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Understanding the Numbers in Your Irrigation Water Report

Leo Espinoza
Associate Professor –
Soil Scientist

Chris Henry
Associate professor
and Water Management
Engineer

Mike Daniels
Professor and Extension
Soil and Water Conservation
Scientist

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Introduction

Arkansas ranks third nationally in the number of irrigated acres with 4.2 million. Irrigation represents a significant portion of the total production costs needed to optimize crop growth potential. The University of Arkansas System Division of Agriculture recommends that irrigation water be tested to ensure that it is suitable to grow a particular crop or to develop management practices that may alleviate existing issues such as high soil salt levels. Not only can poor quality irrigation water damage existing crops, but it can also damage the soil's productivity for future growing seasons. For such reasons, understanding a water analysis report can be critical for sustainable crop production. The objective of this factsheet is to inform readers what the reported irrigation water test results may mean to their production system.

How to Collect a Water Sample

The collection of a representative water sample is critical for the correct quality assessment of irrigation waters. Great attention should be taken regarding sampling recommendations.

Samples should be collected in clean bottles, which can be obtained from your local Extension office. However, any new bottle can also be used to collect water samples. If the water sample comes from a well, let the pump run for at least 30 minutes before collecting the sample. If the sample is coming from a reservoir or river, the water should be collected from the middle of the reservoir and at least one foot deep. Collect no less than 100 ml of water (roughly equivalent to half a cup), but it is preferable that the whole container is filled, with no air gaps left. If the water body to be sampled fluctuates significantly in volume, then more than one sampling time may be appropriate. Always pre-rinse your sample bottle three times with the water you are sampling before taking the actual sample. More information on proper water sampling and handling procedures can be found at the Arkansas Water Resources (AWRC) Center Water Quality Laboratory website (http://www.uark.edu/depts/awrc/index.html).

Typical Water Quality Parameters Measured

The Arkansas Water Resources Center (AWRC) Water Quality Laboratory (WQL), located in Fayetteville, provides analytical services for water samples intended for crop irrigation, livestock and poultry watering, fish pounds, and domestic supplies. The WQL has adopted a Quality Assurance Plan that meets or exceeds all requirements for certification by the Arkansas Department of Environmental Quality and the United States Environmental Protection Agency (USEPA).

A typical irrigation water analysis report will include measures of pH, salinity level (Electrical Conductivity or EC), alkalinity, hardness, calcium, magnesium, sodium, iron, manganese, bicarbonate, fluoride, chloride, sulfate, nitrate-nitrogen, total suspended solids, sodium absorption ratio, and aggressive index.

The **pH** of the water sample, just like with soils, indicates the acidity and alkalinity of the sample. Many of the water samples analyzed by the lab test alkaline (pH >7.0) due to the presence of carbonates. Nutrient availability to plants will increase the pH of the soil and continued use of irrigation water with alkaline pH can affect the availability of some micronutrients, particularly zinc, molybdenum, manganese, and iron. Often, a soil pH gradient can be observed in fields that are flood irrigated with more alkaline pH levels at the top of the field near the water entrance and acidic pH conditions at the lower end of the field where the water exits. Acidic pH (pH < 6.0) will affect the availability of other nutrients, such as phosphorus. The solubility of some of the heavy metals of concern, such as lead and cadmium, increases significantly under acidic conditions.

Salt level (electrical conductivity, EC) is one of the most important parameters requested by farmers, as high concentrations of dissolved salts can severely affect crop growth. While sodium chloride is probably the most common salt compound in irrigation water, a water sample may also contain other salts such as those formed with carbonates, bicarbonates, sulfates, and nitrates, and ions such as sodium, chloride, magnesium, sodium, and potassium. Salinity is then a measure of the concentration of all dissolved ions of the salts in the water sample. Irrigation water testing 2000 µS/cm will add approximately 1000 lbs of salt per acre with each furrow irrigation event (about 3 acre-inches).

Salinity is not measured directly, but rather indirectly using electrical conductivity. The conductivity of water is affected by the presence of the ions mentioned before and by temperature, so the higher the temperature, the higher the EC value. The water analysis report will show EC levels at 75° F; this value will probably be higher if the EC was measured at the edge of the field during the summer months. Electrical conductivity can also be monitored during the season with low-cost hand-held instruments. The WQL reports EC as microsiemens per centimeter (uS/cm). Other labs may report EC in micromhos (µmho) or millimhos (mmho) per centimeter. Table 1 shows conversion units for the different reporting units for electrical conductivity. Table 2 shows reported reference EC values for water samples. Crops vary in their sensitivity to increased salinity levels, with cotton normally being more resistant than rice or soybean. Seedling rice can be susceptible to salt damage at levels near 1200 µS/cm.

Table 1. EC unit conversion table.

Decisiemen per meter (dS/M)	1
Microsiemen per centimeter (µS/cm)	1000
Millimho per centimeter (mmho/cm)	1
Micromho per centimeter (µmho/cm)	1000

Table 2. Reference levels for electrical conductivity in irrigation waters (Adapted from Fipps, 2003).

LIMITATIONS	EC (µS/cm)
None	<750
Moderate	750-3000
Severe	>3000

Alkalinity is the term used to describe water samples testing pH above 8.5, which are normally associated with high bicarbonates (HCO_3^-) and carbonates (CO_3^{-2}) levels. Carbonates readily bond with an H^+ ion and take the acid-forming ion out of the solution thereby raising the pH. The use of alkaline irrigation water prevents the acidifying effect of nitrogen fertilizers. However, that is not the case when using reservoir water, which tends to test lower in alkalinity than well water. Farmers using reservoir water, particularly those who rotate rice with soybeans, should monitor soil pH closely for faster acidification compared with fields where well water is used because most wells contain bicarbonates, which make soils more alkaline. Table 3 shows reference levels for limitations when using irrigation water with different levels of alkalinity.

Table 3. Reference levels for alkalinity in irrigation waters (Adapted from Fipps, 2003)

LIMITATIONS	mg/L as $CaCO_3$
Low	<100
Moderate	100 – 150
Severe	>150

Hardness refers to the amount of calcium and magnesium dissolved in the water sample, although other ions such as manganese and iron can also contribute. Hard water normally forms as the water moves through limestone deposits common to many parts of the state. Hardness is given as mg/L of $CaCO_3$ (calcium carbonate). Hard water results in the accumulation of calcium and magnesium in irrigation lines, which is of particular concern in drip irrigation systems. Water samples testing more than 300 mg/L are classified as hard water (Table 4). Hardness is commonly associated with the need to use more soap or detergent to clean dishes or clothes. Hard water may affect the effectiveness of some herbicides, particularly those which are salt formulated such as glyphosate. Check the label for instructions on how to treat water hardness. However, some level of calcium and magnesium is needed in the water to neutralize acid-forming compounds that may cause corrosion. Alkalinity and hardness are related as the main ions are part of both alkalinity and hardness. Water softeners can reduce hardness if scaling is a problem in drip tubing; however,

Table 4. Reference levels for hardness in irrigation waters (Adapted from Gray, 1994).

LIMITATIONS	mg/L as CaCO3
Low	<150
Moderate	150 – 300
Severe	>300

many softeners lower hardness by adding sodium or other salts.

Iron (Fe) in the water sample is reported in units of mg/L and is mostly present in the ferrous form (Fe^{+3}), but when exposed to air, iron oxidizes to its ferric form (Fe^{+2}), which is fairly insoluble and forms rust. Rust causes a reddish stain as seen in center pivots and could even clog nozzles at concentrations as low as 3 mg/L. Iron can also form complexes with bacteria that can cause a yellow slime which can clog pipe outlets.

Manganese (Mn) results are given in units of mg/L. Manganese is normally dissolved from shale, and it is present in lower concentrations than iron, under most conditions. Manganese does not represent a serious problem in irrigation water, like other metals such as iron, it can complex and precipitate. In drinking water, high levels normally give a metallic taste to the water. Water samples consistently testing above 1.5 mg/L Mn need to be monitored closely.

Fluoride (F) Fluoride at the levels commonly found in waters causes no harm to plants. Research studies have shown plant injury occurs at levels above 100 mg/L.

Calcium (Ca) and Magnesium (Mg) are always part of a water analysis report and are commonly present in every water sample. They are useful in the calculation of SAR (Sodium Absorption Ratio) and are also considered in the calculation of the hardness or softness of a sample.

Sodium (Na) in high concentrations can affect both, the soil and plants. High sodium levels can be toxic to a plant, and they can also induce nutrient imbalances as the chemical properties of this ion are similar to those of several nutrients. But perhaps the most serious problem with high Na levels has to do with a poor soil structure that results in reduced water infiltration. Soil can be saline, sodic, or both. The standard approach to assess the potential negative effects of sodium is to calculate the sodium absorption ratio or SAR, which is provided in the analysis report. While other parameters are important, the SAR combines the relative effect that sodium, calcium, and magnesium have on the osmotic potential in plants. This parameter rates the sodium in the water sample, in proportion to the concentration of calcium and magnesium. SAR levels above 17 are indicative of potential infiltration problems, while levels under 10 are considered fine for crop production (Table 5). To calculate SAR, the concentrations of the ions need to be in meq/L, which is the way they are reported. Briefly, a meq/L is the atomic weight of the ion divided by its valence (charge). For instance, the atomic weight of calcium is 40 and the charge is 2 (2 negative charges), then 1 meq/L of calcium is 40/2= 20 mg/meq. Now, 1 meq/L of sodium equals 23 mg/meq (1 negative charge), while 1 meq/L magnesium is 12.15 mg/meq or 24.3/2 (2 negative charges).

SAR Formula

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Table 5. Reference levels for sodium hazard based on SAR.

LIMITATIONS	SAR
None	<10
Medium	11-17
High	>17

Total Suspended Solids (TSS) are typically measured by filtering a known volume of water and weighing whatever it is left as water is allowed to evaporate. Total Suspended Solids are reported in units of mg/L. Suspended solids provide a quantitative estimation of the turbidity of the water sample. Suspended solids include silt and clay particles, plankton, algae, fine organic debris, salts, and other particulate matter. Total suspended solids often correlate strongly with measurements of EC, especially if the salts are high compared to the other suspended solids.

Total suspended solids are perhaps more useful for surface water samples as high suspended solid levels in surface water may be associated with increased soil erosion. It has been reported that levels around 250 mg/L of total solids can reduce light transmission, which can affect the activity of aquatic organisms. As a rule of thumb, a water sample with a TSS level under 25 mg/L is considered clear, while levels between 50-100 mg/L are typical of cloudy water.

Chloride (Cl) is an essential nutrient, required by plants for optimum plant growth. Plants require relatively small amounts of chloride, however at elevated concentrations can become toxic (Table 6), with the severity of the damage being a function of plant type and variety. For example, some soybeans varieties are known to carry genes that allow for the exclusion of chloride when it is high in the soil solution. Soybean varieties classified as "excluders" allow the cell membranes to exclude chloride, so it is not taken into the plant until the concentration is much higher. Excluders can be identified by delayed leaf burning symptoms, compared to varieties that do not carry the excluding genes. Leaf burning can also be a problem when using sprinkler irrigation with water high in chloride.

Table 6. Reference levels for chloride in irrigation water (Tanji, 1990)

LIMITATIONS	mg/L
None	<144
Medium	144-355
High	>355

Sulfate (SO$_4$) Sulfur is an essential nutrient for plants, but sulfates are normally associated with sodium, magnesium, potassium, and calcium and contribute to the salinity of a soil, but under most conditions do not harm crops. Sulfate, being negatively charged, will move with irrigation water and has the potential to leach below the root zone in sandy soils.

In some areas in Arkansas, well water has a characteristic rotten egg smell caused by **hydrogen sulfide (HS)**. A source of this HS can be bacteria that use some of the sulfate-containing minerals in the soil. A different test would need to be run to obtain more information on HS.

Bicarbonates (HCO_3^-) are components of the total alkalinity in a water sample. They normally form as limestone dissolves in soils. In Arkansas, irrigation waters with a pH above 8 are usually associated with high bicarbonates. In soils, bicarbonates can affect the ability of plant roots to absorb some nutrients such as iron and zinc. In soils, bicarbonates can react with calcium, precipitating as calcium carbonate, leaving less calcium in the exchange sites and increasing the proportion of sodium. Higher sodium increases the sodium hazard potential as indicated by increasing SAR value. Table 7 shows reference values for bicarbonates in irrigation waters.

Table 7. Reference levels for bicarbonates in irrigation waters.

LIMITATIONS	meq/L
None	<120
Moderate	120 - 180
Severe	>180

Nitrate-N

Nitrate and nitrate-N are two different values. Results are normally reported as nitrate-N, which accounts for the actual nitrogen concentration in the sample. A nitrate molecule has three oxygen atoms for every nitrogen atom, meaning that the nitrate molecule is 22.5% N by weight. Therefore, the nitrate value obtained is multiplied by 0.225 to obtain nitrate-N. Water high in nitrate-N can contribute to the nutrition of a crop, however, water with nitrate-N levels above 10 mg/L is not considered safe to feed infants.

The **Aggressive index** is used as an indication of how corrosive water is. It is calculated based on the pH, hardness (H) and total alkalinity (A), and it is unitless [$AI = pH + \log(A * H)$]. The aggressive index values are inverse of most other values on the report, meaning that as the index value decreases, the level of concern or limitation increases (Table 8). Water with an aggressive index under 10 can dissolve metals in plumbing fixtures such as copper and lead.

Table 8. Reference levels for the aggressive index in irrigation waters.

LIMITATIONS	
Low	>12
Medium	12-10
High	<10

Managing Irrigation when Water Quality can Impact Yield

The best way to manage potential yield damage as a result of salts in irrigation water is to get the water tested so a strategy can be planned. The next step is to manage the quality and quantity of water applied so that no excess water is applied which further compounds the quality problem. For irrigation water with a high SAR or other salt-related quality issues, the salts will increase the osmotic potential in the soil, so irrigation frequency will need to be slightly increased and controlled. Using soil moisture sensors, for example, can help determine when water is needed so that over-application is minimized, and ions do not accumulate any more than necessary. Additionally, securing another irrigation source entirely or blending with another higher quality irrigation water source is often necessary to mitigate yield penalties from poor quality irrigation water.

Summary

In general, the irrigation water quality of Arkansas is good and does not cause crop damage. However, in some locations, the water can contain damaging amounts of alkalinity, salinity, and sodium that can damage existing crops and lead to more difficult challenges with future crops. Results from an irrigation water sample can create awareness about how to manage irrigation water with aspects that can potentially impact crop yields.

The University of Arkansas System Division of Agriculture offers irrigation water testing through the Arkansas Water Resources Lab located in Fayetteville (https://awrc.uada.edu/). For more information or assistance, contact your local County Extension office.

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DR. LEO ESPINOZA is associate professor - soil scientist, with the University of Arkansas System, Division of Agriculture in Little Rock. **DR. CHRIS HENRY** is an associate professor and Water Management Engineer with the Rice Research and Extension Center in Stuttgart. **DR. MIKE DANIELS** is professor - soil and water conservation scientist, with the University of Arkansas System, Division of Agriculture in Little Rock.

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