Water and Bacteria Basics

Living Water

- Recirculating Systems
- Starting with the Right Water
- Various Source Water Scenarios
- Source Water Filtration
- Water Temperature, pH and Alkalinity
- Overview of Nitrification Cycle
- Ammonia, Nitrite and Nitrate
- Nitrifying Bacteria and Bad Bacteria

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Recirculating Systems

- Water is recirculated through the system over and over
- Water is typically not discharged (only tiny amounts)
- Bad bacteria can colonize quickly (there is not a complete soil or water ecosystem to keep it in check)
- Contaminants can build up over time
- Aquaponics is very difficult to disinfect if bad bacteria or contaminants are introduced
- Sterilization is impossible with bacteria and fish

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Start with the Right Water

Water is the life blood of your aquaponic system

- If your source water is not good, the system will not be viable
- Make sure you have the “right” to use the water
- “Natural” water isn’t always good water
- Source water filtration is usually necessary

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Start with the right water

Have your source water tested using water standards, bacteria/biological elements and heavy metals

Is your water source free of contaminants?

- E Coli, heavy metals, pesticides, radon, arsenic, chlorine/chloramine, fluoride, other pollutants

Most appropriate water options

- Municipal water – must remove chlorine/chloramine
- Well water – may need to remove bacteria or metals

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Municipal Water

- Must maintain EPA drinking water standards
- Contains chlorine or chloramine (must remove)
  - Chlorine can off gas in about 24 hours
  - Chloramine (chlorine and ammonia) has to be removed with filtration or chemical separation/detoxification
- May have consumption limitations
- May be metered with sewer service
- May require tap fees for “commercial” use
- Municipality may suggest a backflow preventer – not necessary since system water is not “hard lined” to tap

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Well Water

Does the well water have the right alkalinity?

- pH above 8.0 (high alkalinity)
- pH below 5 (too acidic)

Is the water source have high salinity (dissolved salts)?

- Can it be filtered or desalinized?

Does your well have a good refresh rate?

- Do you have enough water for system fill, top off, cooling systems?

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Surface Water

Should you use surface water? NO

(ponds, lakes, streams, agricultural ditch water)

- While surface water may seem natural, it is not the right water for a recirculating system
- Surface water may bring undesirable ecosystem elements, algea, various aquatic lifeforms
- Agricultural ditch water may contain e-coli, salmonella, pesticides, fertilizer, herbicides
  or other chemical runoff

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Rain Water

Should you use rain water? – depends on where you live

- Rain water in a highly polluted area = polluted water that will build toxins in the system over time
- Is it legal to catch rainwater? (getting better in Colorado)
- Is there enough rain water to maintain water levels?
- Is the rain water too acidic? Lower than 6.0
- Can the rain water be captured without other contaminants (roofing materials, bird droppings, etc)

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Starting with the right water

Is it legal to use your water for a greenhouse?

- Some municipalities or housing subdivisions have limitations on domestic vs commercial use related to water availability and consumption demand

Will you have to upsize your tap?

- Some municipalities require a specific tap size for commercial consumption.

Trucking in water is an option for startup up or topoff.

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Water Consumption Meter

- Install a water consumption meter if you are in a building with other tenants, or if you want to know the actual consumption of your business water separate from house, landscaping or other useage
- A water meter is ESSENTIAL for determining when water filter cartridges need to be changed
- Some meters also show flow rate
- Buy a good quality brass meter with revolving dial, not digital

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Water Filtration

- You must remove chlorines or chloramines from your water. They will kill your fish and your bacteria.
- Chlorine can off gas by sitting in an open tank (before introducing to fish system)
- A sediment filter installed prior to the active carbon filter is a good idea to remove heavy metals and particulates
- Install an active or catalytic carbon filter to remove chloramines that do not off gas
- Test your pH before and after your filter

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Types of Source Water Filters

- Sediment Filter – removed rust, silt, dirt, sand, suspended solids (usually first step off tap)
- Active Carbon Filter – Large surface area to absorb contaminants.
  - Removes Chlorine, Volatile Organic Compounds (VOCs), Mercury, Lead and PCBs
- KDF 85 Filter – Catalytic Carbon, Kinetic Degradation Fluxion
  - Removes Chlorine, Chloramine, Heavy Metals, Iron, Sulfur
  - Bacteriostatic prevents microbes to breed in filter

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HydroLogic Source Water Filters

DO NOT allow to freeze, use a water meter, change filter cartridges when specified, do not exceed flowrate

Hooks to garden hose
8,000 gallon limit

SmallBoy KDF
6,000 gallon limit
1GPM, 60 GPH
5 Microns

TallBoy KDF
15,000 gallon limit
2GPM, 120 GPH

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Reverse Osmosis

- Water purification method for drinking water quality
- RO water has no buffer which means fluctuating pH
- Uses a fine membrane and pressure to filter
- Pre-filtration such as sediment and carbon filters to remove large particulate, iron, calcium, dirt, sand, etc
- Can remove bacteria and fine suspended solids
- Often used in hydroponics to guarantee sterile water and to prevent clogging tiny watering emitters
- Isn’t a good idea in aquaponics because it strips everything from the water, minerals, alkalinity, etc.

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Keep a water log

Flourish Farms electric water and gas consumption

Date	Days since last reading	Reading (gal)	Total Consumption (gal)	Daily consumption (gal)	Avg daily Consumption to date (gal)	Reading (gal)	Total Consumption (gal)	Daily Consumption (gal)	Total Gallons Consumed	GrowHaus Consumption (Gallons)	% of GH Consumption	GrowHaus Water Bill	% of GH Water Bill in $	% of GH Sewer Bill in $	Total Amount Paid	
Top Off Water						**Wet Wall Water**										
3/30/2015	30	85,310	3,733	124	145	65,991	2,029	68	5,762	19000	30%	42.46	$12.88	$21.20	$34.08	
4/30/2015	31	90,236	4,926	159	149	70,639	4,648	150	9,574	42000	23%	85.7	$19.54	$35.23	$54.77	
6/2/2015	33	97,229	6,993	212	149	73,736	3,097	94	10,437	43000	24%	168.42	$40.88	$158.24	$38.41	
7/2/2015	30	100,557	3,328	111	147	80,423	6,687	223	10,416	47000	22%	183.46	$40.66	$38.32	$78.97	
8/4/2015	33	108,445	7,888	239	151	89,024	8,601	261	16,983	75000	23%	288.74	$65.38	$64.20	$129.58	0.003849866
9/5/2015	32	113,871	5,426	170	152	95,165	6,141	192	11,871	66000	18%	254.9	$45.85	$44.87	$90.72	
10/6/2015	31	118,663	4,792	155	155	102,341	7,176	231	12,438	7000	178%	33.06	$58.74	$26.46	$85.20	
11/8/2015	33	126,217	7,554	229	160	103,718	1,377	42	9,157	128000	7%	488.02	$34.91	$34.61	$69.53	
12/4/2015	26	131,943	5,726	220	164	103,718	0	0	6,054	31000	20%	65.02	$12.70	$22.88	$35.58	
1/7/2016	34	136,103	4,160	122	167	103,718	0	0	4,421	17000	26%	38.7	$10.06	$16.71	$26.78	
2/5/2016	29	139,860	3,757	130	174	103,718	0	0	4,193	17000	25%	38.7	$9.55	$15.85	$25.39	
3/5/2016	29	147,386	7,526	260	181	103,718	0	0	7,892	14000	56%	33.06	$18.64	$29.85	$48.49	
4/9/2016	35	155,240	7,854	224	190	105,722	2,004	57	10,118	29000	35%	61.26	$21.37	$38.25	$59.62	
5/12/2016	33	161,007	5,767	175	196	107,149	1,427	43	7,419	36000	21%	113.6	$23.41	$28.04	$51.45	
6/5/2016	24	166,544	5,537	231	204	114,371	7,222	301	12,909	39000	33%	134.98	$44.68	$48.80	$93.47	
7/1/2016	26	170,980	4,436	171	211	120,750	6,379	245	10,858	54000	20%	191.23	$38.45	$41.04	$79.49	
8/3/2016	33	177,033	6,053	183	214	134,316	13,566	411	19,934	97000	21%	361.66	$74.32	$79.14	$153.46	
								147								
		Average Daily Usage		170	gallons											
		Average Weekly Usage		1,193	gallons											
		Average Monthly Usage		5,113	gallons											

Equipment | Electrical Consumption | Water Consumption | Gas Consumption

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Water Temperature

Ideal water temperature for aquaponics is between 68^{o} – 74^{o} F (20^{o} - 23^{o} C)

- Tilapia and catfish can growout in warmer water, but warmer than 75^{o} F (24^{o} C) is not ideal for plants
- Water temperatures below 68^{o} F (20^{o} C) are possible with various fish species, but nitrification and plant growth will slow substantially
- Water has the best thermal mass potential for greenhouse *(ability of a material to hold and store heat)*
- Water helps retain heat in winter, and cool in summer
- Water from the tap often comes in at around 49^{o} F (9^{o} C)

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Water and pH

- pH is a measure of the amount hydrogen ions in your water and the acidic or basic characteristics
- Ideal pH for aquaponic systems is roughly 7.0
  - Plants uptake nutrients most effectively between 6.5 – 7.0
  - Fish and bacteria thrive 7.0 – 8.0
- pH often starts around 7.8 (depending on source water), but will naturally decline as part of the nitrification cycling process
- Farm operations commonly require testing and adjusting pH to maintain a health growing environment

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Alkalinity and Buffering

"Alkalinity is a measure of the buffering capacity of an aquatic system."

- Buffering capacity is water's resistance to pH change
- Alkalinity is the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate.
- A very strong buffer capacity (high alkalinity) may be difficult to bring pH down in the short-term
- Nitrification is an acid forming process.
- A weak buffering capacity may create low biofilter performance and the possibility of a pH crash

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Fishless Cycling

Follow these steps to start the nitrification cycle in a new system

- Fill the system and recirculate water
- Allow water to reach desired temperature 75°F (23.8°C) ideal for bacteria to colonize
- Add nitrifying bacteria to biological filter
- Add an amount of ammonia to reach 2ppm
- Test water and record pH, ammonia, nitrite, nitrate
- Add ammonia and bacteria throughout cycling process
- Cycling may take between 20 – 45 days depending on bacteria, temperature, ammonia source, pH, etc.

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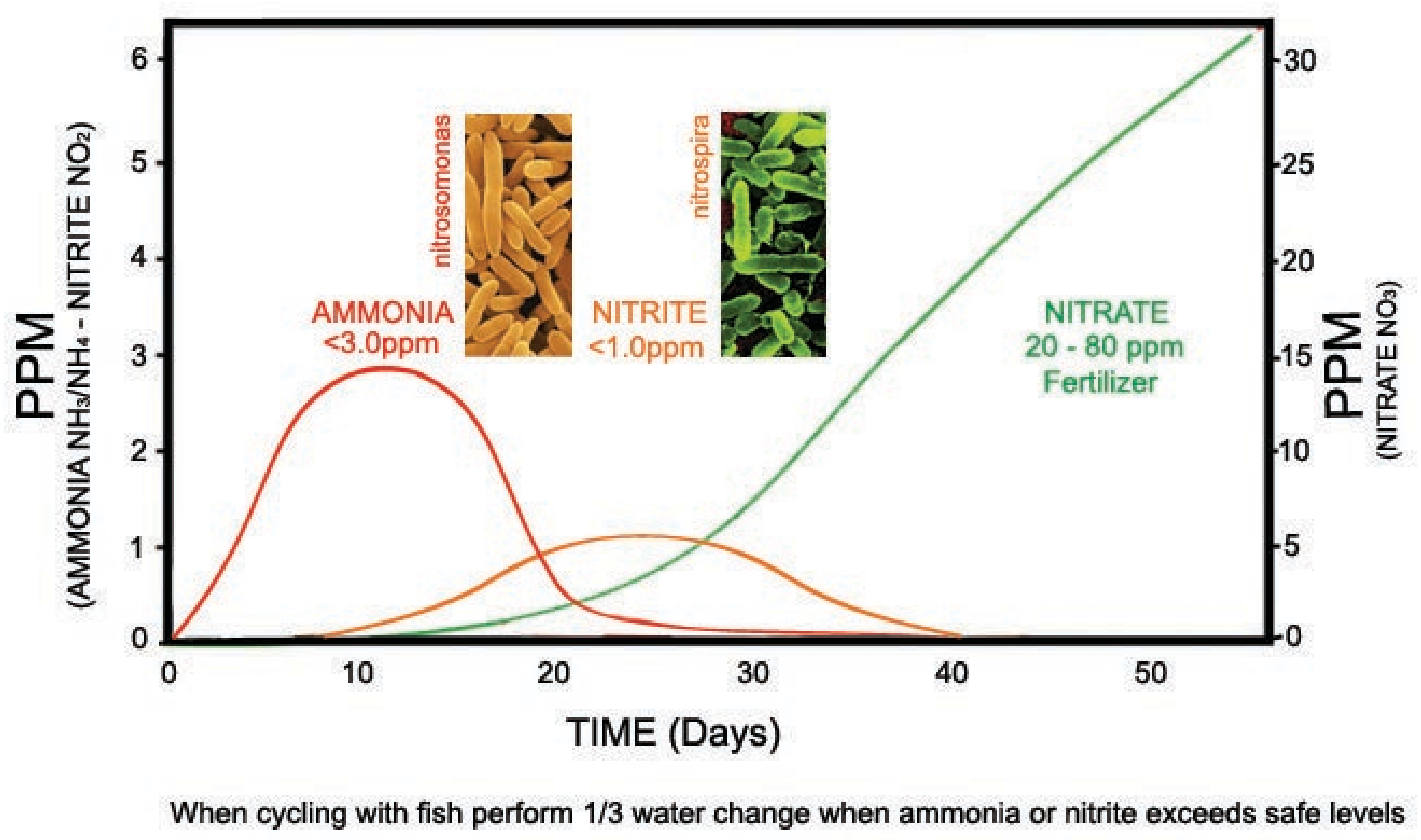
Starting the Nitrification Cycle



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What is Nitrification?

- Nitrification is the biological process of converting

  Ammonia → Nitrite → Nitrate

- The nitrification cycle is essential to a properly functioning aquaponic system, for both fish and plants
- Input is Ammonia from the fish waste and break down of decaying plants, uneatten feed, algae, etc.
- Output is Nitrogen (primarily Nitrate) as a form of fertilizer for the plants
- Nitrification happens in every water way of the world
- ***Nitrification in aquaponics mimics a natural ecosystem***

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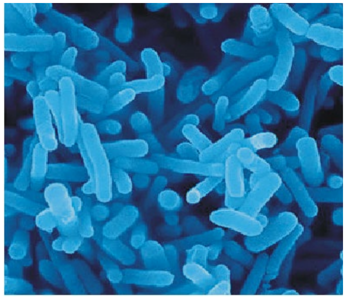
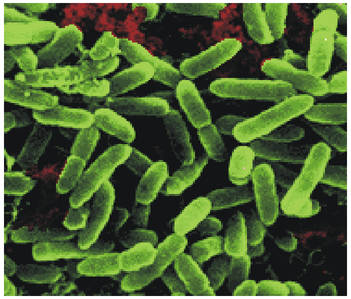
Nitrifying Bacteria

- Ammonia Oxidizing Bacteria (AOB) – Obtain energy by catabolizing un-ionized ammonia. Bacteria genera include *Nitrosomonas, Nitrosococcus, Nitrospira, Nitrosolobus and Nitrovibrio*
- Nitrite Oxidizing Bacteria (NOB) – Obtain energy by oxidizing nitrite into nitrate. Bacteria genera include *Nitrobacter, Nitrococcus, Nitrospira, Nitrospina*
- Bacteria colonize on biofilter, media, tanks, plumbing, rafts, roots, and in the water column





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Ammonia (NH_3 and NH_4+)

- Fish produce Ammonia through their waste streams (urine, feces) and across their gills.
- Pure ammonia added to startup cycle a biofilter
- Ammonia exists in two forms:
  - UIA - un-ionized NH_3 (most toxic to fish)
  - IA - ionized NH_4^+
- NH_3 (see Total Ammonia-Nitrogen TAN table)
  - Toxicity increases with higher pH and temps
  - Toxicity decreases with lower pH and temps

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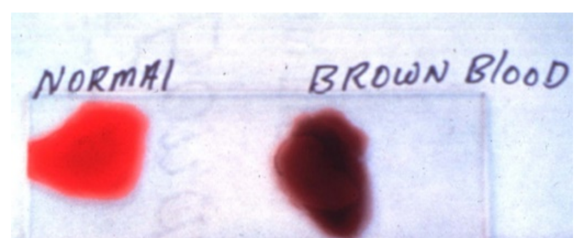
Nitrite NO_2

- Nitrite intermediate product of oxidation from ammonia to nitrate
- Nitrite (NO_2) is toxic to most fish 1 ppm
- NO_2 can be "burned off" sun exposure
- Nitrite is toxic to fish because it effects the blood hemoglobin's ability to carry oxygen, oxidizes iron, resulting in "Brown-Blood Disease"
- Calcium chloride can help reduce impact on fish



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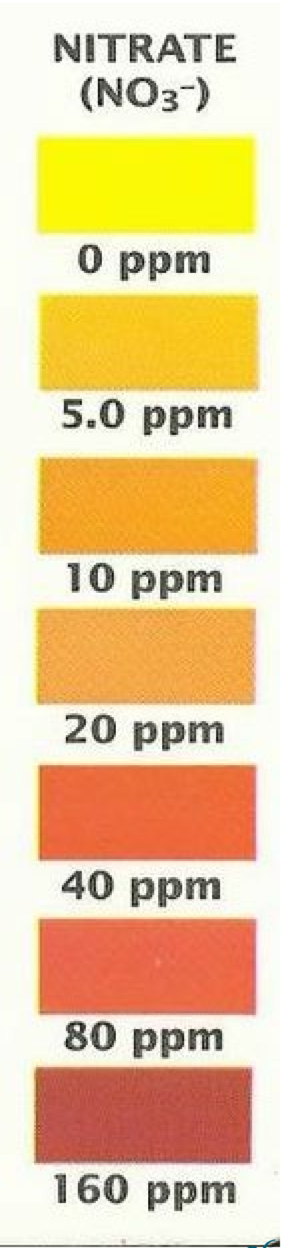
Nitrate NO_3-

- Final stage in the nitrification process
- Safe for fish at relatively high levels (tests have exceeded 1000mg/L without mortality)
- Nitrate is the primary fertilizer for the plants
- Reasonable levels of nitrate for plant production would be between 40 – 200ppm

- Nitrification will cause pH to naturally decline which must be monitored and adjusted as needed.



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Nitrification

- Nitrification requires oxygen – For every 1g of ammonia converted to Nitrate, 4.71g of O^2 is consumed
- Nitrification requires alkalinity - For every 1g of Ammonia-Nitrogen converted to Nitrate, 7g of alkalinity is consumed.
- pH can crash (drop fast) if buffer is not maintained
- pH buffered with Calcium Carbonate, Calcium Hydroxide, Potassium Bi-Carbonate or Potassium Hydroxide
- pH adjuster added to system in defined schedule to maintain consistent buffer and nutrient availability
- Consider bags of shell grit (Ca, Mg) for slow release buffer

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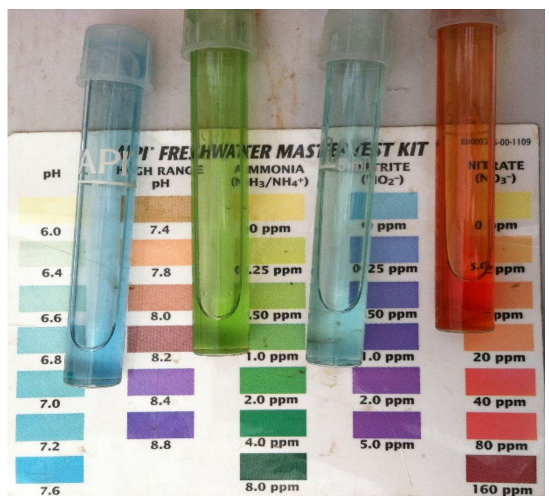
Monitoring System Water Quality

- During system cycling, test water every 2-3 days
- After cycling is complete (usually 25-40 days), water tests can be performed 1-2 times a week
- Record water data to monitor water quality



1/16/2015	DWC	4.9	58.0	4.00	0.25	10.0
1/16/2015	Fish	6.5	58.0	0.50	2.00	
1/17/2015	Fish	6.8	58.0	0.50	2.00	
1/18/2015	Fish	7.2	61.0	0.25	3.00	
1/19/2015	DWC	4.8	60.0	0.25	0.00	40.0
1/19/2015	Fish	7.1	59.0	0.00	3.00	
1/20/2015	DWC	5.6	60.0	0.00	0.00	20.0
1/20/2015	Fish	7.0	59.0	0.00	3.00	
1/21/2015	DWC	5.9	59.0	0.00	0.00	20.0
1/21/2015	Fish	7.3	57.0	0.00	1.00	
1/22/2015	DWC	6.1	61.0	0.00	0.00	20.0
1/22/2015	Fish	7.0	57.0	0.00	0.25	
1/23/2015	DWC	6.5	61.0	0.00	0.00	40.0
1/23/2015	Fish	6.9	60.0	0.00	0.00	
1/26/2015	DWC	6.2	60.0	0.00	0.00	40.0

Nitrifying Bacteria

- Nitrifying Bacteria will colonize over time
- A bottled inoculant such as Microbelift NITE OUT or ZYMBAC can be added to the biofilter to speed up cycling process
- Autotrophic bacteria consume inorganic compounds and require carbon dioxide and oxygen to grow
- Removal of solids before the biofilter is important to maximizing autotrophs (nitrifying bacteria) and biofilter performance

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Heterotrophic and Anaerobic Bacteria

- Consume organic compounds (plant material, uneaten feed, algae, feces) and carbon
- They grow faster than autotrophic bacteria
- Heterotrophic bacteria consume oxygen and space which out populates autotrophic nitrifying bacteria
- Anaerobic bacteria thrive with low/no oxygen
- Signification build up of solid waste encourages increased heterotrophic and anaerobic bacteria populations and can result in Denitrification

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Denitrification

- A microbial facilitated process of **nitrate reduction** where the nitrogen cycle reverses

Nitrate → Nitrite → Nitrogen gases

- Build up of heterotrophic and anaerobic bacteria
- Denitrification takes place in anoxic environments where oxygen consumption exceeds the oxygen supply
- Denitrification can be useful in an AP farm where lower nitrogen levels are appropriate for vining, flowering and fruiting crops.
- Denitrification is controlled by frequency of filter tank cleaning

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What's in Aquaponic Water?

- Ammonia from fish gills and urine
- Uneaten feed or dissolved feed that escapes tank
- Fish feces – fish species have different fecal profiles
- Biofilm – coagulation of microbes which adhere to surfaces
- Biofloc – protein rich aggregate of organic material, bacteria, dead organisms, fecal pellets
- Plant debris – roots, leaves, decaying plant matter, grow media
- Adjusters and amendments – calcium, potassium, iron, etc.
- Minerals – from source water and nutrient additions
- Gases – oxygen, carbon dioxide, nitrogen, hydrogen sulfide

Fish waste solids should be filtered from the water because they will clog the fine root hairs blocking water, oxygen and nutrient uptake

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Bad Bacteria in Aquaponics

If bad bacteria are introduced by humans, animals, fish, planting media, source water or equipment, they are likely to proliferate and be difficult to detect or element, resulting in food safety issues!

- Fish do not produce pathogenic eColi or Salmonella
- Aquaponics is the perfect environment for bacteria (and other biological or microbial life cycle)
- Because Aquaponics is in a controlled environment, there is not a complete “food web”
- Bio-security and appropriate farm practices essential

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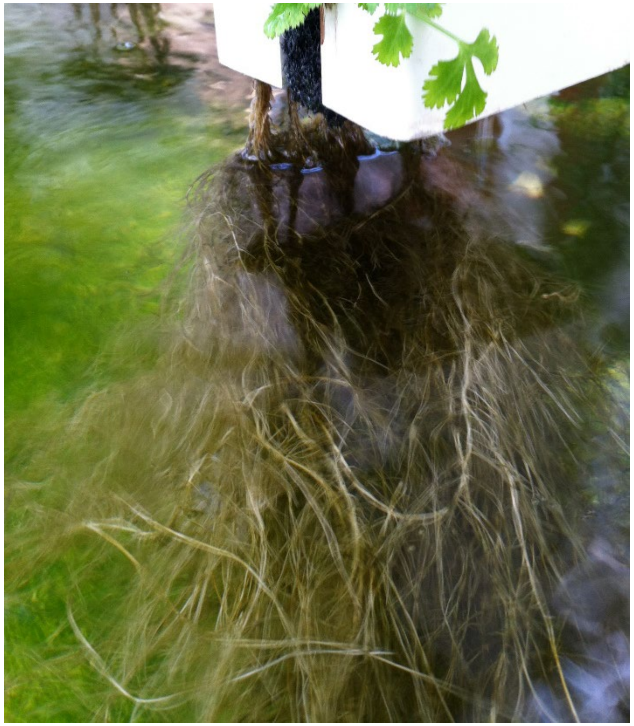
Algae, duck weed, green slime

It lives in nature, but you should PREVENT it in aquaponics

- Algae is nature's "pioneer species", it's the primordial soup
- Algae will grow with water and light
- Prevention - cover water, no sun exposure
- Algae grow in many colors, shapes, forms
- Duck weed is a small aquatic plant
- Both have rapid life cycle, reproduce, consume nutrients (your plant's nutrients), and then die (consuming oxygen), and creating sludge and slim in your system
- They clog pipes, pumps and create issues.
- Don't use Algaecides in Aquaponics, nothing with cooper



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In Summary

- Ensure safe source water
- Meter, filter and replace cartridges, log water data
- Maintain proper water temperature and pH
- Understand the nitrification/denitrification cycle
- You are a bacteria farmers, keep them happy
- Encourage the good bacteria, keep out the bad bacteria

Water is one of the most important assets in Aquaponics

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