Water Testing and Interpretation

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Water Quantity and Quality

- Soilless systems (container production, raised-bed production or hydroponics) require intensive management of water and nutrients for optimal plant growth and production
- Irrigation water quality impacts….
  - Nutrient levels and availability
  - Chemical characteristics of the soilless growth substrate
- Test irrigation water source before starting a crop and possibly during production

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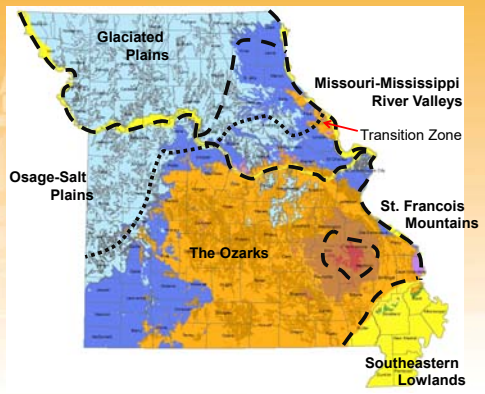
Groundwater Regions in Missouri



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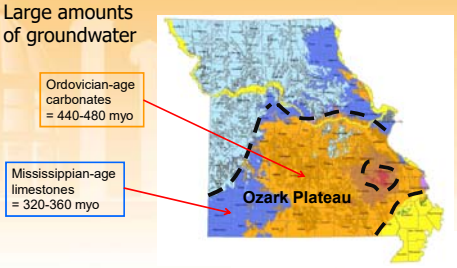
Typical Geology of the Ozark Plateau

- Includes the Salem Plateau & Springfield Plateau
- Underlain by highly permeable limestone and dolomite bedrock (karst)
- Large amounts of groundwater



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Ozarks Plateau Aquifer System

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What is Karst?

- A geologic landscape characterized by the presence of:
  - Sinkholes
  - Caves & underground drainage systems
  - Losing streams
  - Springs
- Created as groundwater dissolves underlying bedrock such as limestone or dolomite

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Karst Map of the U.S.

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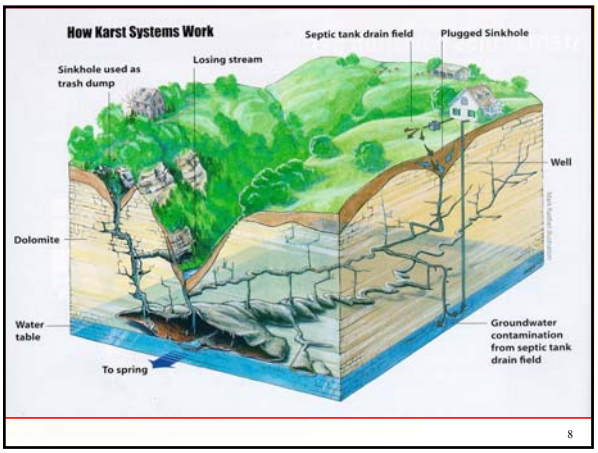

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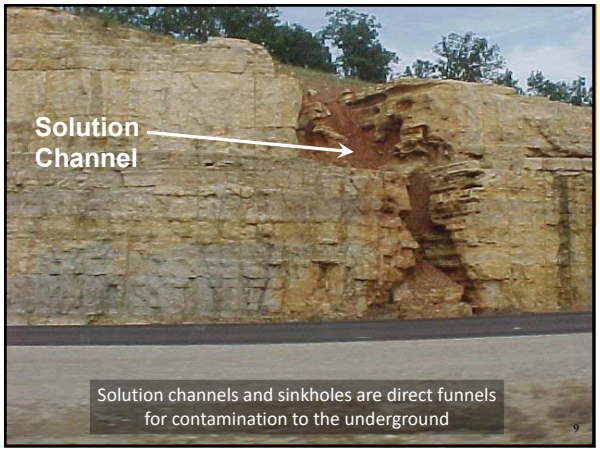

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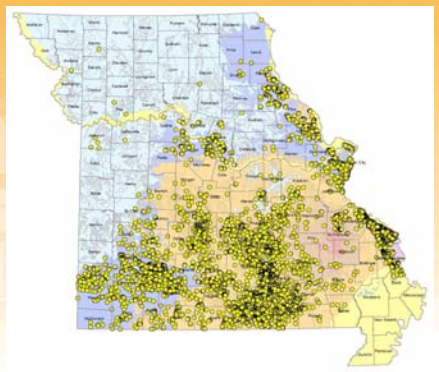
Where are the Sinkholes ?



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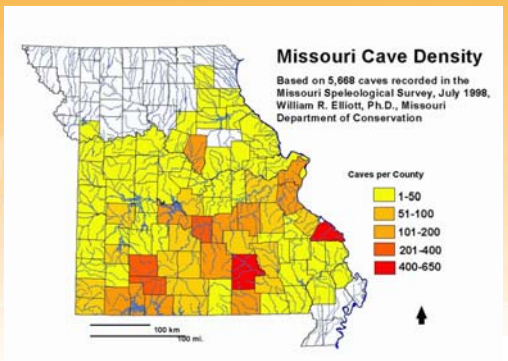
Where are Missouri Caves ?



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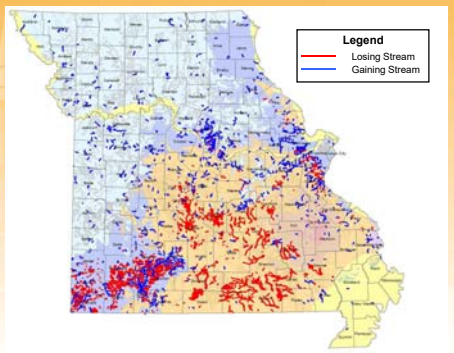
Where are Losing & Gaining Streams?



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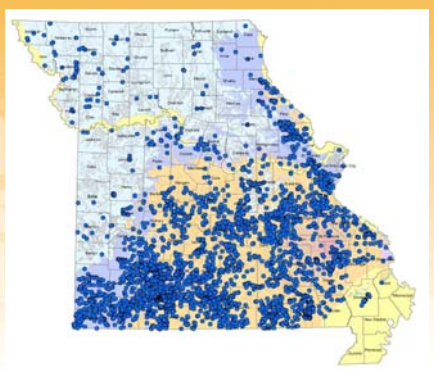
Where are the Springs ?



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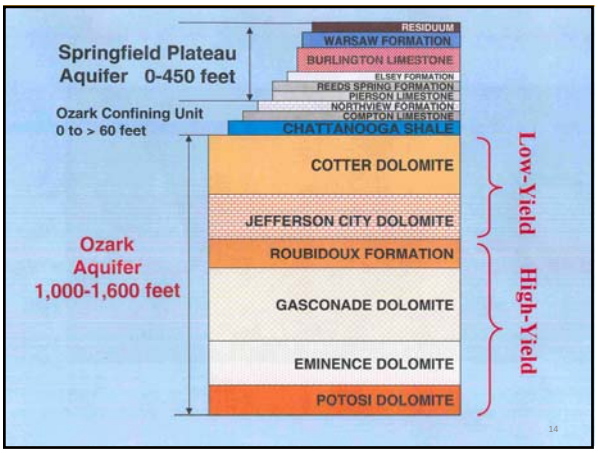

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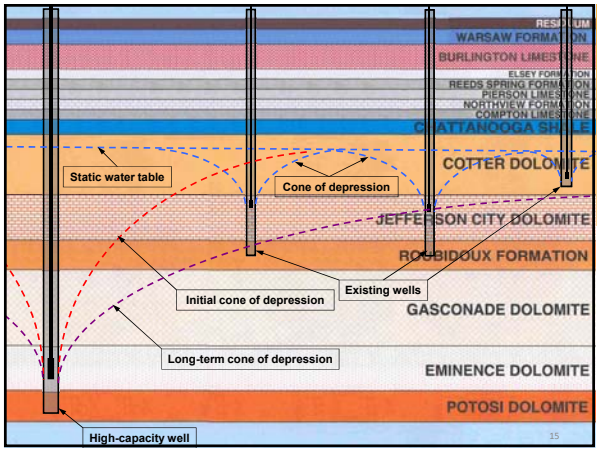

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Water Source Quality

Good

Poor

- Well = check pH & hardness
- Municipal = may be expensive
- Spring = may not be dependable
- River or stream = depends on runoff
- Lake or pond water = sand filters
- Pump to tank on hill = limited use

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Water Quality Factors

- Biological (organic) = bacteria, algae, slime
- Physical (inorganic) = sand, silt
- Chemical
  - pH, alkalinity
  - Electrical Conductivity (EC)
  - Hardness
  - Sulfates & chlorides
  - Carbonates (calcium)
- Plant macronutrients
  - N, P, K, Ca, Mg, S
- Plant micronutrients
  - Fe, Cu, Mg, Zn, Al, B

PVC Casing

Steel Casing

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Water Troubleshooting Guide

Problem	Cause
Green or slimy matter in surface water	Algae or fungi
Turbidity (muddy water)	Suspended clay and silt
White precipitate or film on tape or around emitters	Carbonate precipitation
Reddish-brown precipitate or slime around emitters	Oxidized (ferric) iron precipitation
Water initially clear (no oxygen), but turns red/orange in presence of air	Clear water dissolved (ferrous) iron
Black sandy particles	Iron sulfide precipitation
Black precipitate	Manganese precipitation
Reddish brown slime near emitters	Bacteria feeding on iron
White stringy masses of slime near emitters	Bacteria feeding on sulfur

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Sources for Water Testing

- County health department – bacteria
- University of Missouri (Columbia)
  http://soilplantlab.missouri.edu/soil/water.aspx

  Complete test ($60) = hardness, pH, nitrate-N, sulfate, phosphate, chloride, calcium, magnesium, sodium, SAR, potassium, carbonate, bicarbonate, alkalinity, iron, copper, manganese, zinc, aluminum, silica, electrical conductivity, total dissolved solids, w/o interpretation
- Commercial labs
  https://www.midwestlabs.com (Omaha, NE)
  http://www.waypointanalytical.com (Memphis, TN)

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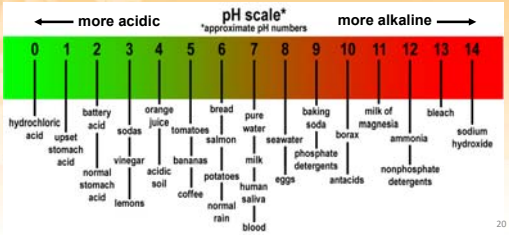
pH

- pH is the measure of the relative concentration of hydroxide ion (OH-) and hydrogen ion (H+) present in the water. pH is measured on a scale of 1 to 14 with 7 being neutral.



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pH

- pH affects the solubility of fertilizers and the efficacy of pesticides and growth regulators
  - The higher the water pH the less soluble these materials are
- Preferred pH
  - Greenhouses = 5.2 to 6.8
  - Substrate solution = 5.4 to 6.3
  - Fruit and vegetable crops = 6.0 to 7.0
  - Pesticide effectiveness = 5.5 to 7.0 (read label)
  - pH <6.0 causes pipe corrosion
  - pH >8.0 causes clogging

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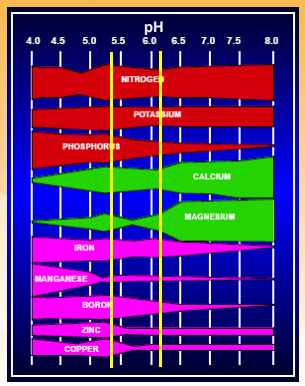
Influence of pH on nutrient availability*



*based on a soilless substrate containing sphagnum peat moss, composted pine bark, vermiculite, and sand

Reference: www.ces.ncsu.edu/depts/hort/hil/hil-558.html

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Problems Associated With Improper pH

Low pH	High pH
• Toxic: – Iron – Manganese – Zinc – Copper • Deficient – Calcium – Magnesium • Sensitive – Ammonium-N	• Deficient: – Iron – Manganese – Zinc – Copper – Boron

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pH Adjustment

- Raise pH
  - Use fertilizer with lower acid residue
    - ammonium vs. nitrate
    - calcium compounds
  - Apply limestone
    - calcitic -- $CaCO_3$
    - dolomitic -- $CaMg(CO_3)_2$
    - hydrated -- $Ca(OH)_2$

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GUARANTEED ANALYSIS

NET WEIGHT 25 POUNDS (11.34 KG)

PETERS® ACID SPECIAL 21-7-7

GUARANTEED ANALYSIS

TOTAL NITROGEN (N) 21%

9.05% AMMONIACAL NITROGEN

11.95% UREA NITROGEN

AVAILABLE PHOSPHORIC ACID (P_2O_5) 7%

SOLUBLE POTASH (K_2O) 7%

Primary Plant Nutrient Sources: Urea, Ammonium Phosphate, Ammonium Sulfate, Muriate of Potash.

Potential Acidity 1560 lbs. Calcium Carbonate Equivalent Per Ton.

Manufactured by: Peters® Fertilizer Products, W. R. GRACE & CO., Fogelsville, Pa. 18051

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pH Adjustment

- Lower pH
  - Use fertilizer with acid residue
  - Apply sulfur-containing compounds

    $S + O_2 + H_2O \longrightarrow H_2SO_4 \longrightarrow 2\ H^+ + SO_4^{-2}$

    (requires action of microbes)
  - Sulfuric acid

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GUARANTEED ANALYSIS

NET WEIGHT 25 POUNDS (11.34 KG)

PETERS® GENERAL PURPOSE SPECIAL 20-10-20

GUARANTEED ANALYSIS

TOTAL NITROGEN (N) 20

12.00% NITRATE NITROGEN

8.00% AMMONIACAL NITROGEN

AVAILABLE PHOSPHORIC ACID (P_2O_5) 10

SOLUBLE POTASH (K_2O) 20

Primary Plant Nutrient Sources: Ammonium Nitrate, Ammonium Phosphate, Potassium Nitrate.

Potential Acidity 422 lbs. Calcium Carbonate Equivalent Per Ton.

Manufactured by: Peters® Fertilizer Products, W. R. GRACE & CO., Fogelsville, Pa. 18

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Alkalinity

- Alkalinity establishes the buffering capacity of water and affects how much acid is required to change the pH
  - Don't confuse with alkaline pH
- Alkalinity of the irrigation water has more effect on the substrate pH than the pH of the water
- pH will change much more gradually in large containers (more substrate volume) than small containers or individual cells in a plug tray

Reference: www.ces.ncsu.edu/depts/hort/hil//hil-558.html

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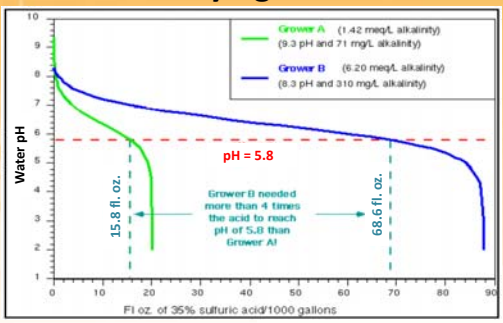
Influence of Alkalinity on Acidifying Water



Reference: www.ces.ncsu.edu/depts/hort/hil//hil-558.html

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Alkalinity

- Recommended ranges & solutions
  - <150 ppm = no problem expected; 100 ppm is high for plug production
  - 150 to 300 ppm = increasing concern if the water pH is >7.5. Use acidifying fertilizers regularly, and use a more acid growing substrate
  - >300 ppm = significant problems if the water pH is >7.5. Acid injection into the irrigation water may be the only remedy

References: www2.ca.uky.edu/agcomm/pubs/HO/HO111/HO111.pdf
https://content.ces.ncsu.edu/alkalinity-control-for-irrigation-water-used-in-nurseries-and-greenhouses

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Electrical Conductivity (EC)

- EC represents the ability of water to conduct an electric current and is an indicator of the soluble salts, or mineral content, of water
- Higher conductivity means more salts in the water, which can lead to plant injury under certain conditions
- EC values for irrigation water:
  - Excellent = 0-500 µS/cm (max. near 0 for hydroponics)
  - Good = 501-1,500 µS/cm (max. 1,000 for potted plants)
  - Fair = 1,501-3,000 µS/cm
  - Poor = 3,001-5,000 µS/cm

Standard - metric conversion: 1 µS/cm = 1 µmho/cm
1 mS/cm = 1 mmho/cm = 1,000 µmhos/cm

Reference: https://extension.tennessee.edu/publications/Documents/SP740-B.pdf

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Checking Injector/Calculations

- Fertilizer companies supply tables of EC values for each of their fertilizers at various concentrations

20-10-20 peat-lite special
- **200 ppm = EC of 1.30**
- **250 ppm = EC of 1.63**
- **300 ppm = EC of 1.95**

- Check accuracy with salts meter every time new batch of stock is mixed

Reference: http://www.4oakton.com/proddetail.asp?parent=2&prod=352&seq=2&Totrec=13

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Hardness

- Hardness is a measure of dissolved minerals (usually calcium and magnesium) in the water
- Hard water sediment can clog irrigation systems
  - <150 ppm or <9 gpg preferred
- Check Ca:Mg ratio if water has high alkalinity or hardness
  - Ratio should be 3 to 5 Ca : 1 Mg
  - High Mg can block calcium absorption leading to calcium deficiency
- Check sodium absorption ratio (SAR) if sodium is high in irrigation water
  - SAR value >4 can cause plant uptake of damaging sodium

Conversion factors:
1 part per million (ppm) = 1 milligram per liter (mg/L) = grains per gallon (gpg) x 17

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Preferred Plant Macronutrient Levels in Irrigation Water

- Nitrate-Nitrogen (NO_3-N) = 0 to 5 ppm
- Phosphorus (P) = 0 to 3 ppm
- Potassium (K) = 0 to 10 ppm
- Calcium (Ca) = >60 ppm
- Magnesium (Mg) = 25 to 50 ppm

Reference: http://www2.ca.uky.edu/agcomm/pubs/HO/HO111/HO111.pdf

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Preferred Plant Micronutrient Levels in Irrigation Water

- Iron (Fe) = 0 to 1 ppm
- Copper (Cu) = 0 to 0.2 ppm
- Manganese (Mn) = 0 to 1 ppm
- Zinc (Zn) = 0 to 0.3 ppm
- Boron (B) = 0 to 1 ppm
- Sodium (Na) = 0 to 50 ppm

Reference: http://www2.ca.uky.edu/agcomm/pubs/HO/HO111/HO111.pdf

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Plugging Potential of Drip Irrigation Systems

Factor	Moderate (ppm)*	Severe (ppm)*
Physical		
Suspended solids	50-100	>100
Chemical		
pH**	7.0-7.5	>7.5
Dissolved solids	500-2000	>2000
Manganese	0.1-1.5	>1.5
Iron	0.1-1.5	>1.5
Hardness***	150-300	>300
Hydrogen sulfide	0.5-2.0	>2.0

* ppm = mg/L ** pH is unitless *** Hardness: ppm = gpg x 17

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Chemical Water Treatment

- Useful to manage both inorganic and organic problems
- Goals of chemical treatment
  - Cause some particles to settle out or precipitate
  - Cause some particles to remain soluble or to dissolve
- Place filtration after chemical treatment
- Backflow prevention is critical

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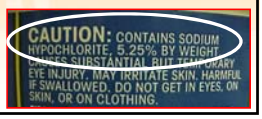
Chemical Water Treatment

- Chlorine
  - Kills microbial activity (algae, bacteria)
  - Decomposes organic materials
  - Oxidizes soluble minerals, causing them to precipitate out of solution
  - Chlorine (<6 mo. old) needs "contact time"
  - Powdered HTH can plug emitters



Shock-Chlorinating Your 6-inch Diameter Well ₁

- Remove well cap or unscrew vent pipe

Newer wells

Older wells

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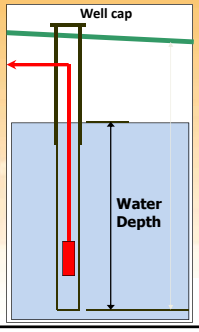
Shock-Chlorinating Your 6-inch Diameter Well ₂

- Mix chlorine and water in bucket. Pour into well
  - Liquid bleach @ 1 pint per 25' of water depth, or
  - Chlorine pellets @ 0.5 lb. per 150' of water depth
- Circulate water back down well
- Load chlorinated water into plumbing system



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Shock-Chlorinating Your 6-inch Diameter Well ₃

- Let chlorine water stand in system at least 4 hours
- Flush system with water, starting outside
- Retest for bacteria after 7-10 days
  - $10 cost; county DHSS office has sterile sample bottle
  - Keep sample cool and dark, get to lab in 6 hours
- Keep test results with important papers

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Chemical Water Treatment

- Chlorine
  - Chlorine concentration of 10-20 ppm for 30-60 minutes daily
  - Work by sections through the system, flushing out lines after treatment
  - If emitters are plugged, higher concentrations of chlorine may be needed to decompose organic matter

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Chemical Water Treatment

- Acid treatment
  - Lowers water pH
  - Help acidify soil for plants (blueberries)
  - Maintains solubility or dissolves manganese, iron, and calcium precipitates
  - Make chemicals work better
- Potassium permanganate
  - Oxidizes iron, causing it to precipitate

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Chemical Water Treatment

- Acid injection rate calculation
  - Amount of acid needed to treat a system
    - Strength of acid used
    - Buffering capacity of the irrigation water (alkalinity)
    - Desired pH of water
  - Perform a titration to determine the acid volume : water volume ratio
- Calibration of injection pumps is critical

Resource: http://extension.uga.edu/publications/detail.html?number=B1130

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Chemical Water Treatment

- Calcium salts (carbonates, phosphatics)
  - Water pH >7.5, bicarbonate levels >100ppm
  - Acid injection
    - Target pH 4.0 or lower for 30 to 60 minutes/daily
    - Sulfuric, phosphoric, hydrochloric, or citric acid used
    - Flush and clean injector
  - Water softening (household systems)

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Three Steps for Iron Removal

- An **oxidizer** is added to the water, which induces **precipitation** of the iron and hydrogen sulfide, and the precipitated contaminant is then **filtered** out of the water
- pH control
  - Low pH (2.0) – iron dissolves
  - High pH (7.2+) – iron precipitates

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Iron Removal Options

- Iron bacteria
  - Chlorine + retention + filtration
- Ferric (red rust) iron
  - Filter, but may require use of coagulant
- Ferrous (clear water) iron < 5 ppm
  - Ion exchange with resin bed, fouls easily

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Iron Removal Options

- Ferrous (clear water) iron 5+ ppm
  - Aeration + retention + filtration
  - Hydrogen peroxide + retention + filtration
  - Ozone (strong oxidizer) + retention + filtration
  - Chlorine (as a gas, calcium hypochlorite, or sodium hypochlorite at 1 part Cl : 1 part Fe) + retention + filtration (by manganese greensand, anthracite/greensand or activated carbon) Greensand is then regenerated by using potassium permanganate (at 0.2 parts of pot. perm. : 1 part of iron)
  - Oxidizing filter media (pyrolusite ore) + backwash it at 25 to 30 gallons per sq. ft.
  - Manganese greensand (high capacity & high flow). Regenerate it with potassium permanganate at 1.5 to 2 oz. per cubic foot of greensand

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Sources for Testing Equipment

- pH, EC, TDS, Salinity, Temperature meter
  - Oakton® PCS Testr 35 ($150-$175) www.4oakton.com/proddetail.asp?parent=2&prod=352&seq=2&Totrec=13
  - Hach® Pocket Pro+ Multi 2 ($200) https://www.hach.com/pocket-pro-multi-2-tester-for-ph-cond-tds-salinity-with-replaceable-sensor/product?id=17990686217

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Sources for Testing Equipment

- Chlorine, Hardness, Iron, and pH Test Kit
  - Hach® Model CN-39WR ($220) https://www.hach.com/chlorine-hardness-iron-and-ph-test-kit-model-cn-39wr/product?id=7640217331

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Irrigation Resources on the Web

- Irrigation System Planning & Management Links extension.missouri.edu/webster/irrigation.aspx
- Wells and drilling guidance https://dnr.mo.gov/geology/geosrv/wellhd/
- Ag Site Assessment Tool agsite.missouri.edu

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Questions??

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  Room 326-W, Whitten Building
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