Introduction to Aquaponics

What is Aquaponics?

The word *aquaponics* is a **hybrid word** formed by taking the two words **Aquaculture** and **Hydroponics** and joining them together.

Aquaculture means raising aquatic animal life by various techniques and is considered to be farming. ***Hydroponics*** means raising plants by soilless means using a water-based nutrient solution.

Aquaponics is a word coined by Dr. James Rakocy of the University of the Virgin Islands. He is considered the Father of Aquaponics. His doctoral thesis was based on two novel ideas:

1. Combining aquatic animals and plants in a **Recirculating Aquaculture System** (RAS) would reduce the nitrate ions in the water

2. This combination would use much less water.

Both of these ideas have been proven to be true. The result was even more dramatic than Dr. Rakocy imagined.

A **third benefit** which was **unforeseen** concerned the nutrient level of the produce. Aquaponically grown produce was found to be much richer in nutrients than hydroponically grown produce.

The water must be circulated to remove fish wastes.

The hydroponics techniques inherent to aquaponics are varied, but all consist of growing the plants in the water that is circulating from the fish tank.

A person raising fish or other aquatic animals in a closed system will soon discover that the waste will poison the fish as the toxin levels increase beyond the ability of the fish to cope with them. In a **recirculating aquaculture system** (RAS) the water must be exchanged regularly to stop the lethal levels of toxins. Perhaps as much as **10% per day** must be exchanged.

Hydroponic gardeners, in spite of constant monitoring and tinkering with the nutrient solution soon discover that **mineral salts levels** will rise to the point that all plants will die. The nutrient solution must be dumped and a new formulation created at regular intervals.

Both aquaculture and hydroponics **waste substantial amounts of water** to dilute the toxins in the water and to replace evaporation loss.

Aquapons (also known as aquaponists and aquaponeers) found that combining the two techniques was the answer to wasting less water and to prevent dumping toxic water into the environment.

Nitrogen Cycle

The mechanism that made all the difference was the Nitrogen Cycle.

A simple explanation of the phenomenon can be stated this way:

1. **Fish give off ammonia** from their gills. Ammonia is a compound **rich in nitrogen** and is extremely toxic to fish

2. Certain bacteria change all the ammonia to **nitrites**, which is even more toxic to fish
3. Still other bacteria change all the **nitrite to nitrates**, which is basically harmless to fish
4. Nitrate is a **powerful plant food** and the plants take up the nitrates which cleans the returning water for the fish by removing all or almost all the nitrates.
5. The nitrogen is thereby removed to non-toxic levels while feeding the plants some of the most nutritious plant food.

This process is called the **Nitrogen Cycle**. Every person that keeps fish quickly learns about the nitrogen cycle or else he will lose his fish. The most important difference between aquaponics and keeping fish in a fish tank is the use of plants to clean the water for the fish and utilizing the nitrates to feed those plants.

Why do Aquaponics?

There is a saying among aquapons that, “It’s not about the fish.” The real benefit to aquaponics is not the fish themselves; it is the increased yield of vegetation while using so much less water.

3xs higher yield of vegetables with only **2% of the normal water in a soil garden**

Very tight plant spacing—only limit is the amount of light getting to the plants

Fresh Fish is A Great Benefit, But…

Fresh, organic fish is a wonderful side benefit, but it is hard to raise enough fish to be a major crop without an equal and balanced vegetable growing system.

These are the major benefits:

- Vastly **increased vegetable yield** due to the nutrient-rich water
- Vastly **decreased water use** due to the closed loop system
- **Better use of garden space** due to higher planting density
- **Rich, clean protein source** if you eat the fish
- **Total control of the inputs** into the system. This is the ultimate organic gardening.
- **Easy to certify as organic** if you desire
- **No weeding**. Seriously, no weeds at all.
- Grow beds usually are elevated so **you do not stoop**
- **Elderly or disabled** individuals are able to garden
- **Very relaxing to most people**. Running water sounds like a mountain brook. Fish are entertaining and interesting.

Why Not do it?

- This is **not just a lark** or a fun experiment. It requires planning, research and networking with others.
- It **takes commitment** for a long haul. Inattention means fish and plants will die.
- You must **obey the principles of aquaponics** faithfully or you will lose all the fish and plants. Things can go sour very quickly.
- You must have **some power source to move water** at a minimum and most likely to **pump air** also. Solar or grid power is a necessity. Soil gardens don’t need power.

- Depending on the species of fish you choose, **temperature may need to be tightly controlled**.
- Someone that understands what to do to fix problems if necessary **must check on the system every day**. This is like having a milk cow or a goat.
- The **setup is more expensive** than a soil garden.
- Aquaponics in temperate climates **usually require a greenhouse** or other shelter

How to do Aquaponics.

There are many types of aquaponics systems. Usually they are broken down by the type of plant growing system and the type of fish tank used.

Types of Plant Growing Systems

- **Raft** and NFT (Nutrient Film Technique)
- Media **Grow Beds**
- Barrelponics™
- Growing Power
- Integrated Aquaponics (Earthan Group of Australia)

Types of Fish Tanks

- Aquariums
- Barrels
- Tanks
- Pond-based

Plant Growing Systems

- **Most** small-scale aquaponics gardens utilize the **media bed** system.
- **Most commercial facilities** utilize the **raft or NFT** system.

Raft and NFT systems

The raft and NFT systems require much more monitoring and constant attention consistent with a commercial facility. If you envision an analogy of a family with one milk cow milking by hand as the normal media bed system and a large commercial dairy as a raft or NFT system, then you will see the picture fairly closely.

Nutrient Film Technique (NFT) refers to constantly flowing nutrient-rich water in a loop from the fish past the plants and back. Plant roots **hang down into the water flow** and there is no media around the roots.

Usually in NFT the flow is in **pipes or trays** that are shallow.

In a raft system, the **trays are deep and the plants are held up by a raft** that floats on top of the water. So these two methods are very similar and vary only in the method used to move the water and if there is a raft floating on top of the water. The growing characteristics are quite similar.

Since the water flows all around the roots, it is important to **filter the water** to prevent the solid fish waste from choking the roots over time. To this end, the water is filtered before it flows through the trays.

Since some of the **nutrients are lost to filtering**, some types of plants do better in these systems. Lettuce, kale, and other cold season crops do quite well in these systems. Warm weather, heavy feeder crops such as tomato and cucumber do less well or take more care.

These systems usually require a higher level of attention and frequent filter cleaning than other systems. Pumping and aeration throughout the system consumes a great deal of electrical power.

Since media bed systems are more closely akin to the goals of this course, we are not going to dwell on the NFT and raft systems. Some people do mix methods and utilize some NFT or raft systems with their grow beds even in small-scale gardens. Aquaponics is flexible.

Media Grow Beds

Media beds are growing beds that are **filled with soilless media**. The media filters the water and provides a substrate for the bacteria and worms and a support for the growing plants. There is a variety of media that can be used. Each has strengths and weakness.

There are two major divisions of media bed systems.

Ebb and Flow (also called Flood and Drain) systems

In the ebb and flow system, water **fills** the grow bed and **then drains** back out at intervals. This action draws oxygen into the grow bed. Without this cycle, most plants will have some sort of failure in the root system. The ebb and flow cycle is accomplished in two usual ways:

1. **Timed pump—**the pump is turned on and off at regular intervals by a timer
2. **Auto siphon—**the pump runs constantly but a self-regulating siphon device times the flood and drain cycle within the grow bed

Most aquapons use the ebb and flow grow bed. The more sustainable timing is done with the auto siphon.

The reason for the ebb and flow is to bring oxygen to the root zone of the plants. The constant flow is more likely to clog and become anaerobic.

Constant Flood or Constant Flow

In the constant flood grow bed, the pump is constantly running and the level of water in the grow bed is basically constant. This method is not used as often as the ebb and flow.

Constant flow beds are good for starting seedlings and for growing water plants like water hyacinth*, water spinach*, water lettuce*, water chestnut, watercress, taro and other water-loving plants.

Most plants need the roots to have some **period of drying** and oxygen drawn into the root zone. Constant flood systems never dry out the root zone and the oxygen available is dependent on the level of dissolved oxygen in the water. The **roots may become choked** with bio-slime (the sticky product of the bacteria in the water) and lose the ability to capture oxygen from the water. Water-based plants tend to do well in constant flood beds. Examples are water hyacinth*, water spinach*, water lettuce*, water chestnut, watercress, taro and others.

****Caution!*** Many states restrict these and other water plants. For example, in Texas, these and some other species of plants (and some fish) are strictly illegal to possess or transport. It is a necessity to comply with the state regulations concerning invasive and/or exotic species.

Integrated Aquaponics—integrating soil into aquaponics

Considering the characteristics of a soil garden, we felt the need to use soil with our aquaponics. We knew that Will Allen of Growing Power was doing something with soil, but it was not what we were looking for.

We found a consultant in Australia who was integrating soil with aquaponics. He is with the Earthan Group. The group was very supportive of our efforts and made their expertise available to us.

Based on what we have learned from them, we are moving ahead with a large integrated aquaponics greenhouse this year.

I have been running an integrated system for about 6 months and I am happy with the results.

Layers necessary in the Integrated system

Large Gravel layer
Fine gravel layer
Weed blocking layer
Soil layer
Weed blocking layer
Mulch

Soil never goes down into the water flow because you do not allow any surface water to carry it there.

Nutrients wick up into the soil with the water.
The soil regulates the pH without affecting the pH of the water.

Water flow exits out the exit assembly. The water level is controlled by the height of the drain pipe inside the assembly. Water stays at this level and wicks up into the soil.

Basic Rules of Aquaponics

This introduction is too general to delve too deeply into the rules for each type of system.

General guidelines:

1. Determine how much room you have for the grow beds
2. You need equal volumes for fish tanks and grow beds
3. You need 1 lb of fish for every sq. ft. of 12” deep grow bed (1 cu ft)
4. You need 1 lb of fish for every 5 to 7 gallons of fish tank volume. When the fish are small, reduce the number of plants or plan to harvest fish as they grow.
5. 250 gallon fish tanks or larger seem to build a more stable system. You need a minimum of a 50 gallon fish tank.
6. Grow bed media
    a. Must be inert—won’t alter the pH of the system water
    b. Must not decompose
    c. Must be the proper size ($^1/_2$ to ¾”)
7. **Water**
    a. No chlorine or chloramine—let the water sit for 3 days before using tap water if you have chlorinated water. Use chemical de-chlorinators if you have tap water with chloramine. Rainwater is always better than any other.
    b. Temperature. You must match your fish to the temperature range you will be keeping the system at.
    c. Oxygen—you must keep enough oxygen dissolved in the water by air bubblers or agitation or both.
    d. pH should be between 6.8 and 7.0. A functioning system will tend to drop in pH and gravel with limestone in it will tend to raise pH.
8. **Fish.**
    a. Stocking Density
        i. 1 pound of fish per 5 – 7 gallons of tank water (.5 kg per 20-26 liters)
    b. Fish selection should take into account the following
        i. Edible vs. ornamental
        ii. Water temperature
        iii. Carnivore vs. omnivore vs. herbivore
        iv. Oxygen needs
    c. When introducing new fish into your system
        i. Be sure your system is fully cycled
        ii. Match pH
        iii. Match temperature
    d. Feeding Rate

    Feed your fish as much **as they will eat in 5 minutes**, 1 – 3 times per day. An adult fish will eat approximately 1% of its bodyweight per day. Fish fry (babies) will eat as much as 7%. Be careful not to over feed your fish.

    If your fish aren’t eating they are probably stressed, outside of their optimal temperature range, or they don’t have enough oxygen.

9. Plants

    Avoid plants that prefer an acidic or basic soil environment. Otherwise just about any plant can be grown in an aquaponics system

Plants can be started for aquaponics the same way they would for a soil garden – by seed, cuttings or transplant

If your plants are looking unhealthy after the first few months it is probably for one of two reasons

Nutrient imbalance caused by out of range pH - Maintain pH between 6.8 and 7.0 for optimal nutrient uptake by your plants

Insect pressure

Worms

Add a handful of composting red worms to each grow bed once your system is fully cycled and fish have been added.

Starting your System or "Cycling"

1. Cycling with Fish
    - ***a.*** Add only ½ as many fish as you would to be fully stocked
    - ***b.*** Test daily for elevated ammonia and nitrite levels. If either gets too high do a partial water exchange.
    - ***c.*** Feed once per day or less to control ammonia levels.
    - ***d.*** Some people add bacteria
        - ***i.*** From an established system
        - ***ii.*** From a stable aquarium
        - ***iii.*** From bottled starter kits
2. Fishless Cycling
    - ***a.*** Add bacteria starter
    - ***b.*** Add ammonia--Sources of ammonia
        - i. *Synthetic - pure ammonia and ammonium chloride*
        - ii. *Organic* – urine and animal flesh

          The process:
          Add the ammonia to the tank a little at a time until you obtain a reading from your ammonia kit of ~5 ppm.

          Record the amount of ammonia that this took, and then add that amount daily until the nitrite appears (at least 0.5 ppm). If ammonia levels exceed 8 ppm stop adding ammonia until the levels decline back down to 5 ppm

          Once nitrites appear, cut back the daily dose of ammonia to half the original volume. If nitrite levels exceed 5 ppm stop adding ammonia until they decline to 2.0.

          Once nitrates appear (5 – 10 ppm), and both the ammonia and the nitrites have dropped to zero, you can add your fish.

The Murray Hallam Cycling Technique

- Add liquid seaweed to the system
- Add plants

- Wait for two weeks
- Then add fish.
- pH should be between 6.8 and 7.0
- Plant your system as soon as you begin cycling. Adding liquid seaweed will help your plants quickly acclimate to their new environment
- Adding bacteria will dramatically speed up the cycling process. Keeping the temperature of your water above 70 will help as well

System Maintenance

1. Ammonia, Nitrites, Nitrates – after cycling,
    a. Ammonia and Nitrite levels should be less than .75 ppm
    b. If you see Ammonia levels rise suddenly, you may have a dead fish in your tank.
    c. If you see Nitrite levels rise you may have damaged the bacteria environment in your system.
    d. If either of the above circumstances occur, stop feeding your fish until the levels stabilize, and, in extreme cases, do a 1/3 water exchange to dilute the existing solution.
2. Nitrates can rise as high as 150 ppm without causing a problem, but much above that, you should consider harvesting some fish and/or adding additional plants or another grow bed to your system.

Aquaponics is much more detailed than we can cover in this introduction. Please let us know if you have interest in further seminars in the future.

Contact information

Pat Chesney
Sustainability Consultant

254-716-3568
pat@sustainablelivingconsultants.com