Introduction to Village Aquaponics

ECOLIFE FOUNDATION 2011

Thank you Shultz Steel for generously funding this sustainable project

Shultz Steel Company

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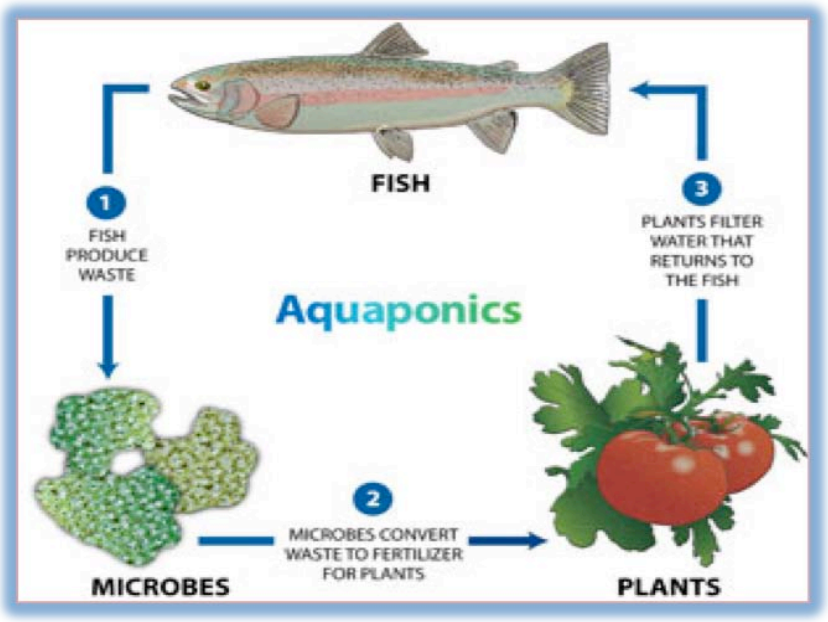
INTRODUCTION TO AQUAPONICS

Defining Aquaponics

WHAT IS IT?

- Aquaponics is the symbiotic growing of plants and aquatic animals in a re-circulating environment. It combines hydroponic farming with aquaculture. Water is cycled between fish tanks and vegetable growing areas. Fish waste acts as a natural fertilizer for the crops. Plants and beneficial bacteria scrub ammonia and other nitrogenous compounds from the water, making it safe for the fish.



Why is it better than other methods?

- Aquaponic systems can run with near zero environmental impact. They can be used to produce high-quality hormone-free fish and organic vegetables, all without the use of artificial fertilizers, pesticides, or herbicides.

- Aquaponics is water-wise. It uses 90% less water than conventional vegetable gardens and 97% less water than standard aquaculture methods.

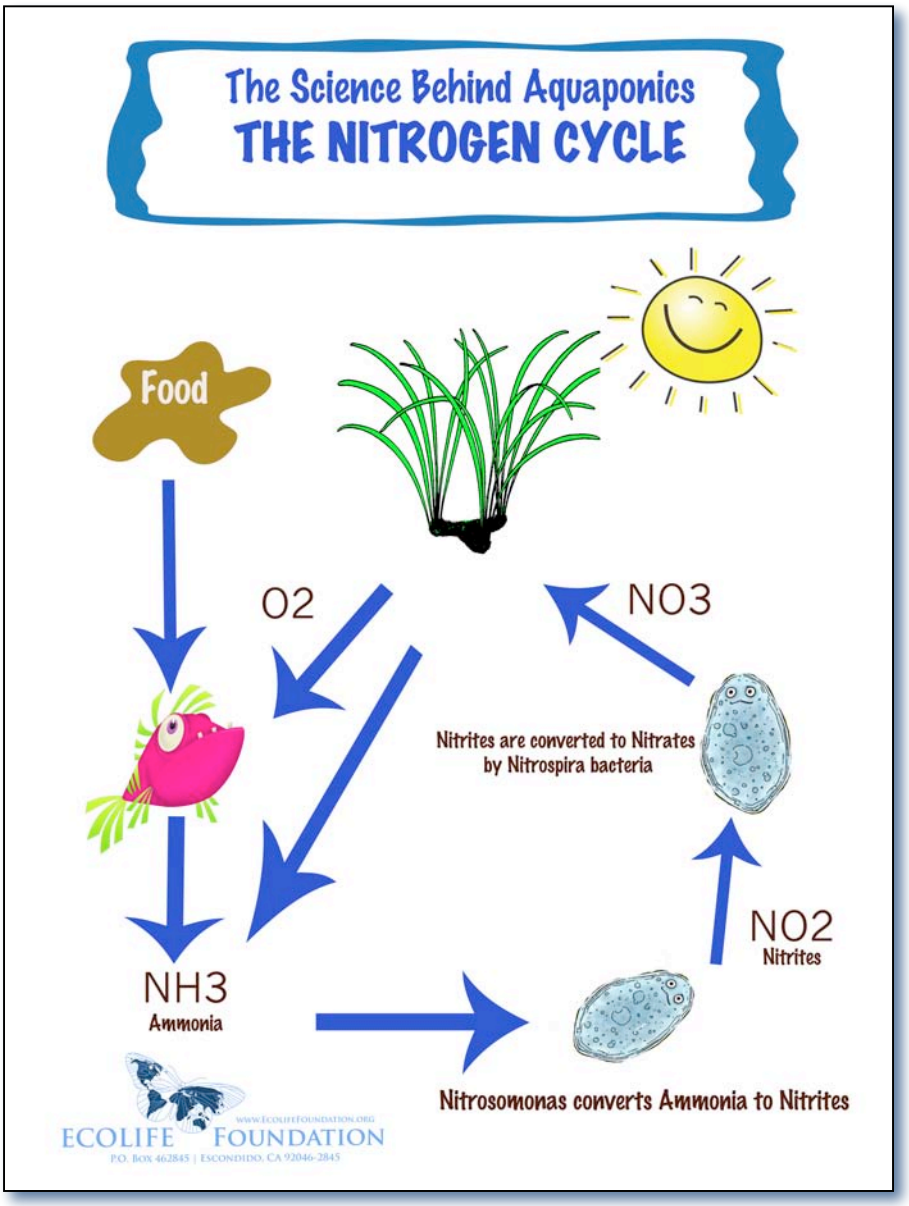
- Aquaponics is versatile and adaptable. Systems can be built to any scale and fitted to any space.

INTRODUCTION TO AQUAPONICS

The Magic of the System – The Nitrogen Cycle

Aquaponics makes use of the nitrogen cycle to create a balanced productive system. Plants get their Nitrogen in a fixed form such as nitrate ions, ammonia, or urea. Animals get their Nitrogen from plants or from animals that have eaten plants. Nitrifying bacteria facilitate the conversion of waste products back to the plants.

The diagram below illustrates this cycle in an in an aquaponic system.



OVERVIEW OF THE SYSTEM

What can we grow?
A wide variety of fish and other aquatic organisms can be cultured in these systems. Freshwater, herbivorous or omnivorous fish are ideal choices for their sustainability, ease of feeding and a more efficient conversion from feed to fish. Leafy crops such as lettuce and herbs work well in small-scale aquaponic systems. Fruiting plants such as tomatoes and peppers may require larger systems with deep growing area and more nutrients.

Fish
Best fish for aquaponic systems:

- tilapia
- large mouth bass
- sunfish
- crappie
- koi
- fancy goldfish
- pacu
- various ornamental fish such as angelfish, guppies, tetras, swordfish, mollies

Other fish and aquatic animals raised in aquaponic systems:

- blue gill/breem
- carp
- barramundi
- silver perch, golden perch
- yellow perch
- catfish
- large mouth bass
- prawns
- crayfish

Plants
Plants that will do well in an aquaponic system:

- green leaf, red leaf, and other leafy lettuces
- pak choi (bok choi)
- Swiss chard
- spinach
- arugula
- basil
- mint
- watercress
- chives

many common house plants

OVERVIEW OF THE SYSTEM

Every pound of fish can yield 70 pounds of vegetables!

These plants have higher nutritional demands and only do well in a heavily stocked, well established aquaponic system:

- tomatoes
- peppers
- cucumbers
- beans
- peas
- squash

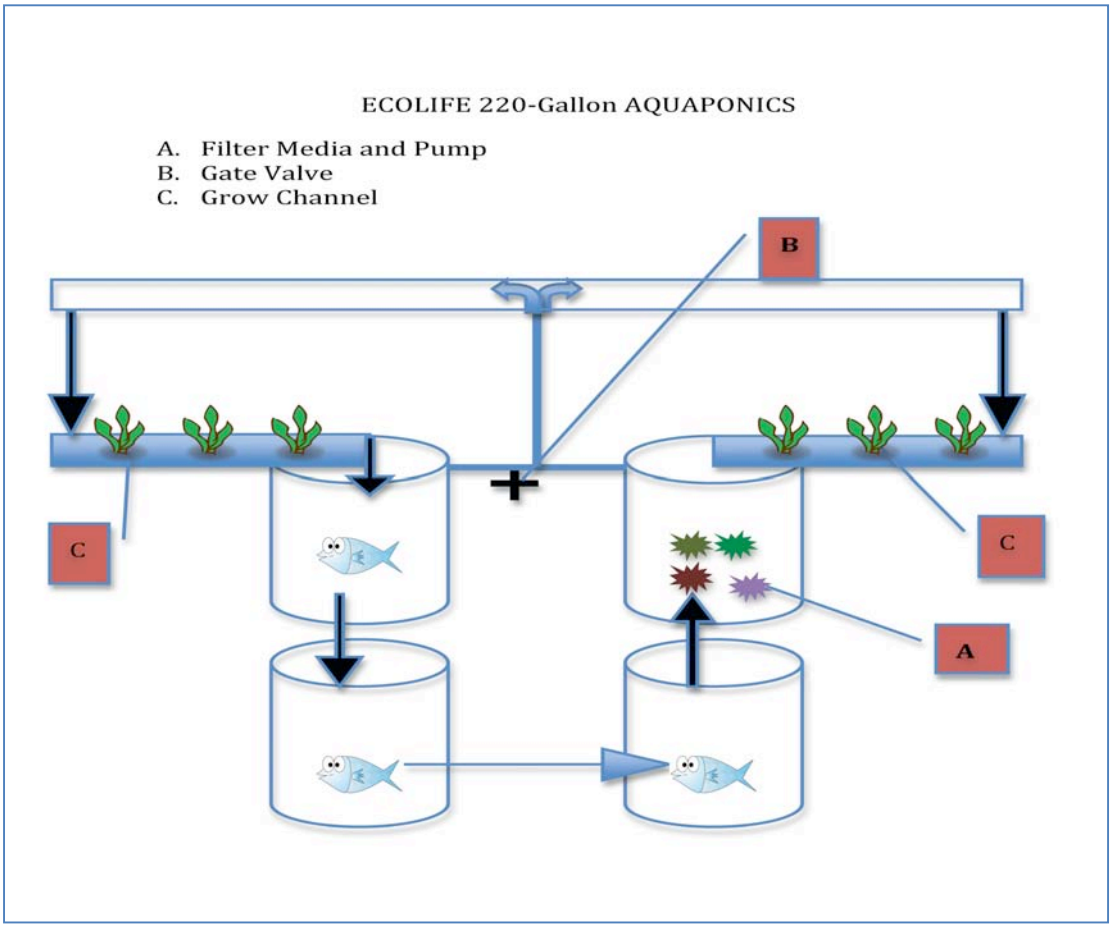
Aquaponic Methods:

There are three primary methods practiced in aquaponics: Nutrient Film Technique (NFT), Grow Bed, and Raft or Deep Water culture.

Nutrient Film Technique (NFT)

Nutrient Film Technique or NFT is presently the most popular technique used in hydroponics, and it is easily adapted for use in aquaponics. With this method a thin layer of water containing the dissolved nutrients from the fish tank is pumped through the bare roots of plants in a watertight gully, or channel. The depth of the re-circulating stream is very shallow, allowing for an abundant supply of oxygen to the roots of the plants. The main advantage of the NFT system is that the plant roots are exposed continuously to adequate supplies of water, oxygen and nutrients. A downside of NFT is that it has very little buffering against interruptions in the flow, e.g. power outages, but overall, it is one of the more productive techniques.

OVERVIEW OF THE SYSTEM

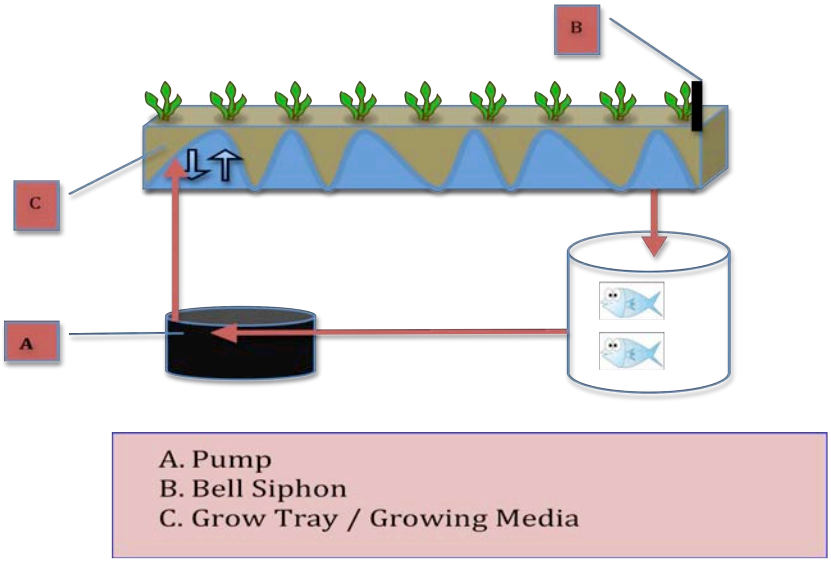


Grow Bed / Ebb and Flow

Another method widely used by backyard growers is the Grow Bed aquaponics. The growing area is a wide deep container with good surface area. This container is filled with gravel, LECA, or other soil-less growing medium and the vegetables are planted directly into the medium. These systems are often designed to provide water to the plants intermittently. A water pump controlled by an adjustable timer is used to provide water to fill the tub in an "ebb-and-flow" manner. As the pump runs the grow bed is saturated with water. When the pump is off the water slowly drains out. As it drains oxygen is pulled through the roots.

OVERVIEW OF THE SYSTEM

Ebb and Flow
ECOLIFE 220-Gallon AQUAPONICS



Another means of providing the ebb and flow of water is with the use of a bell siphon. A siphon is a mechanism for drawing water from a higher container to a lower container. A simple siphon is traditionally used for such things as cleaning fish aquariums. Siphons have also been adapted to control flooding and draining of the grow beds in an aquaponics setup. In this usage, they are called autosiphons.

OVERVIEW OF THE SYSTEM

An autosiphon is simply a siphon that can start and stop itself in response to changing water levels.

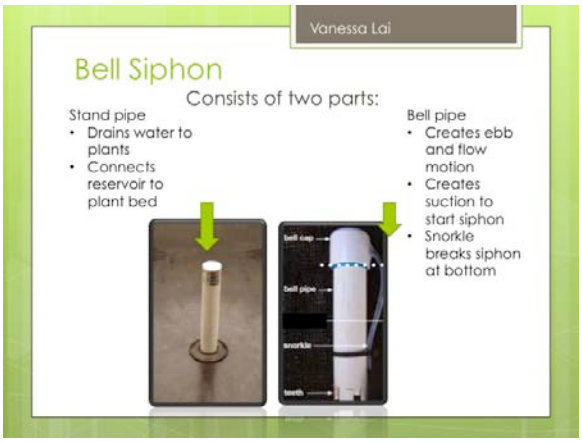
The bell autosiphon consists of:

1. A vertical standpipe

2. A bell pipe placed over the standpipe. The bell pipe is freestanding, slightly taller than the standpipe, and is fitted with an end-cap. Additionally, the base has pieces cut out to allow free movement of water.

3. Small air holes or an air tube to assist in breaking the siphon when the water level has dropped low enough.

As the grow bed fills, water flows up between the walls of both pipes then down the inside of the standpipe and out the bottom. With enough velocity, a siphon is created, rapidly moving the water out of the container. When the water level drops to the intake end of the air tube, the siphon is broken.

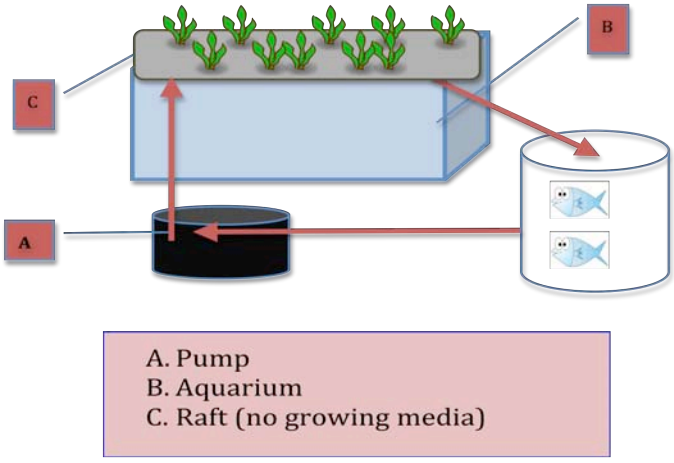


OVERVIEW OF THE SYSTEM

Raft or Deep Water Culture:

Raft aquaponics is the technique used most frequently in large-scale or industrial aquaponics. With this technique, the plants are grown on perforated rafts, usually made of Styrofoam, which float in water tanks. The roots of the plant are constantly in the water. This is a highly productive method, but requires intensive biological and mechanical filtration to keep the water clean.

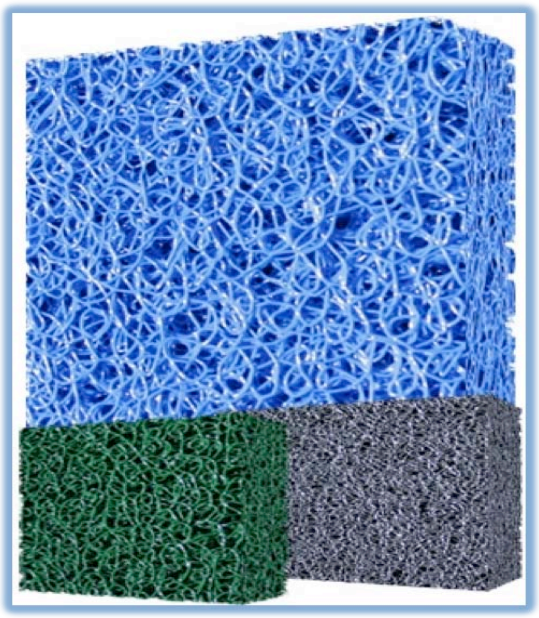
RAFT AQUAPONICS DIAGRAM



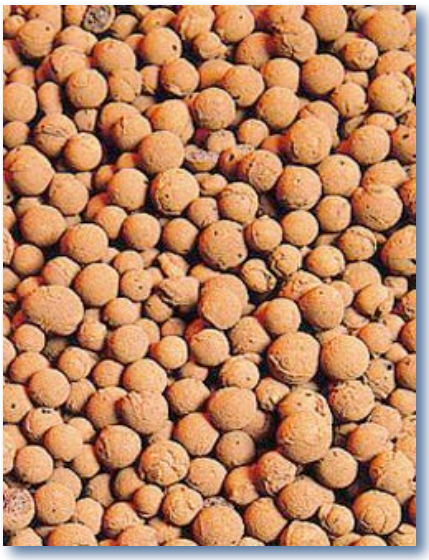
OVERVIEW OF THE SYSTEM

Filtration

There are two primary types of filtration used in aquaponic systems: biological filtration and mechanical filtration.



Biological filtration or bio-filtration is the most critical for insuring proper water quality, thus the well being of the fish. In bio-filtration naturally occurring aerobic bacteria convert the toxic ammonia produced by decomposing fish waste, uneaten food, and dead plant matter into nitrite (also toxic) and then to relatively non-toxic nitrate. Bio-filtration is achieved in a number of ways in these systems, but all work on the same basic principal -- moving oxygenated water through an inert material with high surface area which nitrifying bacteria colonize. One type of bacteria called *Nitrosomonas* converts ammonia to nitrite, a second bacteria called *Nitrospira* converts that nitrite into nitrate which is in turn utilized by plants, or in the case of aquaponics, by the vegetables you are growing.



These beneficial bacteria are ubiquitous and will eventually colonize where there are nutrients. As with a freshly set up aquarium, a new aquaponics system must first be "cycled" before adding a large number of fish. Cycling is the process of building up sufficient nitrifying bacteria colonies in the bio-filter to optimally handle the waste produced by the fish population. This is achieved by adding just a few fish to the system initially. These fish will add enough ammonia to start the cycle. Gradually the ammonia level will rise. As this happens the bacteria (Nitrosomonas) begin to make use of the ammonia, converting it to nitrite. As the ammonia peaks, other bacteria (Nitrospira) begin to convert the nitrite to nitrate. The cycle stabilizes in three to five weeks, after which more fish may be added to the system. This is best done on a gradual basis – slowly building up to capacity.

There are also alternative “fishless” cycling methods and head-start bacteria cultures available that can help to bolster and speed up the cycling process.

With aquaponic systems using grow beds, the medium that the plants are rooted in, usually gravel or LECA, also acts as the biological filter. In NFT systems utilizing individual grow pots with small amounts of medium or those employing the raft technique with roots growing directly in the water, a separate bio-filter is usually required.

Mechanical filtration is the removal of solid waste before it is broken down by biological processes. This may be achieved by passing the water through a fine material such as a foam sponge, filter sock, or other synthetic barrier, which traps the solids and is manually removed and cleaned on a regular basis. The manual removal of organic solids benefits the system by taking some of the demand off of the biological filtration, reducing the amount of oxygen used by bacteria in the mineralization and nitrifying processes. This is important, as your fish need that oxygen. If there is too much solid waste in the system – uneaten food, plant matter, etc., the dissolved oxygen may drop to dangerously low levels.

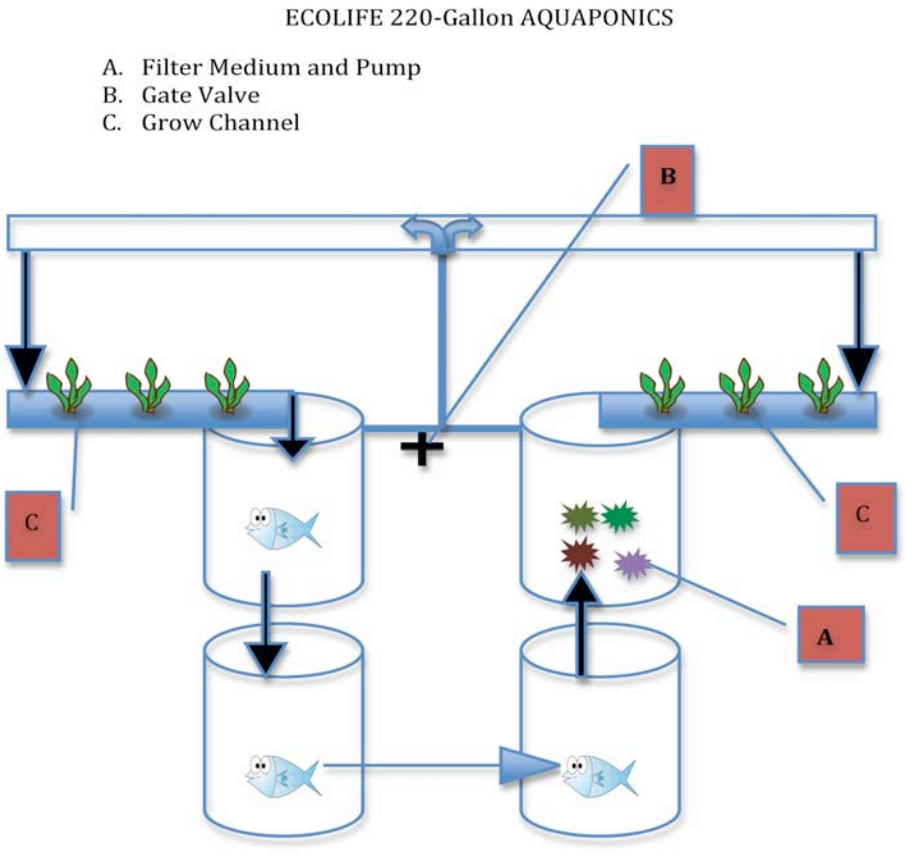
Water Flow

In aquaponic systems a water pump is used to move water flows from the fish holding tank through the filters to the plant roots and back to the tank. If multiple tanks or barrels are used, water may also be diverted to circulate through all of the tanks consistently, or a separate pump can be used for this circuit. The water pump(s) should be of quality and power to allow an even strong flow through all of the tanks and consistent current through the roots of the plants. Providing strong water movement through the fish tanks reduces dead spots and improves overall oxygenation.

OVERVIEW OF THE SYSTEM

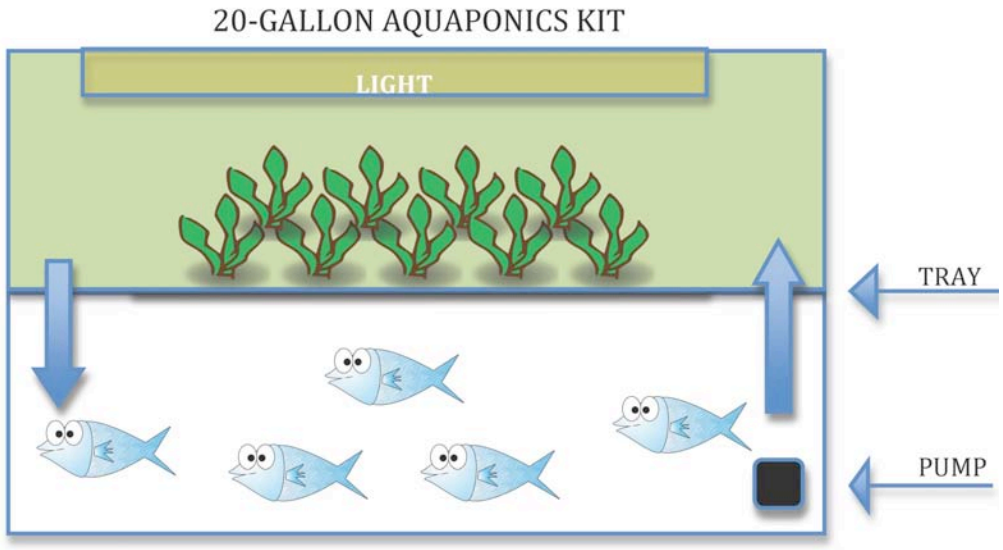
Some Example Systems

- **ECOLIFE's 220 gallon barrel system**:



A submersible water pump circulates the water through the barrels in a counter-clockwise direction. The water flow is also tapped and diverted to two growing areas on either wing of the system. The water then flows through four 10 foot channels of rain gutter downspout that has been modified to accommodate 22 grow pots in each channel, for a total of eight channels and 176 grow pots. The water flows through the complete length of the channels and drains back into the fish barrels, hydrating and delivering nutrients to the plant roots along the way. In the process the water is continually scrubbed of nitrates and other nutrients.

OVERVIEW OF THE SYSTEM



ECOLIFE's 20 gallon desktop aquaponic system:

This table-top system includes a frame that holds 2 T5 grow lights, a tray with pots, LECA bio-media, a small pump for irrigation and power filter for mechanical filtration.

BUILDING YOUR SYSTEM

Basic Parts and Supplies

- Fish Tanks or Barrels
- Grow Trays or Channels
- Growing medium
- Plumbing
- Mechanical / Biological Filters
- Water Pump
- Water Heater
- Lighting (if indoors)
- Air pump / Diffusers
- Net Pots

Fish Tanks or Barrels

A variety of containers may be utilized to hold fish, including aquariums, plastic storage barrels, prefab and liner ponds, and others. ECOLIFE's barrel system uses four interconnected 55-gallon plastic food-grade storage barrels to hold fish.

Grow Trays and Channels

Specialty growing trays and NFT (nutrient film technique) channel are available through hydroponic and agriculture equipment suppliers. Common and inexpensive materials may also be adapted to work for this purpose. For example, plastic cement mixing trays and plastic storage containers of appropriate size can work well as growing trays, and rain gutter downspout is easily adapted to accommodate growing pots. Both items are readily available through hardware and building supply retailers.

BUILDING YOUR SYSTEM

Grow Media

We use Hydroton ™ LECA (lightweight expanded clay aggregate). It is inert, reusable, and highly porous, providing extensive surface area for biological filtration. LECA is widely available in the US through hydroponics supply houses. Other good options for grow media include coconut husk, pea gravel, and rockwool – a specialty product for hydroponic growing.

Biological and Mechanical Filters

This is the material used to provide a growing surface for beneficial nitrifying bacteria.

In our systems, one barrel is dedicated specifically for biological filtration. There are many specialty plastic and ceramic bio-media that may be used for this application, as well as other generic materials. Lava rock, for example, works well and is inexpensive and widely available. We use a commercial pond filter media called Matala ™, which can be obtained through most pond equipment suppliers. It works well for our systems because it is available in a 21" roll, which happens to fit perfectly inside a standard 55-gallon barrel. Matala™ has a very high surface area making it an effective bio-media. It is available in four densities, which may be stacked from less dense to most dense for optimum filtration.

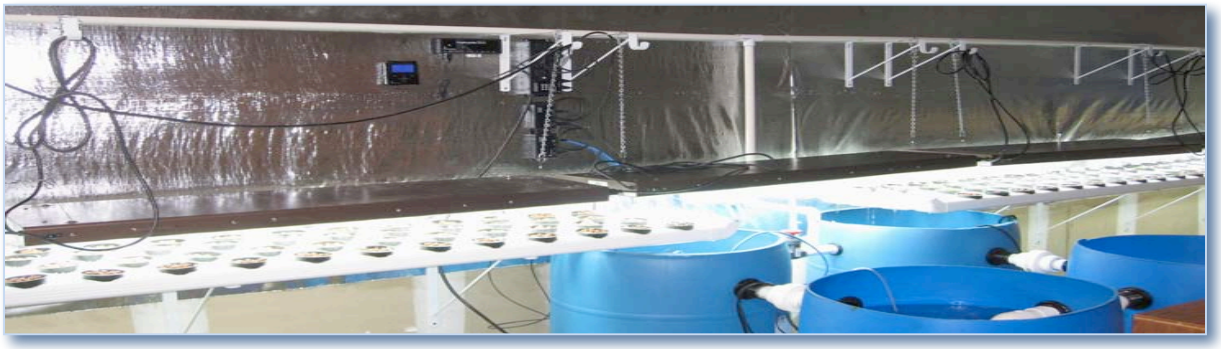
LECA, the fired clay pellets we are using in the grow beds, has extremely high surface area and may also be used as bio-media.

As discussed earlier, mechanical filtration functions to allow the removal of solid waste before being broken down by biological processes. This may be achieved by placing a polyester filter sock, foam sponge, or similar barrier in the line of water flow. Filter socks and other specialty filter materials are available through aquarium and pond suppliers. A mechanical filter is also easily constructed with parts from the hardware store. For example, a length of rain gutter drilled with many small holes for drainage and lined with foam sponge or polyester filter floss may be placed in-line where water returns to the barrels. Mechanical filtration works best when the filter media (sponge, etc.) is not submerged in the water, so position the unit above the water line to catch water as it flows from the growing channels back to the fish. The sponge may them be removed, cleaned, and replaced on a regular basis.

BUILDING YOUR SYSTEM

Net Pots or Basket Pots
These are another specialty item available through hydroponic equipment suppliers. They are plastic pots that are perforated to allow water flow while containing the soil-less growing media. The net pots are made in various sizes. We use the 3" pots for our channel systems.

Lighting for Indoor Systems
There are a number of light source options for indoor gardening, including high output fluorescent, metal halide, mercury vapor bulbs, LED, and plasma lights. We use T5 high output fluorescent fixtures and reflectors by Hydrofarm. We find these to be very effective, with low heat output and minimal power consumption. This has worked very well for leafy greens like basil, lettuce, and chard. Some vegetables may require the more intense light lighting when growing indoors.



Water Pumps
A wide variety of submersible water pumps are available through aquarium and pond suppliers and hardware stores. Pump size will vary depending on the system capacity and height that the water will need reach to. For example, our system uses a pump rated at 550 gallons per hour with a max height (or head) of 14.3 feet. It is always best to have a little more power than you need. You can always manage the flow rate using a ball or gate valve.

BUILDING YOUR SYSTEM

Submersible Heaters
If culturing fish from tropical regions, such as the commonly farmed Mozambique tilapia, a submersible water heater will be required. Wattage will be determined by the system capacity and ambient temperature of the surrounding area. For tabletop units of 10 – forty gallons, standard aquarium heaters in the range of 100 – 250 watts are adequate. For larger systems or those that are exposed to outdoor temps, high wattage models are required. We use a **Finnex ™** brand 800-watt titanium heater for most of the year. During colder months when the ambient temps are in the low 50s F or colder, we add an additional heater to stabilize the temperature at 80 F.

Air Pumps and Air Stones
Aeration is very important for maintaining adequate oxygen levels for fish respiration. Air pumps and diffusers along with airline tubing and gang valves to manage flow are used to achieve this. Like most of this equipment these items are available in a large variety of sizes and power ratings. Most aquarium models are rated to a gallon capacity. In order to have sufficient aeration, it is recommended to go one or two sizes higher. The depth of the water is also an important consideration when selecting an air pump. A diffuser in deep water requires a much stronger air pump than that of a shallow system of the same capacity. Air pumps and aeration accessories are available through most pet shops and aquarium suppliers.

FISH

Tilapia has become the third most important fish in aquaculture after carps and salmonids. Because of their large size, rapid growth, and palatability, a number of tilapiine cichlids are at the focus of major aquaculture efforts, specifically various species of *Oreochromis*, *Sarotherodon*, and *Tilapia*, collectively known colloquially as tilapias. Like other large fish, they are a good source of protein and a popular target for artisanal and commercial fisheries.

Mozambique Tilapia (*Oreochromis mossambicus*) is native to Malawi, Mozambique, Swaziland, Zambia, Zimbabwe and South Africa. The Mozambique Tilapia has been introduced to many tropical and subtropical parts of the world, as well as to some warmer temperate regions.

The Mozambique Tilapia is considered a freshwater species but it can be found in estuaries and coastal lakes as well, especially in the southern part of its geographical range.

Breeding Mozambique tilapia is not difficult and the fish can start reproducing at 7-8 months of age. Males and females are very similar and can be difficult to sex. One of the easiest ways of obtaining a pair is to let at least 5-6 fishes grow up together and form their own pairs.

Before any spawning takes place, the male will dig out a saucer-shaped nest on the sandy bottom. During spawning, the female releases her eggs into the nest. The Mozambique tilapia is a maternal mouthbrooder. The female waits until the male has fertilized the eggs in the nest. She will then pick them up and keep eggs, larvae and small fry protected inside her mouth until the fry are large enough to be released. The eggs will normally hatch after 3-5 days, but it will then take 10-14 days before the fry are released.

FISH

Maintenance

Housing

- Tilapia can be raised in aquariums but will eventually require a large aquarium as they can reach 16 inches or more in length as an adult.
- 55 gallon barrels work great for growing tilapia to plate size, 1 – 1.5 lbs.
- As a guideline, the ratio of fish to water is approximately one pound of fish per five gallons of water.

Feeding

- Feed fish as much as they will eat in 3-5 minutes, 1 – 3 times per day. Allow four to five hours between feedings for optimal metabolism
- Provide a high-quality fish pellet of appropriate size – fingerlings will take a much smaller grain size than juvenile and adult fish.
- 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.

Fish that are not eating may be:

- Stressed due to high ammonia level
- Outside of their optimal temperature range
- Lacking sufficient oxygen (discontinue feeding if dissolved oxygen drops below 3ppm)

TROUBLESHOOTING AMMONIA AND NITRITE IN SYSTEM

If you see ammonia levels rise suddenly, you may have a dead fish in your tank.

Rising nitrite levels may indicate damage to the bacteria environment.

Stop feeding your fish if ammonia and nitrite levels rise suddenly.

Extreme increase in nitrite and ammonia levels - do a 1/3 water exchange to dilute the existing solution.

Nitrate levels higher than 150 ppm, should consider adding another grow bed to your system.

Water Temperature

- The optimal temperature for growing Mozambique tilapia is 80 – 85 degrees Fahrenheit.

Water Quality Basics

- We try to keep the pH in our systems at neutral (7.0). This is a compromise between the optimal ranges for the fish, the plants, and the bacteria. Tilapia thrive best in a pH of 6.5 to 8.0. For plants optimum pH ranges from 5.0 to 7.0.

FISH

- Nitrification (the bacterial conversion of ammonia to nitrite and then nitrate) works best at a pH of 7.5 to 8.0. Test pH at least once a week.

- **Ammonia** and **nitrite levels** should be less than .75 ppm. High ammonia and nitrite levels are the number one killers of fish in an aquaponic system.

- Be sure there is plenty of **oxygen** in your fish tank.
    - Provide sufficient aeration
    - Strong water flow improves oxygen saturation.
    - Avoid overfeeding or overcrowding the fish, to keep oxygen levels up as well.
    - Fish gasping for air at the water surface is a sign they are lacking oxygen.

Harvesting

- Tilapia are generally ready to harvest at 6 - 9 months of age but growth rate is dependent upon feeding regimen and number of fish in a system.

WATER

Source

Most people use municipal tap water to charge the system. While in some regions water may be ready to use right out of the faucet, many municipal sources have added chlorine and chloramines to the water for disinfectant purposes. These compounds make the water safe for us to drink but are toxic to fish. There are a number of water conditioners available at pet and aquarium shops used to neutralize these chemicals. Check to make sure that they are safe for use with fish and plants that are intended for human consumption. An easy and safe alternative is ascorbic acid or Vitamin C. Adding 500 mg of ascorbic acid per 50 gallons of water effectively neutralizes chlorine. There are also Vitamin C shower pre-filters are also available from some health product retailers.

Replacement water, (water that is added to the system for a water change or due to evaporative loss) should also be treated with water conditioners.

In our warm-water system with a 220-gallon capacity, we add about 40 gallons of water per month to make up for evaporative loss.

Using rainwater to fill the system will avoid these concerns.

PLANTING

ECOLIFE uses grow pots or "net pots" to contain our plants. These are plastic baskets perforated to allow sufficient water flow. The pots contain a growing soil-less medium, in our case LECA (lightweight expanded clay aggregate). This versatile medium has hundreds of tiny pores that retain moisture. Large 8 to 16 mm average diameter size allows for maximum oxygen to the roots while providing a stable base for plant roots grown in active hydroponic systems or passive hydroculture applications.

Perfect for passive, wick, and sub-irrigation use, individual hydroculture pots or hydroponic systems, LECA is also completely pH neutral. Reuse over and over by rinsing out roots then sterilizing in a very mild bleach solution. Rinse well before using. These small porous brick-colored balls are inert and hold moisture well. This medium also has exceptional surface area for nitrifying bacteria colonization.

Planting Methods

- For seeding the pots we place a small amount of LECA in each pot, then a small piece of dampened paper towel.
    - Seeds are sprinkled on the paper towel, and then covered by additional LECA.
    - The paper towel acts to better hold the seeds when the pots are first placed in to the channel and washed sporadically with water flow.

- **Wick Method**
  Wicking uses capillary action where liquid spontaneously rises in a narrow space such as a thin tube, or in porous materials such as paper. To start plants from seed in an NFT system, we use a small piece of paper towel in each pot to create wicking action. With this the seeds stay moist and germinate in a couple days. The paper towel gradually degrades as the plants' roots begin to reach the water.

    - Cut paper towel into a long rectangular strip.
    - Fold end of paper towel into bottom of pot.
    - Place one layer of growing media (i.e. LECA) on top of towel.

- Fold the rest of the paper towel over media.
- Moisten towel and place seeds on it.
- Then add a second layer of growing media until top of pot.
- Voila!

- For most common veggies the seeds germinate in 2 - 5 days. If germination does not occur check if seeds are getting wet. Adjust as needed.

RESOURCES

Barrels and Containers:

San Diego Water Recycling
www.sandiegowaterrecycling.com

Pacific Export
6088 Federal Blvd
San Diego, CA 92114
TEL: 619.263.5667 FAX: 619.266.8524
E-mail: sales@pacific-export.com

LECA, Grow Pots, Lighting, and other indoor growing supplies:

Greentrees Hydroponics
2581 Pioneer Avenue, Suite D
Vista, CA 92081
Voicemail: 760-598-7551
Fax: 760-598-6486
www.hydroponics.net

Innovative Growing Solutions, Inc.
5060 Santa Fe Street, Suite D
San Diego, CA 92109
858-578-4477
www.igshydro.com

Marine Depot
www.marinedepot.com

Water pumps, bulkhead fittings and other plumbing supplies:

Grangetto's Farm and Garden Supply
1105 West Mission Avenue
Escondido, CA 92025-1664
(760) 745-4671
www.grangettos.com

Aquatic Warehouse
5466 Complex Street Suite 204
San Diego, CA 92123
www.aquaticwarehouse.com

Aquatic Eco Systems, Inc.
www.aquaticeco.com

Fish:
Tilapia - Tilapia Mama - www.mybackyardfishfarm.com
www.aquaticcommunity.com/tilapia

Bulk Fish Food:
www.aquafarmsfishfood.webs.com
www.brineshrimpdirect.com
www.angelsplus.com
www.kensfish.com

Seeds:
Peace Valley Farm Supply
PO Box 2209
125 Clydesdale Court
Grass Valley, CA 95945
(888) 784-1722

Sprout People
170 Mandell St.
San Francisco, CA 94124
www.sproutpeople.com

Aquaponics Journal
www.aquaponicsjournal.com

Nelson and Pade
www.aquaponics.com