Wilbur-Ellis Company

Water Quality, Interpretation And Effects on System Management

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Potential Effects of Water Chemistry

- Total salt accumulation
- Specific ion toxicity (B, Na, Cl)
- Reduced infiltration (Na and ECw)
- Lime deposits (aesthetics, surface crusts)
- Iron deposits (aesthetics)
- Nutrient contribution (nitrate/sulfate)
- Micro-irrigation systems

Potential Effects of Water Chemistry

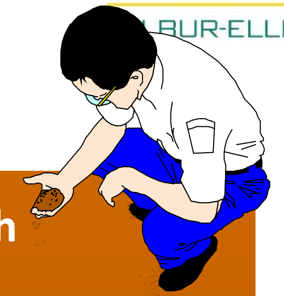
- OVER TIME SOIL WILL REFLECT QUALITY OF IRRIGATION WATER USED ON THAT LAND

Soil and Water Reports –
First Step in Assessing Potential Impact

PROBLEMS

* Chemistry is everyone's favorite subject
* Lack of clear instruction on how to effectively interpret reports
* Lack of instruction on how to construct effective recommendations
* Too much reliance on lab interpretations
* Prevalence of misinformation (suppliers, consultants)
* Valid differences in opinion

Soil and Water Quality
Are Complex and Interrelated



Acidic soils	How bad is bad, how to correct, how much and what to use?
Alkaline soils	What problem, pH vs sodium, amendment sources, speed of response, expectations?
Sodic or alkali soils	How to interpret, how to correct?
Saline soils	Source, management, hazard, how to correct?
Specific ion toxicities	Na, Cl, B, source, hazard, how to correct?
Physical problems	Crusting, compaction, infiltration, textural layers, fluctuating water tables, so what?

Water quality affects all of the above

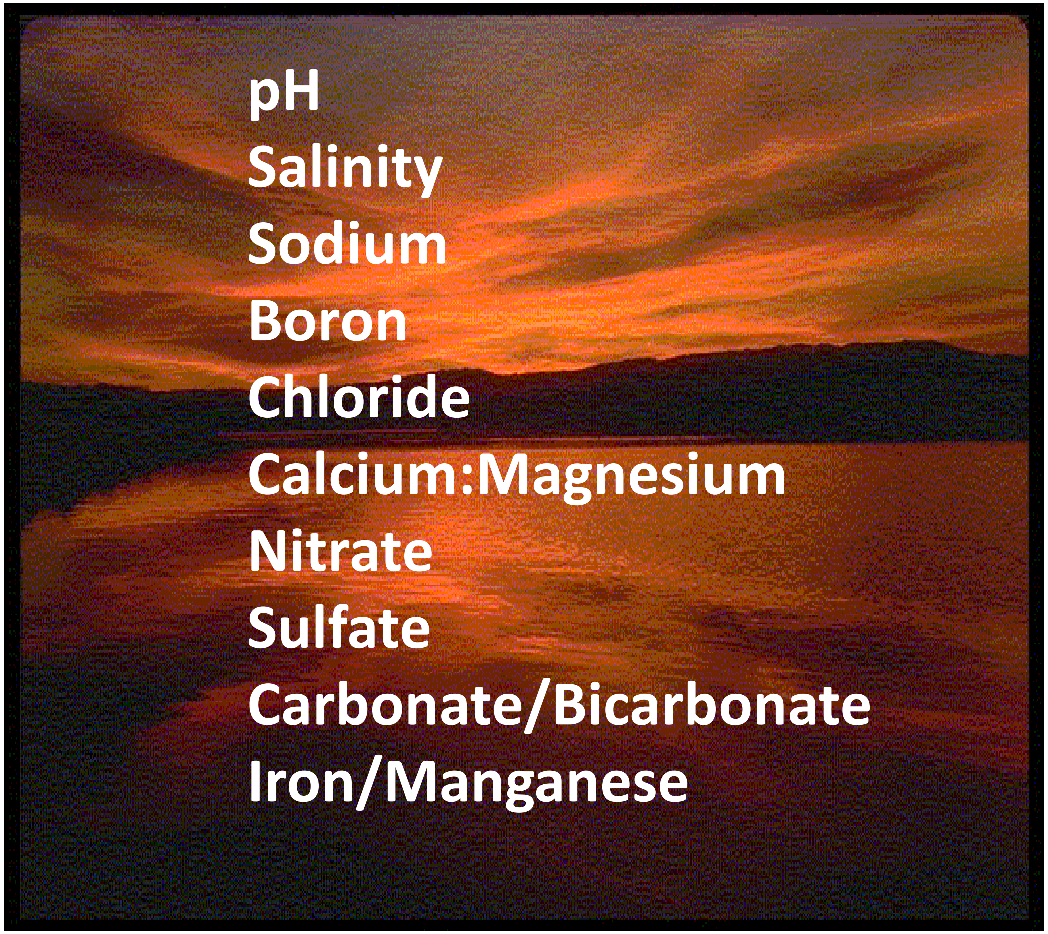
When and How often Should Water Samples be Collected?

- Prior to first time use
- New well
- Spring vs. late summer
- Trouble shooting

Otherwise every other year is acceptable

- Wait until pump has been operating for > 30 minutes
- Fill container – no head space
- Do NOT use glass (some leak B)
- Keep in cool location until shipped
- Always use a clean container

Water Analysis: Not All Waters are Created Equal



Will vary by source, use history, seasonality and year.

<u>Don't assume!</u>

Accumulation of Salts and Toxic Elements

Parts per million in irrigation water X 2.72 = pounds applied per acre-foot of water

ECw of 1.0 = 640 ppm

Do the math and consider years and years of application

Assuming 3-feet of irrigation water applied annually:
EC of 1.0 ds/m = 5,000 lb salt applied to soil each year!

350 ppm Cl will load the soil with nearly 30,000 lbs Cl over a 10 year period

Saline Soils

“Soils which have a electrical conductivity of the saturation extract greater than 4 ds/m (or mmhos/cm).”

1. As soil salts increase, plants require more energy to absorb clean water against a concentration gradient. = “osmotic potential” (drinking from a long straw).
2. Form of stress
3. At higher salt concentrations soil becomes “physiologically dry” even when physically wet.
   - cell destruction
   - desiccation
   - death
4. Accumulation of specific elements to toxic levels
   - species specific
   - sodium, chloride and boron
5. Seedlings and perennial crops with greater sensitivity

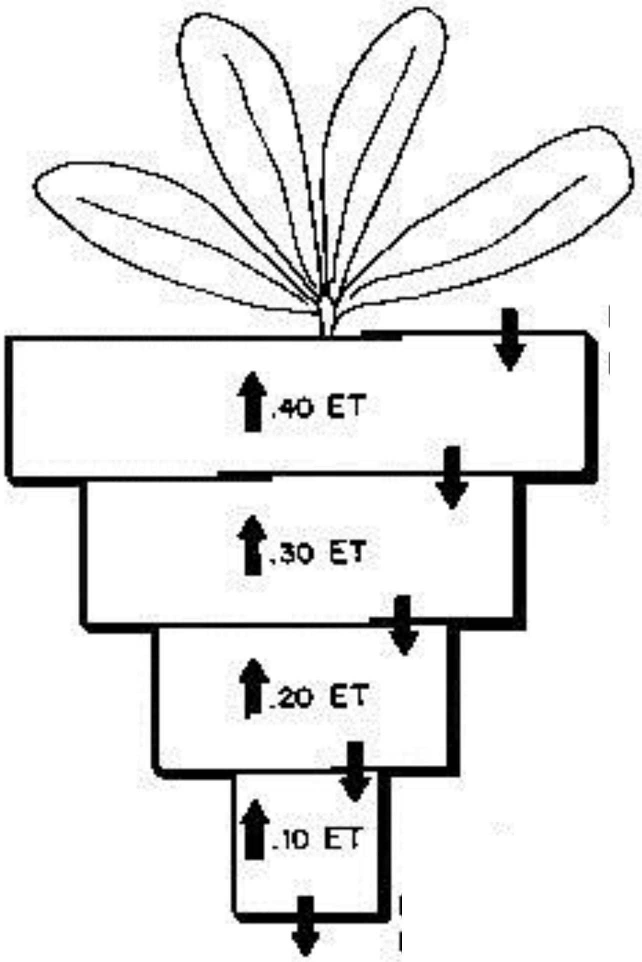
Saline Soils – Sources and Considerations

1. Natural, marine deposits.
2. Change in water source as in new well – test FIRST!
3. Seasonal changes in groundwater quality – drought vs. wet year.
4. Subsurface salt deposits move to surface due to changed water table.
5. If ECe (soil) > 3x ECw (irrigation water) then suspect insufficient leaching fraction or problem with internal drainage.
6. If ECe higher in shallow soil than deeper soil, then suspect shallow water table, restrictive soil layer or insufficient leaching fraction.

Portable water salinity meter:

Change in water table moved previously undetected salts into root zone of wine grapes creating irregularly shaped areas suffering acute salt toxicity.

Generalized Crop Water Use Pattern



Schematic diagram illustrating general crop water use pattern of 40%, 30%, 20% and 10% used in each quarter of the root zone. By maintaining adequate soil moisture and safe salinity levels in the top 50% of the root zone, crops will preferentially obtain their water from the less saltier, shallow water. Only when shallow soil moisture becomes depleted will crops rely on deeper, saltier water that requires greater amounts of energy to absorb.

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Crop Management in a Saline Environment
It's a Matter of Moving Salts Out of the Root Zone

1. Sprinkler and rainfall best – moves salts down.
2. Repeated wet-drain cycles better than continuous ponding – saturated flow less effective at moving salts than unsaturated flow.
3. Soil salinity will never be lower than salt concentration of irrigation water.
4. Don't force crop to forage for saltier water deeper in profile – keep shallow soil moisture adequate.
5. Avoid use of chloride containing fertilizers
6. Remember, fertilizer are salts – use judiciously
7. Minimize salt accumulation in root zone during early stages of plant growth

General Rule of Thumb

- 6" of water moving through the soil will leach approx. 50% of the salts from the top foot
- 12" 80%
- 24" 90%

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Specific Ion Toxicities

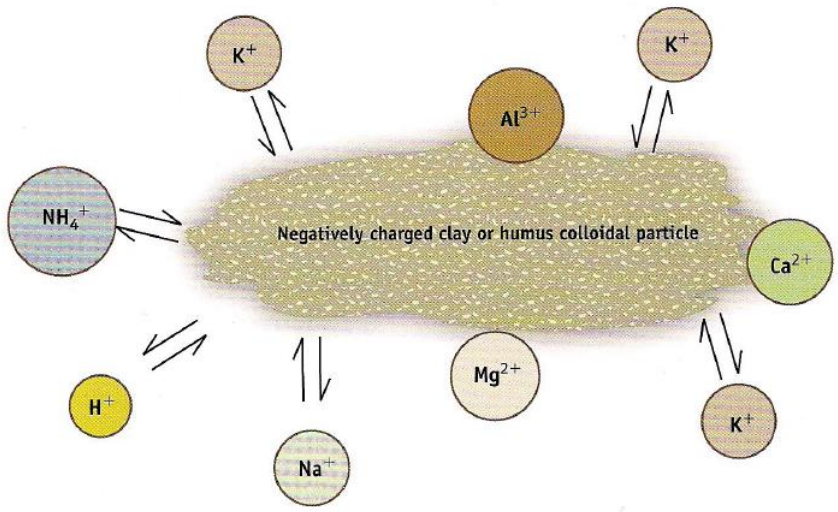
Chloride – very mobile in soil solution
- manage same as soil salts – leaching and drainage
- do not use potassium chloride

Boron - much lower soil mobility (3x water required to leach than Cl)
- lime to raise pH (reduce availability) or gypsum may reduce uptake or improve soil drainage – inconsistent
- check water source and change if possible.
- do not use foliar B to enhance fruit set where naturally occurring boron levels are high

Cl and B Toxicity threshold values for soil or irrigation water have not been established for all crops. Use tissue analysis to confirm cause of suspected toxicity situation.

Sodium

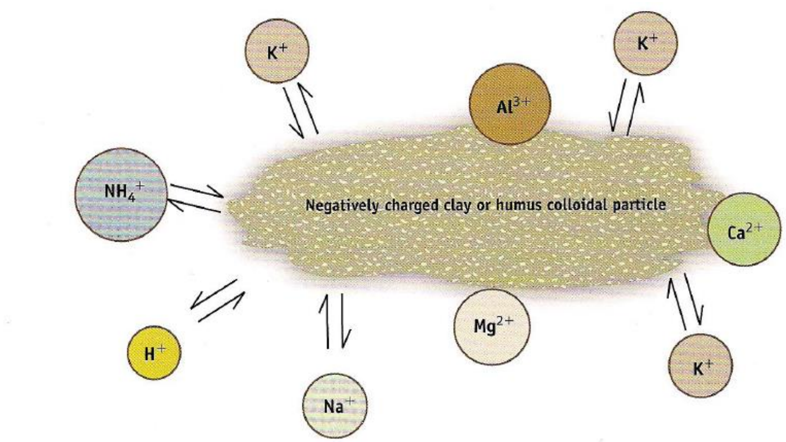
A. The Sodium and Bicarbonate Link

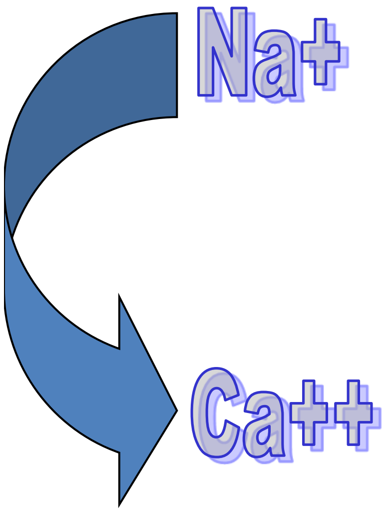


Displacement Series: H > Ca > Mg > K > Na

Sodium

A. The Sodium and Bicarbonate Link





$$Ca + 2HCO_3 \xrightarrow{\text{Upon drying}} CaCO_3 + CO_2 + H_2O$$

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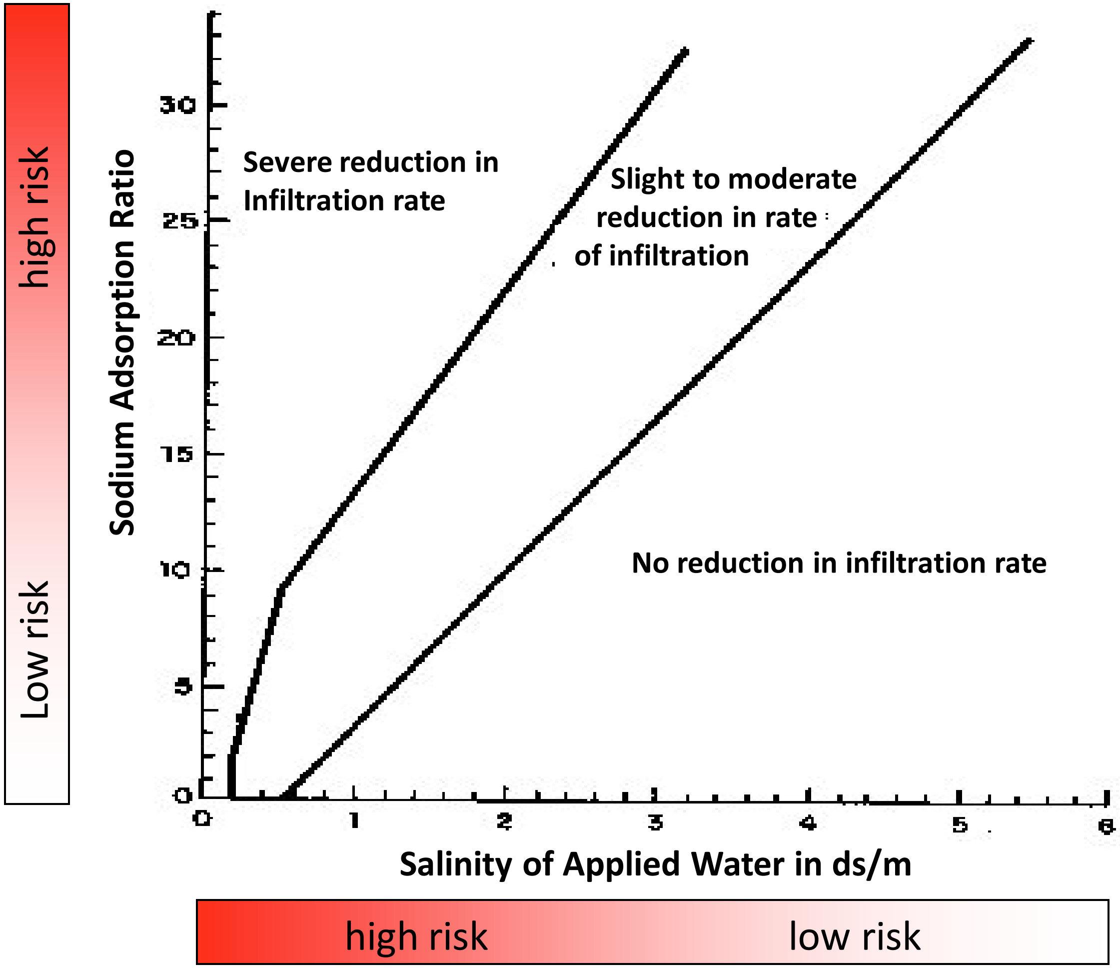
B. The Sodium and Salinity Link - Infiltration



Physical Soil Quality

Rearrangement of Soil Particles

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A. Structural Crust

Surface run-off and ponding indicating poor infiltration is common where very pure, low-salt irrigation water is used.

Description: Rainfall or irrigation containing very low levels of dissolved salts (<0.3 ds/m) causes leaching of calcium from soil surface. Lack of calcium causes soil to collapse sealing off soil surface. Crusts usually very thin (<0.25-0.5").

Distribution: Common where snowmelt irrigation water is used. Less common on coast, coastal valleys and arid interior.

Solution: Adding salt (gypsum) to irrigation water or on soil surface to be dissolved by irrigation water. Do not incorporate.

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Water and Nutrient Management Considerations

- Quality
- Quantity
- Positional Availability

Nutrients Contained in Irrigation Water

- Nitrate, sulfate, calcium, magnesium, boron and chloride contribution may be significant
  - ppm x 4 = lb/acre-foot of water
- P, K, Zn, Fe, Mn, Cu, Mo usually not contained at significant levels

Potassium
Factors Affecting Availability

1. **High Cation Exchange Capacity:**
   - * Larger "magnet" fixes K aggressively
   - * Heavy soils have higher CEC than lighter textured soils
2. **High Shrink-Swell Soils:**
   - * Clay particles swell when wet, shrink when dry
   - * K trapped between lattice upon shrinking
   - * For 2:1 clays only (montmorillonite, illite)
3. **Extremes in Soil Moisture:**
   - * **Saturation excludes oxygen required for root activity**
   - * **Dry soil means no nutrients in solution**
4. **Compaction or hard pan:**
   - * Restricts root exploration of soil – smaller root mass
   - * Common when wet ground mechanically tilled
5. **Excess Magnesium or Sodium**
   - * Cation competition
6. **Root Damage**
7. **Excess N Rates**

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Water Quality Considerations for Low Volume Irrigation Systems

STOP

Don't Assume – Test First!

Due to the low volume of irrigation water applied and the reduced volume of soil wetted, problems associated with water quality are usually exaggerated under drip:

* Total dissolved solids (TDS = ECw x 640)
* Chloride
* Boron
* Sodium

In addition low volume irrigation presents challenges unique to this form of irrigation management:

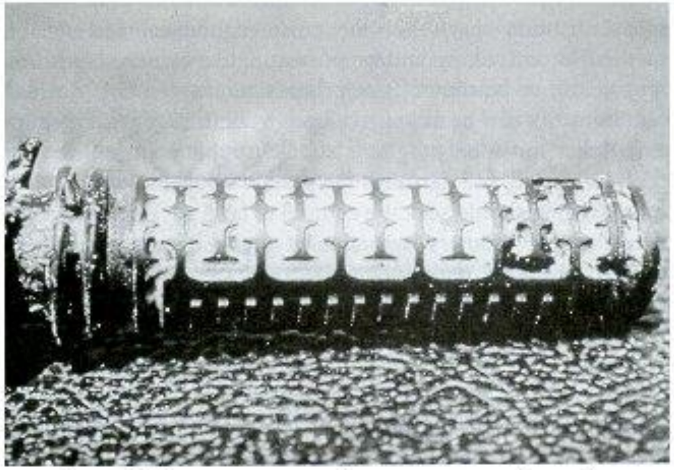
* Bicarbonate and calcium
* Iron and manganese
* Algae, bacterial slimes, suspended solids
* Fertilizer injection

Problems Unique to Low Volume Irrigation
Mineral Precipitation

Limestone formation leading to plugging of emitters

$$Ca + 2HCO \xrightarrow{\text{upon drying}} CaCO_3 + CO_2 + H_2O$$

Plugged emitter with cover removed to show precipitate formed in flow channels.



Plugged drip emitter with cover removed to show precipitate formed in flow channels.

Regular injection of acids to prevent precipitate formation (pH 5.5-6.5) or periodic acid shock treatments to dissolve precipitates (pH 3-4) are the prescribed remedies.

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Problems Unique to Low Volume Irrigation
Mineral Precipitation

Iron or manganese at very low concentrations may form troublesome precipitates when water is aerated. Usually restricted to well waters. Iron and manganese precipitate are tenacious and difficult to remove.

Avoidance is best remedy. Test water before designing system. If iron or manganese are over **0.3-0.5 ppm**, then aeration and settling ponds provide the most reliable and trouble free solution. Scale inhibitor compounds injected on a continuous basis offer some promise.

Phosphorous

Reaction with Calcium

Liquid P injected in buried drip system reacts with calcium carried in the irrigation water forming insoluble mono calcium phosphate.

•Injecting to maintain P_2O_5 below 200 ppm may minimize or negate formation of calcium phosphate precipitate.

*Can be avoided by dual acid injection (pH < 4.5)

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Calcium Phosphates also Called "Rock Phosphate"

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Phosphate Fertilizer Precipitation Test

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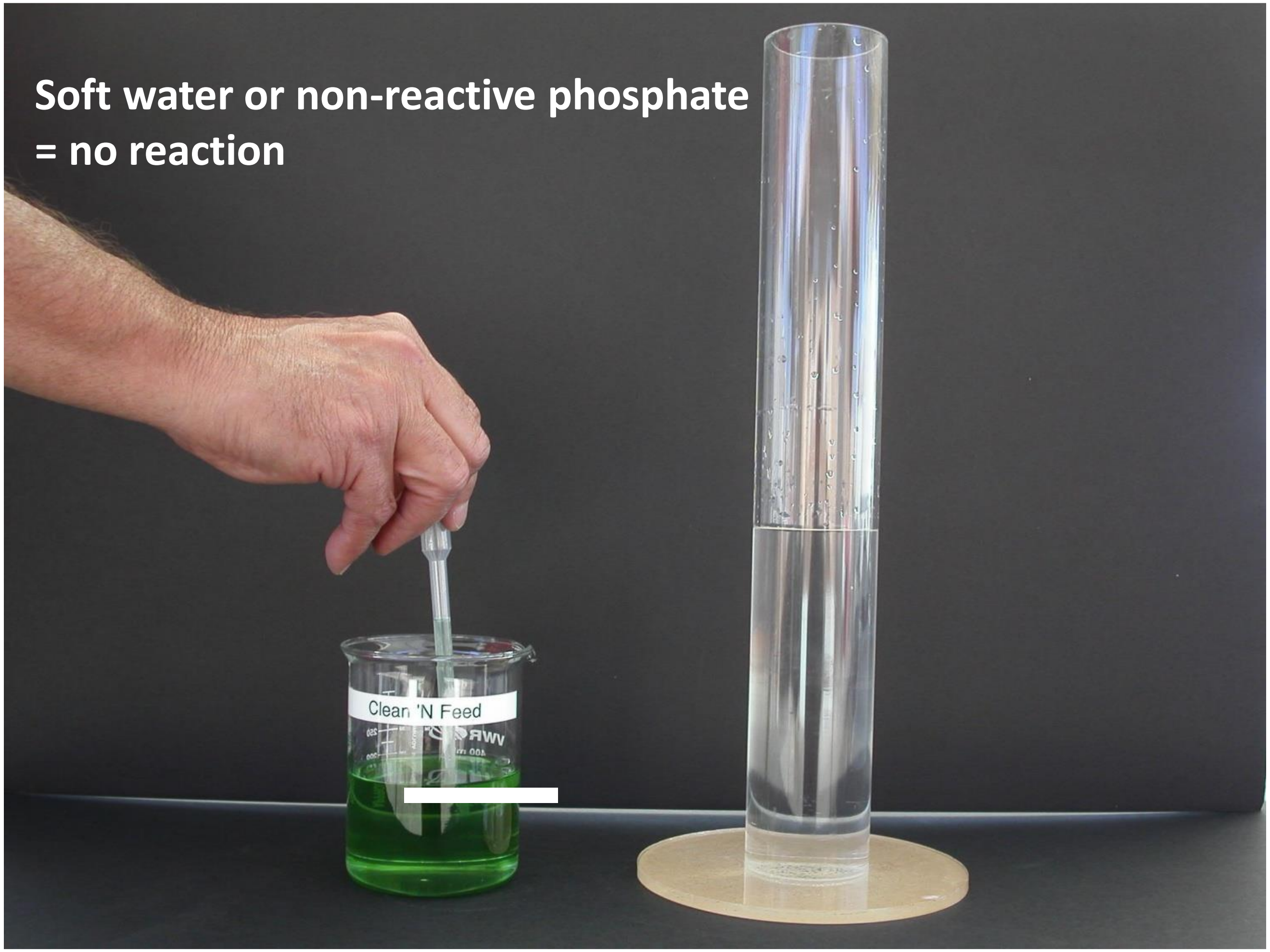
Phosphate Fertilizer Precipitation Test



Water Analysis by the Numbers

Factor	Effect	Prefered Range
ECw	Poor infiltration	> 0.5 mmhos/cm
	Salt toxicity	< 1.0 mmhos/cm
TDS	Poor infiltration	> 320 ppm
	Salt toxicity	< 640 ppm

Water Analysis by the Numbers

Factor	Effect	Prefered Range
SAR	Infiltration	< 3
	Toxicity	< 3

Water Analysis by the Numbers

Factor	Effect	Prefered Range
Chloride	Toxicity	< 5 meq/l < 175 ppm
Boron	Toxicity	< 0.5 ppm

Water Analysis by the Numbers

Factor	Effect	Prefered Range
Bicarbonate	Speckling	< 1.5 meq/l < 90 ppm

Water Analysis by the Numbers

Factor	Effect	Prefered Range
Ca:Mg:K	Soil structure, nutrition	4:2:1 as meq/l

Water Analysis by the Numbers

Factor	Effect	Prefered Range
Calcium	Clogging emitters	< 2 meq/l < 40 ppm
Bicarbonate		< 2 meq/l < 120 ppm
Iron		< 0.3 ppm
Manganese		< 0.3 ppm
Hydrogen sulfide		< 0.5 ppm
Bacterial populations		< 10,000/ml

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WATER ANALYSIS RISK INTERPRETATION GUIDE

		Degree of Risk		
Potential Irrigation Problem	**Units**	**None**	**Slight to Moderate**	**Severe**
pH			Normal range 6.5 - 8.4	
Salinity (affects crop water availability)				
ECw (or) TDS	dS/m or mmhos/cm mg/L*	< 0.7 < 450	0.7-3.0 450-2,000	> 3.0 > 2,000
Infiltration (affects soil infiltration rate)				
SAR = 0-3 and EC_w =		> 0.7	0.7-0.2	< 0.2
SAR = 3-6 and EC_w =		> 1.2	1.2-0.3	< 0.3
SAR = 6-12 and EC_w =		> 1.9	1.9-0.5	< 0.5
SAR = 12-20 and EC_w =		> 2.9	2.9-1.3	< 1.3
SAR = 20-40 and EC_w =		> 5.0	5.0-2.9	< 2.9
Specific Ion Toxicities				
Sodium (Na)				
Surface irrigation	SAR	< 3	3-9	> 9
Sprinkler irrigation	meq/l	< 3	> 3	
Chloride (Cl)				
Surface irrigation	meq/l	< 4	4-10	> 10
Sprinkler irrigation	meq/l	< 3	> 3	
Boron (B)	mg/L*	< 0.7	0.7-3.0	> 3.0
Bicarbonate (HCO_3) (Overhead sprinkling only)	meq/l	< 1.5	1.5-8.5	> 8.5
Clogging Micro-irrigation Systems				
Suspended solids	ppm	< 50	50-100	> 100
Dissolved solids	ppm	< 500	500-2,000	> 2,000
pH		< 7.0	7.0-8.0	> 8.0
Iron (Fe)	ppm	< 0.1	0.1-1.5	> 1.5
Manganese (Mn)	ppm	< 0.1	0.1-1.5	> 1.5
Hydrogen sulfide (H_2S)	ppm	< 0.5	0.5-2.0	> 2.0
Bacterial populations	#/ml	< 10,000	10,000-50,000	> 50,000
Miscellaneous Effects				
pH normal range 6.5-8.0 NO_3-N ppm x 2.72 = lb N/acre-foot of water NO_3 ppm x 0.612 = lb N/acre-foot of water EPA limit for nitrates 10 ppm for drinking water				

* mg/l interchangeable with ppm.

Interpretive guidelines provided above are generalized.
Crop specific table should be referenced for more accurate risk evaluations for boron, chloride and total salts.
For each of the risks presented (salinity, infiltration, specific ion toxicity, miscellaneous and clogging micro-irrigation systems), locate the specific factor and unit to determine the risk for that factor. For example, boron at 3 ppm or greater presents a severe toxicity risk.


Thank You!