Water Quality for High Quality Crops

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¡Se habla Español!

Take-Home Message #1:
Understand the risks and benefits of each water source.

Know what is in your water!

Water sources differ in quality

Call the food safety inspector!

- High-quality sources: Municipal treated, wells, rainwater, and reverse osmosis.

  Recirculated nutrient solutions

- Low-quality sources: surface water

Water quality parameters

1. **Chemical:** pH, total concentration of salts, specific salts, dissolved oxygen, and agrochemicals
2. **Microbial:** good and bad, algae, biofilm
3. **Physical:** organic particles or inorganic precipitates, temperature

Water sources differ in quality & risk of problems

- Low risk:
  RO, rainwater, deep wells, & municipal
- Intermediate risk:
  Shallow wells
- Higher risk:
  Surface water (pond, lake, rivers)
  Agricultural wastewater

Photo: Paul Fisher, UF

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Water source	Potential Risks
Drinking water	**Chemical:** Chlorine (i.e. bleach) & fluoride
Deep wells	**Chemical:** iron, manganese, & calcium **Microbial:** iron oxidizing bacteria
Rainwater and reverse osmosis-treatment	None. **Storage:** microbial load or physical solids

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Water source	Potential Risks
Shallow wells	**Chemical:** pesticides, herbicides, and fertilizers **Microbial:** plant pathogens **Physical:** sediments
Rainwater and reverse osmosis-treatment	None. **Storage:** microbial load or physical solids
Recirculated water	**Chemical:** pesticides, herbicides, fertilizers, PGRs **Microbial:** plant pathogens, algae, and biofilm **Physical:** organic suspended solids

Take-Home Message #2
Start with the highest quality of water possible.

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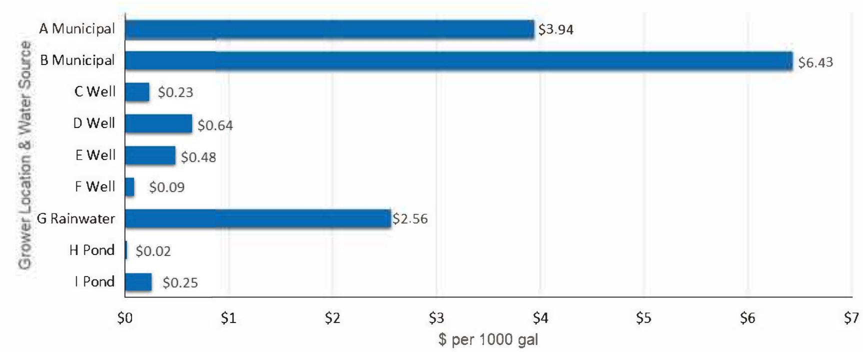
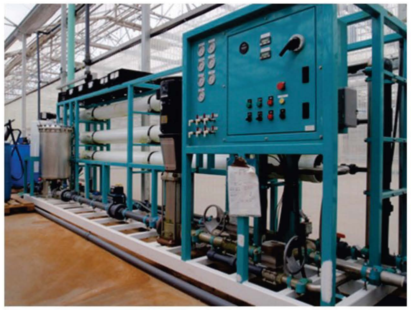
Cost of irrigation water

High quality water is expensive



Reverse Osmosis (RO) : Membrane filtration (<1 micron)



- RO removes all elements from the solution, except boron.
- **Pros:** It's a clean sheet.
- **Con:** Expensive, specialized and recurrent maintenance, removes elements that are essential for the plant, & it can be corrosive.

Take-Home Message #3: Not everyone needs RO.

Test the suitability of water source for irrigation:

Complete nutrient analysis

Check:

- ✓ Total salts (EC)
- ✓ Individual elements
- ✓ pH
- ✓ Alkalinity ("dissolved limestone")

EMW-400 : Water Irrigation Suitability

Components		Results mg/L	meq	Target Ranges (mg/L)	Acceptable (mg/L)
MAJOR CATIONS					
Potassium	K	3.73	0.10		<100
Calcium	Ca	11.22	0.56	25 - 75	<150
Magnesium	Mg	3.23	0.27	10 - 30	<50
Sodium	Na	40.54	1.76	0 - 20	<50
MAJOR ANIONS					
Phosphate	PO4	0.71	0.02		<90
Sulfate	SO4	18.97	0.39	0 - 120	<240
Chloride	Cl	41.00	1.14	0 - 20	<140
HCO3 Alkalinity	HCO3	45.87	0.75		
CO3 Alkalinity	CO3	0.00	ND		
Ammonium Nitrogen	NH4-N	ND			<10
Nitrate Nitrogen	NO3-N	ND			<75
pH	pH	7.10		5.50 - 7	4-10
Soluble Salts	EC	0.26		0.20 - 0.80	0-1.5
Total Alkalinity	CaCO3	37.60		40 - 160	0-400
Iron	Fe	0.16		< 1	<4
Manganese	Mn	0.01		< 1	<2
Boron	B	0.04		< 0.10	<0.5
Copper	Cu	0.06		< 0.10	<0.2
Zinc	Zn	0.05		< 0.50	<1
Molybdenum	Mo	0.02		< 0.10	<0.2
Aluminum	Al	0.16			

Factors that limit water suitability

Element	Ideal	High
Electrical conductivity (mS/cm)	< 0.5	>1.0
Sodium (ppm)	<30	>60

Water EC >0.5 mS/cm requires further analysis.

Ranges in between are manageable, but should not be recirculated.

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Electrical Conductivity

- Electrical conductivity (EC) is an **indicator of the total concentration of salts in the solution**.
- Essential or non-essential elements.
- Ions in that contribute to EC:
  - **In water: Ca^{+2}, Mg^{+2}, SO_4^-, Na^{+2}, Cl^-, HCO_3^-**
  - In fertilizers: NO_3^-, NH_4^+, PO_4, K^+, Ca^{+2}, Mg^{+2}, SO_4^-, Cl^-

Units: 1 mS/cm = 1000 µS/cm = 1dS/m=1 mmhos/cm = 1000 µmhos/cm

Essential elements in water: adjust NS

Nutrients (ppm)	Water	Target	Action
Nitrate-N	ND	125-225	None
Ammonium- N	ND	5-10	None
Potassium	3.7	200-350	None
Calcium	50	120-180	Add 40 ppm (use alternative N-source)
Magnesium	3.3	30-60	None

Nitrogen in the water source indicates agricultural contamination.

Specific ions that limit water suitability

Element	Ideal	Excessive
Chloride (ppm)	<50	>100
Iron (ppm) TOTAL	<1.0	>4.0

Tomatoes tolerate up to 100 ppm chloride.
Cucumbers are sensitive to chloride.

Iron can be removed with potassium permanganate + filtration.

Classification Water Quality

Class	EC (mS/cm)	Sodium (ppm)	Chloride (ppm)	Notes
1	0.5	<30	<50	Good for all purposes
2	0.5-1.0	30-60	50-100	Only when leaching is an option
3	1.0-1.5	60-90	100-150	Not recommended for sensitive crops (cucumber)

Management options:

1. Know the crop's tolerance to specific ions. For ex.,Tomato can grow with up to 100 ppm Cl (OMAFRA, 2010).
2. Use alternative water sources: replace the source or dilute (RO + non-RO).
3. Remove salts: reverse osmosis or ion exchanger.
4. Do not use closed-irrigation systems with low-quality water.
5. Adjust fertilizer program (Ions of the same charge "compete")
   - Increase cations to prevent sodium damage
   - Reduce Ca^{+2}, Mg^{+2}, SO_4^- from fertilizer program

Water pH affects nutrient solubility

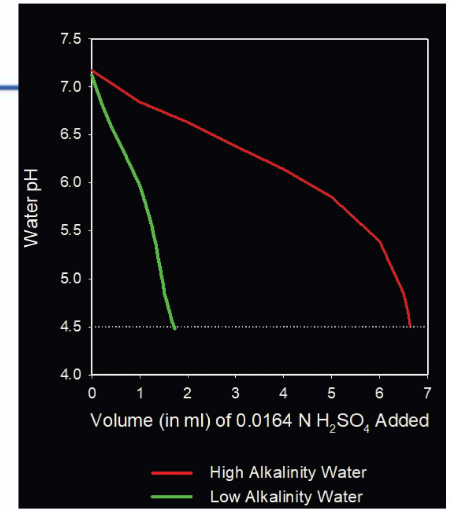
- Iron and zinc are less available.
- pH >6.5 phosphate precipitates

pH 4
Very soluble
Fe^{3+}, Fe^{2+}

pH 7
Insoluble
$Fe(OH)_3$

Water alkalinity

- Alkalinity: is the neutralizing capacity of a solution (acid-buffering capacity)
- Think of "dissolved limestone"
- Bicarbonates
  - HCO_3^- (Ca, Mg, Na)
- Carbonates
  - CO_3 (Ca, Mg, Na)



Courtesy: Paul Fisher, Univ. of Florida

Water alkalinity

- Alkalinity > 200 ppm CaCO3 equivalents is **HIGH**
- Alkalinity < 60 ppm CaCO3 equivalents is **LOW**
- Carbonates or bicarbonates (Ca, Mg, Na)
- If low (rainwater, RO) ➔Add potassium bicarbonate to reach 100 ppm CaCO3
- If Ca & Mg are the source of alkalinity ➔Use acid to neutralize the buffering capacity and adjust nutrient programs.
- If Na is the source of alkalinity ➔Use acid to neutralize the buffering capacity and increase EC (calcium). Or remove with RO.

How much acid should I add to reach a target pH?

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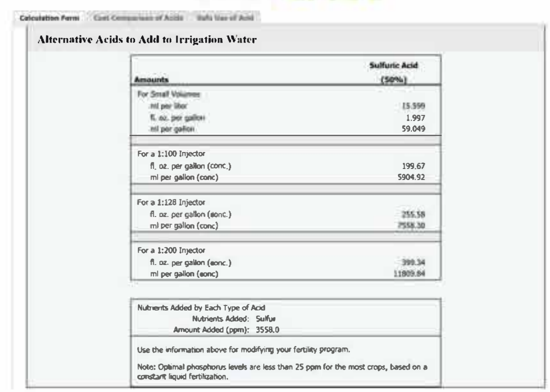


Calculation Form

Alternative Acids to Add to Irrigation Water

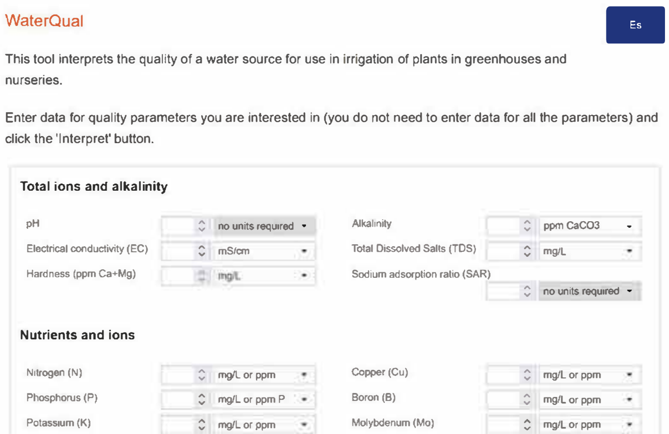
Amounts	Sulfuric Acid (50%)
For Small Volumes	
ml per liter	15.599
fl. oz. per gallon	1.997
ml per gallon	59.049
For a 1:100 Injector	
fl. oz. per gallon (conc.)	199.67
ml per gallon (conc)	5904.92
For a 1:128 Injector	
fl. oz. per gallon (conc.)	255.58
ml per gallon (conc)	7558.30
For a 1:200 Injector	
fl. oz. per gallon (conc.)	399.34
ml per gallon (conc)	11809.84

Nutrients Added by Each Type of Acid
Nutrients Added: Sulfur
Amount Added (ppm): 3558.0

Use the information above for modifying your fertility program.

Note: Optimal phosphorus levels are less than 25 ppm for the most crops, based on a constant liquid fertilization.

www.cleanwater3.org
Search for Tools>WaterQual



Water chemistry summary

- Water EC is an indicator of the total amount of salts in the water.
- Water complete nutrient analysis is used to determine fertilizer rates and management options.
- **Use the water analysis to tailor the nutrition program.**
- Water alkalinity is the pH buffering capacity of the water.

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Drinking water can also cause problems.

Water source: City water

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Measure the chlorine in your water

	Tap Water	Post-activated carbon filter	Deep Water Pond
pH	7.9	7.9	5.1
EC (µs/cm)	422	435	1963
Dissolved oxygen (mg/L)	9.6	9.6	9.3
Total Chlorine (mg/L)	1.86	0.60	0.56
Free Chlorine (mg/L)	1.56	0.49	0.51
ORP (mV)	789	725	690
Total suspended solids (mg/L)	0	0.4	0.2
Pythium	-	-	-
Total bacteria (cfu/mL)	0	24	7,400

a McGehee, Ph.D. student, UConn

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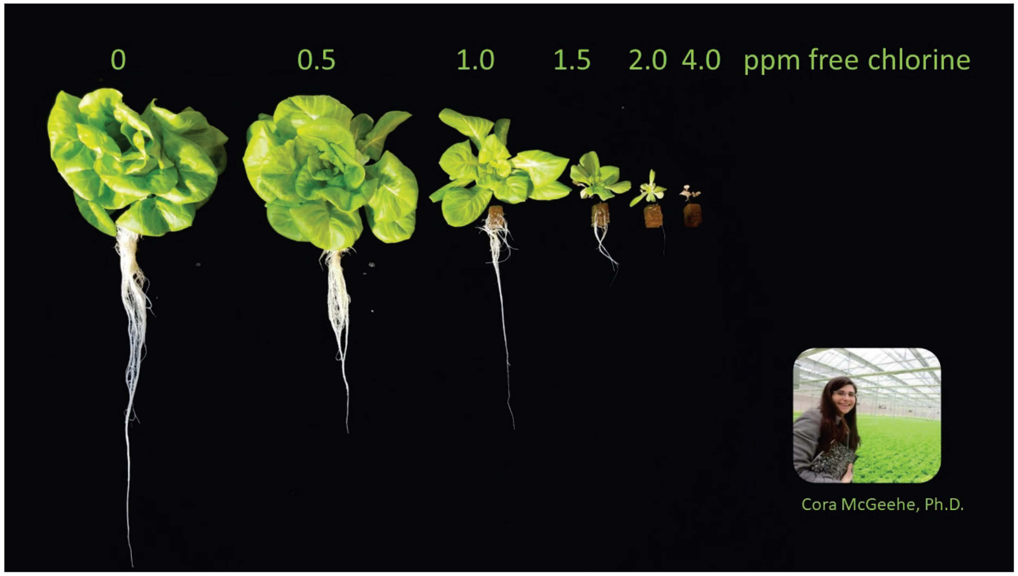

Chlorine interacts with ammonium

Chlorine at 1 and 2 mg/L is *safe* for tomatoes in hydroponics.[1]
Chloride levels build up to 12 mg/L.

Chlorine by-products:

- Chlorate: tomatoes (0.2 mg/kg) and carrots (0.3 mg/kg)[1]
- Chloride, chlorite, chlorate, & perchlorate

[1] Dannehl et al. 2015 Effects of hypochlorite as a disinfectant for hydroponic systems on accumulations of chlorate and phytochemical compounds in tomatoes. European Food Research and Technology, http://dx.doi.org/10.1007/s00217-015-2544-5

Chlorine (and agrochemicals) can be removed with Granular Activated Carbon (GAC) filters

Reports of plant pathogens by water source

Pathogen group	Well	Surface
Oomycetes		
Phytophthora	1	70
Pythium	0	52
Bacteria	3	19
Fungi	10	44
Nematodes	0	11
Viruses	0	6
TOTAL	14	202

Adapted from: Hong C. Ch. 11-Component Analyses of Irrigation Water in Plant Disease Epidemiology from: Biology, Detection, and Management of Plant Pathogens in Irrigation Water APSPress, 2014

Common plant pathogens in hydroponics

Water molds: *Pythium, P. dissotoccum, Globisporangium irregulare, G. ultimum, Phytophthora*
Zoospores have flagella: actively move freely in the water. Other stages: move with organic matter.

Fungi: *Rhizoctonia, Fusarium, Thielaviopsis, Alternaria, Sclerotinia, Botrytis, etc.*
Most structures move with organic matter.

Bacteria: *Clavibacter michiganensis subsp. michiganensis, Crazy root bacteria,*

Viruses?

To control waterborne pathogens, start by removing organic debris from the water.

When it comes to plant pathogens:

- Water sources are a risk if they have been in contact with agricultural runoff.
  - Shallow wells
  - Recirculated solutions
  - Surface water bodies
- HOWEVER, water can spread pathogens.

Testing water for pathogens

1. NC State Plant Disease & Insect Clinic
   Assay of pear baits used to determine whether Phytophthora is present in irrigation ponds.
2. UMass Plant Diagnostic Clinic
   Test for Pythium presence.
3. University of Guelph Plant Testing Services
   DNA fingerprint of common pathogens

Target Organism	Detection Level	Result
Botrytis cinerea	0	Not Detected
Fusarium spp.	7	High Levels
F. oxysporum	3	Low Levels
F. solani	1	Low Levels
Olpidium bornovanus	0	Not Detected
O. brassicae	0	Not Detected
O. virulentus	0	Not Detected
Phytophthora spp.	0	Not Detected
P. cactorum	0	Not Detected
P. capsici	0	Not Detected
P. cinnamomi	0	Not Detected
P. cryptogea	0	Not Detected
P. drechsleri	0	Not Detected
P. fragariae	0	Not Detected
P. infestans	0	Not Detected
P. nicotianae	0	Not Detected
Pythium spp.	7	High Levels
P. aphanidermatum	4	Moderate Levels
P. dissotocum	0	Not Detected
P. irregulare	0	Not Detected
P. polymastum	0	Not Detected
P. sylvaticum	0	Not Detected
P. ultimum	0	Not Detected
Rhizoctonia solani	0	Not Detected
Sclerotinia spp.	0	Not Detected
Thielaviopsis basicola	0	Not Detected
Verticillium spp.	0	Not Detected
V. albo-atrum	0	Not Detected
V. dahliae	0	Not Detected

Summary

- Water sources pose different risks.
- Not all salts need to be removed from the solution (use all the tools in your toolbox).
- Assume plant pathogens are always present and implement integrated disease management.

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Match Treatments to Problems

Disease
- Integrated disease management
- Sanitizers
- Physical erradication

Chemical
- Manipulate chemistry
- Examples: Reverse osmosis, oxidation, acidification, fertilization

Particles
- Filtration
- Oxidation, flocculation, & settling

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Components


Filtration


Sanitation


Chemical treatment

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Coarse particles ➔ Coarse filters First stage of filtration

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Filtration options






- Contaminants
- Labor
- Complexity
- Consumables
- Pressurized
- Backflushing
- Flow Rate
- Staging

Combine multiple stages of filtration

Courtesy: Paul Fisher, University of Florida

Sanitation

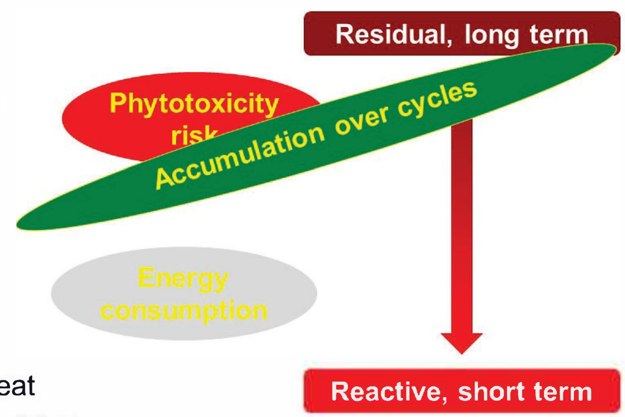
Microbial inoculum

Water treatments only target the (plant & human) pathogens in the water.

Water treatments are only **one** component of disease management!

Sanitation options

- Copper ionization
- Peroxyacetic acid
- Surfactants
- Chlorine
- Chlorine dioxide
- Ozone
- Ultraviolet light, heat

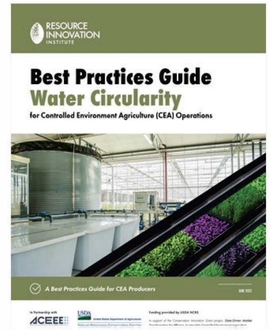


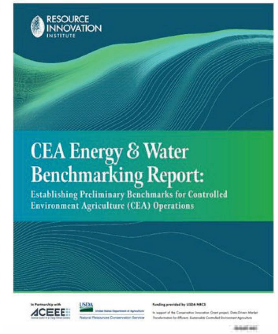
Courtesy: Paul Fisher, University of Florida

Key points on irrigation design

1. Reduce water volume with precise irrigation (time and volume).
2. Design with water source and target problem in mind.
3. Match the technology to the problem.
4. Filter first, then sanitize.
5. Program a monitoring and maintenance schedule as part of the design
   a. Monitoring constantly
   b. Shocking the system between crops
6. Water treatments only target the pathogens in irrigation.
7. Implement a systems approach to prevent other sources of contamination and conducive conditions.

CEA Water Circularity Resources





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Best Practices Guide
Featuring contributions from 15 Working Group member companies

Benchmarking Report
Featuring annual resource consumption and productivity of twelve producers growing a variety of crops in greenhouse and indoor facilities across the US.

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