free lime, elemental sulfur could be broadcast. The sulfur solubilizes the calcium from the free lime already in the soil. If gypsum is used, the leaching requirement may be increased (Practice 2).
6. Restricted use. Use only during drought periods to supplement below normal rainfall or when other sources of water are inadequate. Occasional use of practice 4 may be necessary.

Which combination of the above practices should be used? That depends on which hazard or hazards are associated with the water you plan to use, and the severity of the hazards. Sometimes the risk and cost is too great to attempt using the water. *Table II* will provide some help but you may wish to seek the advice of an expert if the water constitutes a high or very high hazard.

Table II. Sodium Hazard of Irrigation Water Based on Sodium Adsorption Ratio (SAR) and Electrical Conductance (EC_w). To determine sodium hazard match your EC_w value with appropriate column, read down to your SAR or SAR_{adj} value, and read sodium hazard in left-hand column.

<table>
<tr><th></th><th colspan="4">Salinity Hazard, EC_w</th><th></th></tr>
<tr><th></th><th>0.75 Low</th><th>0.75-1.50 Medium</th><th>1.50-3.00 High</th><th>>3.00 V. high</th><th>Expected Permeability and Management</th></tr>
<tr><th colspan="5">SAR[1] or SAR_{adj} Ranges</th><th></th></tr>
<tr><td>Low</td><td>less than 6</td><td>less than 6</td><td>less than 4</td><td>less than 2</td><td>No permeability problems expected.</td></tr>
<tr><td>Medium</td><td>6 to 9</td><td>6 to 8</td><td>4 to 6</td><td>2 to 4</td><td>Usually no permeability problems expected except when soils are high in clay and EC_w is high or very high.</td></tr>
<tr><td>High</td><td>9 to 12</td><td>8 to 10</td><td>6 to 8</td><td>4 to 6</td><td>Possible permeability problems. Can use on sandy soils if LR is met. May need soluble calcium added if silt loam or finer texture. Monitor by soil test.</td></tr>
<tr><td>V. high</td><td>greater than 12</td><td>greater than 10</td><td>greater than 8</td><td>greater than 6</td><td>Serious permeability problems expected. Requires added soluble calcium or use only limited amounts as supplement to rain fall or good quality water. Monitor with soil test at the end of each season.</td></tr>
<tr><td colspan="6">[1]Use SAR_{adj} if water is used to irrigation soils containing free calcium carbonate (lime). Soil pH will exceed 7.0.</td></tr>
</table>

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