Irrigation Water Analysis and Interpretation

Guide W-102

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INTRODUCTION

This workbook, available at http://aces.nmsu.edu/pubs/_water/W-102_workbook.xlsx, is designed for Cooperative Extension Agents, NRCS Field Offices, private consultants, and others who work with individuals who need assistance understanding irrigation water analysis reports. The workbook covers elements of a water quality analysis and assesses limitations associated with an irrigation water source (Figure 1). Leaching fraction is calculated based on additional user inputs. You must have Microsoft Excel 2007 installed on your computer; please set your security preferences in Microsoft Excel to allow macros with this workbook.

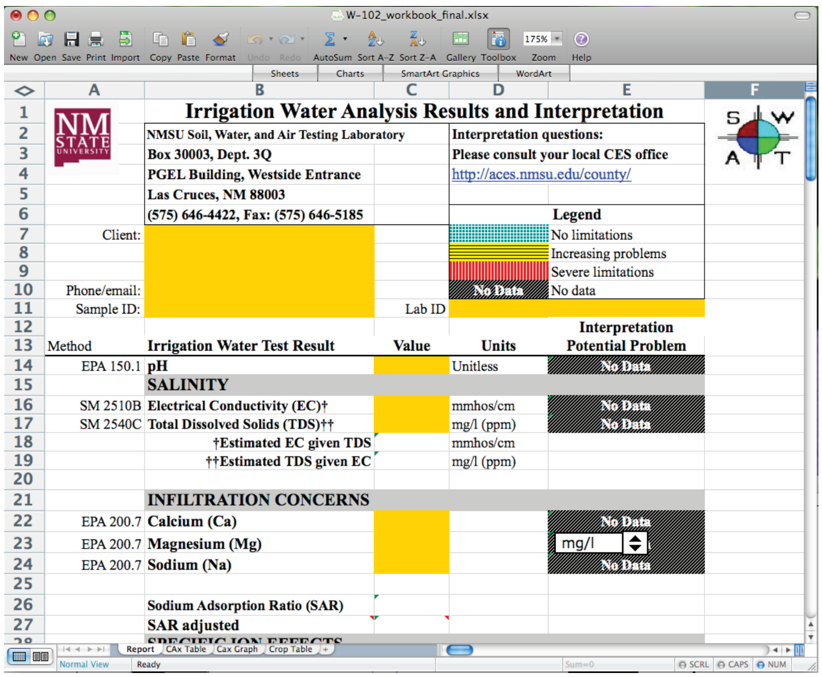

Figure 1. **The Irrigation Water Analysis Results and Interpretation workbook, available at http://aces.nmsu.edu/pubs/_water/W-102_workbook.xlsx.**

INPUTS

Users can enter irrigation water test report results directly into the "Report" tab of the workbook. The following analyses are considered useful in determining irrigation water quality for agriculture: pH, electrical conductivity (EC), calcium (Ca), magnesium (Mg), sodium (Na), chloride (Cl), boron (B), sulfate (SO_4), and bicarbonate (HCO_3). Users can select the units the lab uses to report the values (mEq/l or mg/l). Cells highlighted in orange are for user inputs.

DIRECTIONS

Cells B7 to B11 and D11 are used for client information and sample identification. Data from the laboratory report are entered in cells C14 (pH), C16 (EC), C17 (total dissolved solids, TDS), C22 (Ca), C23 (Mg), C24 (Na), C32 (Cl), C34 (B), C35 (HCO_3), C38 (SO_4), C39 (nitrate, NO_3), and C40 (potassium, K). Units can be toggled just to the right of each cell in column D. If there are no data for a particular test, that cell should be left blank and "No Data" should appear to the right of the blank cell.

SECTIONS

Salinity. Laboratories may report either TDS or EC. A useful conversion factor was provided by Rhoades et al. (1992): For water with an EC between 0.1 and

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5.0 mmhos/cm, multiply EC by 640 to estimate TDS in mg/l. For water EC greater than 5.0 mmhos/cm, multiply EC by 800 to estimate TDS. This calculation is performed in the report sheet in cells C18 and C19 (mmhos/cm = dS/m, mg/l = ppm). The EC for water is also often abbreviated ECw.

Infiltration Concerns. Calcium, magnesium, and sodium are used to calculate the sodium adsorption ratio (SAR) of the irrigation water (cell C26). The adjusted SAR (cell C27) is calculated using information from Suarez (1981), which includes the bicarbonate content of the irrigation water. The permeability hazard of an irrigation water sample is related to both the SAR and EC of the irrigation water. Cells Q21 to BQ68 on the "Report" tab are a lookup table based on Suarez (1981) that estimates the permeability hazard based on SAR, or adjusted SAR, and EC. The adjusted SAR relies on a calcium precipitation factor referred to as Ca_x. Ca_x is estimated from a lookup table, but can also be estimated from the "Ca_x Graph" tab: Move the vertical red line to the x-axis value shown in cell C39. Then move the horizontal red line to intersect the ECw value nearest the reported ECw along the vertical red line. Enter the Ca_x value found along the Y-axis into cell D42.

Specific Ion Effects. Bicarbonate, boron, chloride, and sodium are four ions that can have negative effects on plant growth. Please refer to Rhoades et al. (1991) or Horneck et al. (2007) for descriptions of these ion effects.

Nutrient Status. Sulfate, nitrate, and potassium are often an option for water quality test reports. Accounting for these nutrients in nutrient management plans is necessary and can save money in fertilizer input expenses. The workbook calculates the pounds of nutrient added to an acre of soil that receives an inch of water (cells E38 to E41).

Suggested Leaching Fraction for Selected Crop or Soil EC and Irrigation Frequency. This section allows the user to select a combination of crop and location from a pull-down menu in cell B46. Each crop/location combination is tied to values for estimated consumptive use and soil saturated paste EC (abbreviated EC_e) at which there is a 10% yield reduction. The table can be found on the "Crop Table" tab and is also provided by New Mexico NRCS salinity workbook AGRO-61 "Irrigated Leaching Index and Salt Management Tool for New Mexico" (Sporcic and Sheffe, 2001), available at http://www.nm.nrcs.usda.gov/technical/tech-notes/agro.html.

Cell C46. Users must find the EC 10% value for their selected crop/location from the "Crop Table" tab and enter that number in cell C46 on the "Report" tab. The user may also enter, in cell C46, the desired or current soil test EC from a saturated paste extract.

Irrigation frequency will have an effect on your current irrigation water management practices. The leaching fraction for a high frequency or low frequency irrigation system is calculated in cells D46 and E46, respectively. High frequency systems include drip and sprinkler systems that are run frequently to deliver water to a crop. A low frequency system is one that delivers water infrequently through gated pipe, border/dike, or flooding methods. Leaching fractions will be greater for low frequency systems.

Estimated consumptive use and leaching fraction are calculated for both the low and high frequency systems. The quantity given in cells D48 and E48 does not take irrigation system efficiency into account. Consumptive use varies by location. Leaching fraction is calculated from the following formulas:

Low Frequency:	0.3086/(ECe/ECw)^1.702
High Frequency:	0.1794/(ECe/ECw)^3.0417

Plugging Potential. Total suspended solids, bacterial content, hydrogen sulfide, iron, manganese, and bicarbonate all contribute to potential plugging of small openings in drip irrigation systems. These openings can be the emitters or the screens through which water is filtered. Please refer to Bucks et al. (1979) and Encisco et al. (2004) for more information.

GUIDELINES FOR INTERPRETING IRRIGATION WATER QUALITY

pH

Normal range for irrigation water is between 6.5 and 8.4.

Salinity EC = electrical conductivity of the water

Usually no problems when below 0.7 mmhos/cm

Increasing problems when between 0.7 and 3.0 mmhos/cm

Severe limitations when above 3.0 mmhos/cm

TDS = Total Dissolved Solids

TDS contributes to the salinity of the water.

Usually no problems when below 450 mg/l

Increasing problems when between 450 and 2,000 mg/l

Severe limitations when above 2,000 mg/l

Infiltration Concerns

High-sodium water has the potential to reduce or stop water from moving into soil. Water SAR is used in combination with EC to assess potential soil-related infiltration problems as a result of using the water. The SAR is calculated from the ratio of sodium (Na) to calcium (Ca) and magnesium (Mg) (where units are in mEq/l):

$$\frac{Na}{\left(\frac{Ca+Mg}{2}\right)^{1/2}}$$

Adjusted SAR (cell C27) uses the bicarbonate to calcium ratio (HCO_3/Ca) to account for calcium precipitation in the soil as lime. Adjusted SAR will be either the same or larger than SAR.

- For water with SAR < 3, there should be no restrictions on use or plant growth.
- Problems increase when SAR is between 3 and 9.
- SAR above 9 may cause severe limitations to soil properties.

Specific Ion Effects

Trees, vines, and woody ornamentals are usually sensitive to excess sodium. Annual crops are not affected directly by high sodium, but are affected by its contribution to soil salinity (Table 1). Sodium and chloride can burn leaves when the rate of evaporation is high, humidity is low, and temperature is high.

Table 1. Tolerance of Selected Crops to Foliar Injury from Overhead Irrigation

Na or Cl concentrations causing injury (mEq/l)			
<5	5–10	10–20	>20
Apricot	Grape	Alfalfa	Cauliflower
Plum	Pepper	Barley	Cotton
	Potato	Corn	Sunflower
	Tomato	Cucumber	
		Safflower	
		Sorghum	

Boron: A small amount of boron is needed for plant growth. The following is a list of plants and their relative sensitivity to boron (boron tolerance given in parentheses).

- **Very sensitive** (<0.5 mg/l): Blackberry
- **Sensitive** (0.5–0.75 mg/l): Cherry, pecan, grape, fig, onion, cowpea
- **Moderately sensitive** (0.75–1.0 mg/l): Garlic, wheat, barley, sunflower, beans, peanut
- **Less sensitive** (1.0–2.0 mg/l): Red pepper, pea, carrot, potato, cucumber
- **Moderately tolerant** (2.0–4.0 mg/l): lettuce, oats, corn, squash, muskmelon
- **Tolerant** (4.0–6.0 mg/l): Sorghum, tomato, alfalfa

Nutrient Status Per Acre-Inch

Sulfate, nitrate, potassium, and boron are often reported in water analyses, and all can serve to provide plants with needed nutrients. Sulfate, nitrate, and potassium can contribute to the overall salinity of the water.

Suggested Leaching Fraction for Selected Crop or Soil ECe and Irrigation Frequency

This section estimates the leaching fraction for a given crop in a given area of New Mexico from a pull-down menu. Users should be familiar with tolerable levels of soil salinity (EC) for a given crop, or at least have a soil test value to enter below the 90% yield heading (cell C46). The leaching fraction is estimated for both low frequency (border/dike or furrow) and high frequency irrigation systems (sprinklers and drip systems).

The estimated crop consumptive water use from the selected crop/location is added to the estimated leaching fraction needed to keep salinity at the entered level. (Consumptive use information from Sporcic and Sheffe [2001].)

Plugging Potential

This section is relevant for drip irrigation systems. Drip systems have small openings called emitters through which water flows, and these small openings are prone to plugging from solids and bacterial contamination. Filtration should remove everything greater than 1/10 the size of the emitter.

Total Suspended Solids. River water is usually suspect for this contaminant. Water for drip systems should have less than 50 mg/l of suspended solids. Suspended solids above 100 mg/l can severely limit the type of emitters that are used. Filtration systems must be used with water containing more than 50 mg/l of total suspended solids.

Bacterial Count (×1,000). This is a measure of the presence of bacteria that can develop into an obstacle for water flow or cause growth inside the tubing. When colonies dislodge from the tube linings, there is a greater chance of plugging. Populations with less than 10,000 counts per ml are considered safe for use in drip systems. Bacterial counts greater than 50,000 per ml can cause severe plugging if left untreated. Sample containers used to collect the irrigation water must be sterile prior to collecting the sample.

Hydrogen Sulfide. The presence of this foul-smelling gas indicates the potential for sulfur-oxidizing or sulfur-reducing bacteria. **Sulfur-oxidizing bacteria** produce effects similar to those of iron bacteria. They convert sulfide into sulfate, producing a dark slime that can clog plumbing. **Sulfur-reducing bacteria** (most common) live in oxygen-deficient environments. They break down sulfur compounds, producing hydrogen sulfide gas in the process. Hydrogen sulfide gas is foul-smelling (like rotten eggs) and highly corrosive. Water with levels greater than 0.1 mg/l may encourage the growth of sulfur bacteria.

Iron and Manganese. The presence of these two minerals can encourage the growth of iron bacteria, which are oxidizing agents. In the presence of oxygen, these bacteria will produce a foul-smelling brown slime that can coat well screens, pipes, and plumbing fixtures. While it is not a health hazard, it does cause unpleasant odors and can corrode plumbing equipment. If conditions are right, the bacteria can grow at amazing rates, and an entire well system may be rendered virtually useless in just a few months. Iron and manganese levels should be less than 0.1 mg/l. There are increasing problems as levels exceed 0.1 mg/l, and severe limitations at levels above 1.5 mg/l.

Bicarbonate. The presence of bicarbonate leads to the precipitation of calcium carbonate (scale) at water pH greater than 7.5. The scale can be very difficult to remove. Acidification of the water is the best way to manage bicarbonate. Water levels with less than 1.5 mEq/l will not cause problems. Severe problems can develop at levels above 2.5 mEq/l.

REFERENCES AND ADDITIONAL READING

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