INTRODUCTION TO aquaponics

This manual is brought to you by ECOLIFE.

Saving Ecosystems. Saving Lives.

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www.ecolifeconservation.org

Mission:
ECOLIFE Conservation® is an organization dedicated to a world in which people and nature prosper together. We focus on integrating community health and environmental sustainability through simple, adaptive approaches.

The Challenge:
Conventional agricultural practices wreak havoc on the environment in many ways, depleting vital resources and posing major health risks to both humans and wildlife. Additionally, the number one cause of species extinction is loss of habitat, which is overwhelmingly lost from the conversion of forest to farmland.

Conventional agricultural practices are known to be:

- plays a major role in climate change
- the number one cause of species extinction
- a threat to vital resources
- a threat to human health - According to the WHO, nearly 3 million people suffer from pesticide poisoning worldwide each year
- a threat to the environment as harsh pesticides and chemicals pollute the air, drinking water, and soil

Our Approach:
At ECOLIFE®, we focus on using conservation as a tool that is adaptable and integrative rather than confrontational. Our approach matches green technologies with education to improve upon our use of precious natural resources such as water, land, and forest.

HOW ECOLIFE HELPS

Aquaponics Education Program

Our programs focus on aquaponics education which works to engage students in a unique classroom experience filled with hands-on science. Each program is designed to break from the conventional classroom setting and immerse students into a world where sustainability is a concern that directly affects their future. The emphasis of our program is on project-based learning, which addresses community engagement and real-word issues such as resource depletion.

ECO-Cycle: San Diego, California and Across America

Start teaching aquaponics with the ECO-Cycle, our easy-to-use indoor garden system. This system is designed to work with a standard 12" x 24" fish tank, and will provide students with a fun, daily reminder of the value of a sustainable food system. Give students the opportunity to care for aquatic animals while growing healthy veggies they will actually ask to eat! We offer quarterly webinars and trainings for dedicated teachers who want to utilize an ECO-Cycle Aquaponics Kit and STEM curricula as learning tools in the classroom.

ECO-Garden: San Diego, California

Our ECO-Garden Program is designed to be integrated with Next Generation Science Standards at middle and high schools. Classrooms will analyze the major global challenge of sustainable food production and come up with solutions that account for societal needs and wants. Students work together to design an aquaponics system that is practical, easy to maintain, within the given budget, and allows for scalable food production to best fit the needs of the school. We teach the students to become aquaponics experts and share detailed descriptions and presentations of what they have learned to other classes at their school. Current projects for this program will conclude in Fall 2017.

How Do I Get Started?

To begin the application process, please review our eligibility requirements and submit your grant application on our website. You can also adopt a classroom and provide this program to a teacher of your choice. We offer trainings, curriculum, and workshops for any interested educators - please contact us today for more information!

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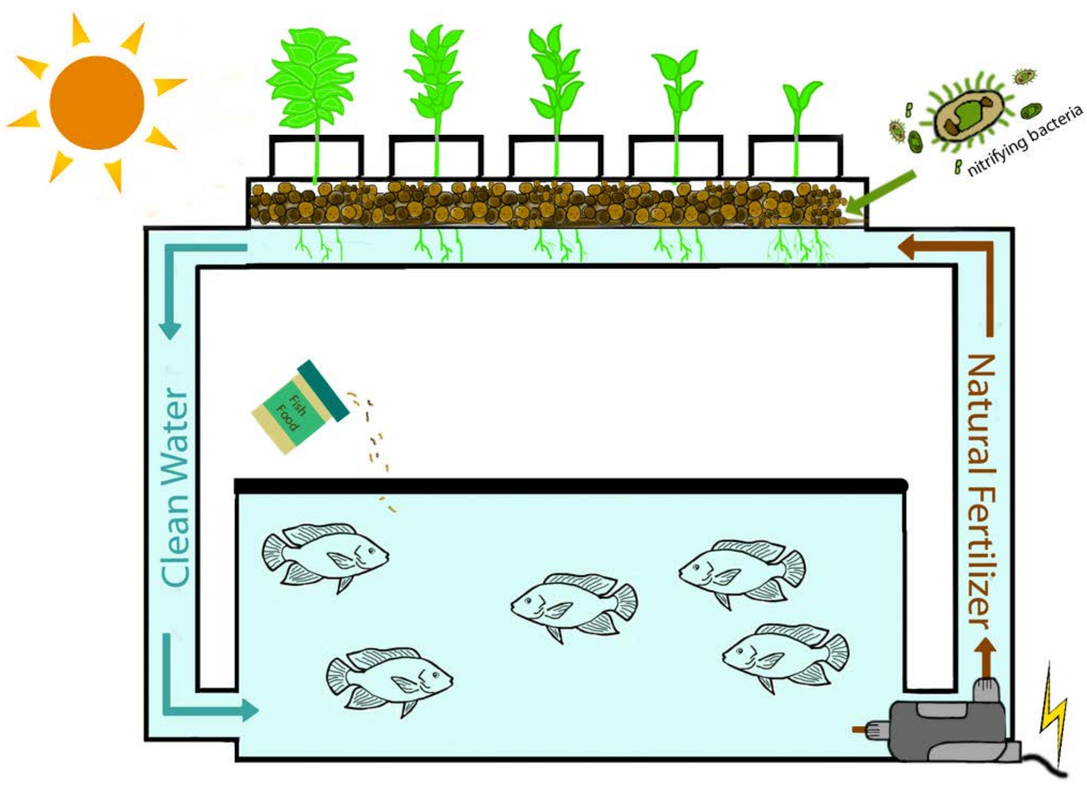
INTRODUCTION TO AQUAPONICS

What is Aquaponics?

Aquaponics is a sustainable method of food production combining aquaculture (raising aquatic animals) and hydroponics (cultivating plants in water). In this circulating system, fish waste acts as a natural fertilizer for plants, plants then take up those nutrients and return clean water to the fish. Perfect harmony! Aquaponics is especially valuable in areas where land and water aren't plentiful. Aquaponics is beneficial for everyone who wants to grow food, and it can be done just about anywhere that has access to clean water and energy.



Why Use Aquaponics?

- Aquaponic systems operate with little environmental impact to produce high-quality, hormone-free fish and organic vegetables, without the use of artificial fertilizers, harmful pesticides, and dangerous herbicides.

- Aquaponics emphasizes water conservation. Generally, aquaponics uses 90% less water than conventional vegetable gardens and 97% less water compared to standard aquaculture methods. Additionally, the recirculating system keeps waste out of watersheds.

- Aquaponics is a versatile and adaptable method of sustainable farming. Systems can be built on just about any scale and designed to fit in almost any space - talk about efficient land use!

THE NITROGEN CYCLE

The Nitrogen Cycle - The Magic of the System

Nitrogen is an essential nutrient for plant growth and is abundant in a healthy aquaponics system. Nitrifying bacteria convert ammonia and ammonium (found in fish waste) into nitrates, a form of nitrogen that plants can use as fertilizer. You will find three forms of nitrogen and two main types of bacteria in an aquaponics system:

Forms of Nitrogen:

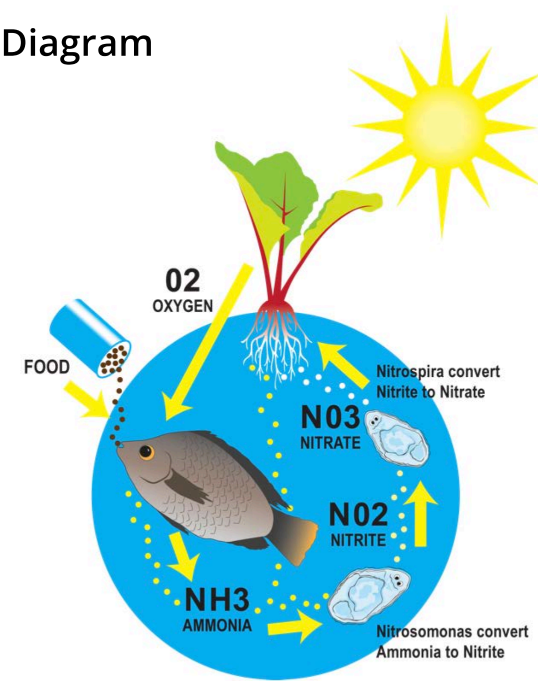
1. Ammonia/Ammonium
2. Nitrites
3. Nitrates

Bacteria:

1. Nitrosomonas
2. Nitrospira

Remembering the name of the bacteria is less important than knowing their functions. The first set of bacteria essentially consumes the ammonia/ammonium produced from fish and converts it into nitrite. The second set of bacteria consumes the nitrites and produces nitrates - the most accessible form of nitrogen for rapid plant growth!

The Nitrogen Cycle Diagram



PLANTS

What Plants Can Be Grown?

A wide variety of plants may be grown using aquaponics. Here are a few plants that have grown successfully using aquaponics:

- Green leaf, red leaf, and other leafy lettuces
- Bok Choi
- Swiss Chard
- Arugula
- Basil
- Mint
- Watercress
- Chives
- Microgreens
- Many common tropical plants / house plants

Some fruiting plants may have higher nutritional demands and therefore, will do best in heavily stocked, well-established systems. We recommend adding potassium sulfate (sulfate of potash) to your water to trigger flowering.

These include:

- Tomatoes
- Peppers
- Cucumbers
- Beans
- Peas
- Squash

FISH

Which fish grow best?

A wide variety of fish and other aquatic animals can be farmed in aquaponic systems. Freshwater, herbivorous or omnivorous fish are ideal choices for their sustainability, ease of feeding, and efficient conversion of feed. Here are the top five fish we recommend:

- Tilapia
  - Ideal for large scale aquaponics systems
  - Easy to breed, starting at 7-8 months of age
  - Optimum temperature range between 65° - 85°F
  - Grow fast – up to 500g in 6 months
  - Can be harvested to eat and are an excellent source of lean protein

- Catfish
  - Ideal for large scale aquaponics systems
  - 300+ gallon tank necessary because catfish can grow up to a size of 40-50 lbs.
  - Grow very quickly
  - Can be harvested to eat
  - Optimum temperature range 75° - 86°F
  - Can tolerate temperatures between 41° - 93°F
  - Resistant to many diseases and parasites
  - Can withstand a wide pH range

- Koi
  - Beautiful and long life-span
  - Most comfortable in 250+ gallon tanks
  - Can tolerate temperatures from 35-85 °F
  - Resistant to many parasites
  - Can withstand a wide pH range

- Goldfish
- Tropical
    - Perfect for in-home aquaponics systems
    - Widely available
    - Produce waste quickly
    - Inexpensive
    - Can tolerate temperatures between 50-75°F
    - Gentle community fish if placed with similar sized, non-tropical fish

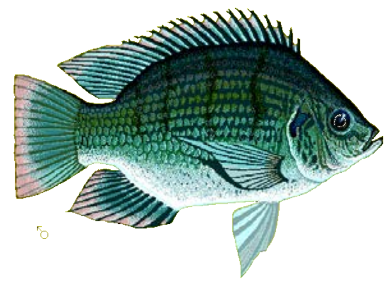
- Tropical Fish
    - Beautiful and fun option
    - Perfect for in-home and smaller aquaponic systems
    - Heater necessary
    - Examples: suckermouth fish, cichlids, mollies, clown loaches, tetras
    - Or smaller tanks try the Albino Bushynose Pleco, which grow no longer than five inches

** Please note that some fish species are regulated, and in some cases restricted, in parts of the country. Check with your local fish and wildlife regulatory agency to learn about the specific ordinances and any required permits for your region.*

Other options of fish to consider are:

- Pacu
- Trout
- Crappie
- Barramundi
- Silver perch
- Golden perch
- Yellow perch
- Freshwater prawns
- Crayfish

Some Notes on Tilapia



Tilapia has become a very popular fish to use in aquaponics because they can handle a wide range of water quality. Due to 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

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 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 take 10-14 days before the fry are released.

Housing

- Fingerling tilapia may be reared in small aquariums but will eventually require a large tank or pond, as they can reach 16 inches or more in length.
- 55 gallon barrels work great for growing tilapia to plate size, 1 – 1.5 lbs.
- As a guideline, the ratio of fish to water capacity is approximately one pound of fish for every five to ten gallons of water.

Feeding

- Feed fish as much as they will eat in three to five minutes, three times per day. Allow four to five hours between feedings for optimal metabolism
- Take care not to overfeed fish
- Provide a high-quality fish food of appropriate size – fingerlings will take a much smaller pellet size than juvenile and adult fish
- An adult tilapia will eat approximately 1% of its bodyweight per day
- Fish fry (babies) will eat as much as 7%
- Fish that are not eating may be stressed due to: high ammonia levels, outside of their optimal temperature range, lacking sufficient oxygen (discontinue feeding if dissolved oxygen drops below 3ppm)

Water Temperature

The optimal temperature for Mozambique Tilapia is 75° – 85° Fahrenheit.

Water Quality

- Tilapia thrive best in a pH of 6.5 to 8.0.
- Ammonia and nitrite levels should be less than .25 ppm. High ammonia and nitrite levels are the number one killers of fish in an aquaponic system.
- Oxygen
  - Provide plenty of aeration in your fish tanks with a strong water flow.
  - Avoid overfeeding or overcrowding the fish.
  - Fish gasping for air at the water surface is a sign they are lacking oxygen.

Harvesting

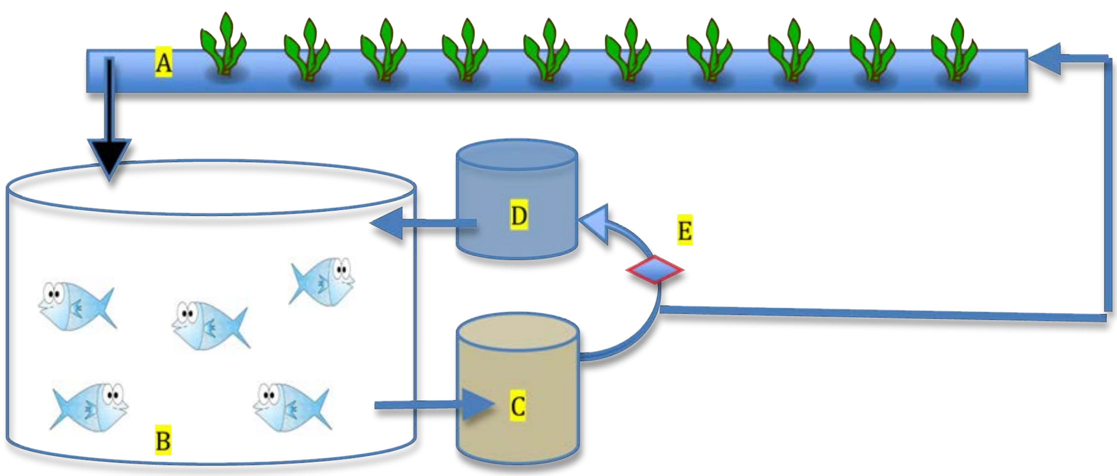
Tilapia are generally ready to harvest at 6 - 9 months of age but growth rate is dependent upon feeding regimen and the number of fish in a system.

AQUAPONIC METHODS

There are three primary growing methods in aquaponics: Nutrient Film Technique (NFT), Ebb & Flow, and Raft or Deep Water Culture (DWC).

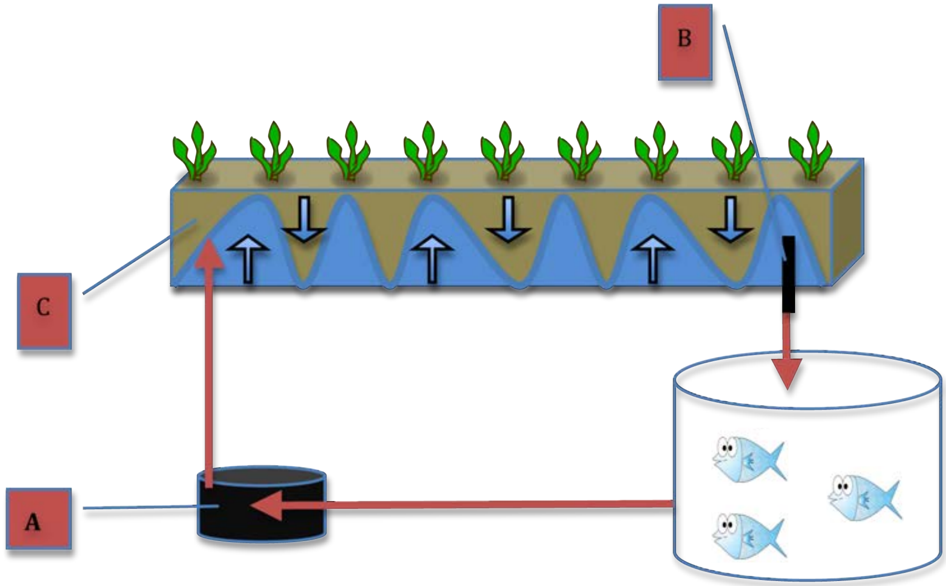
Nutrient Film Technique (NFT)
Aquaponic System

A. NFT Grow Channel
B. Fish Tank
C. Mechanical Filter / Solids Removal
D. Biological Filter
E. Gate Valve (To direct flow to grow channels)



Nutrient Film Technique (NFT) is the most popular technique used in hydroponics and is easily adaptable for use in aquaponics. With this method, a thin layer of water containing dissolved nutrients from the fish tank is pumped through the bare roots of the 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 reach the plant roots. The main advantage of the NFT system is that the plant roots are exposed to a continuous supply of water, oxygen, and nutrients. A downside of NFT is that it has less buffering against interruptions in the flow, e.g. power outages, but overall it is a very productive technique.

Grow Bed / Ebb and Flow
Aquaponics System



A. Pump
B. Bell Siphon
C. Grow Tray / Growing Media

Another widely used method by backyard growers is Ebb and Flow Aquaponics. The growing area is a wide deep container with sufficient surface area. This container is filled with gravel, LECA, or other soil-less growing medium where the vegetables can be planted. The water pump is controlled by an adjustable timer which is used to circulate 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 begins to drain back into the fish reservoir. As it drains, oxygen is pulled through the roots.

An alternate means of providing water in an ebb-and-flow manner is through the use of a bell siphon. A siphon is a mechanism for drawing water from a higher container to a lower container. Siphons can be adapted to control the flooding and draining of grow beds in an aquaponics setup. In this usage, they are called auto-siphons - siphons that can start and stop in response to changing water levels. Specifically, bell siphons and loop siphons are two useful and commonly used techniques for this application. Bell siphons can also be used in biological filters to create a wet/dry environment beneficial to aerobic nitrifying bacteria.

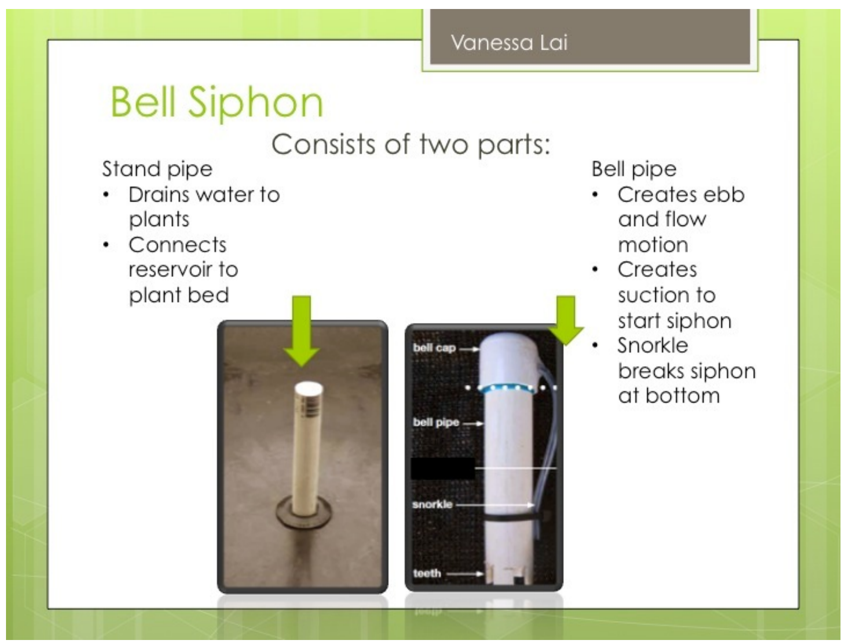
The bell auto-siphon consists of:

1. A vertical standpipe

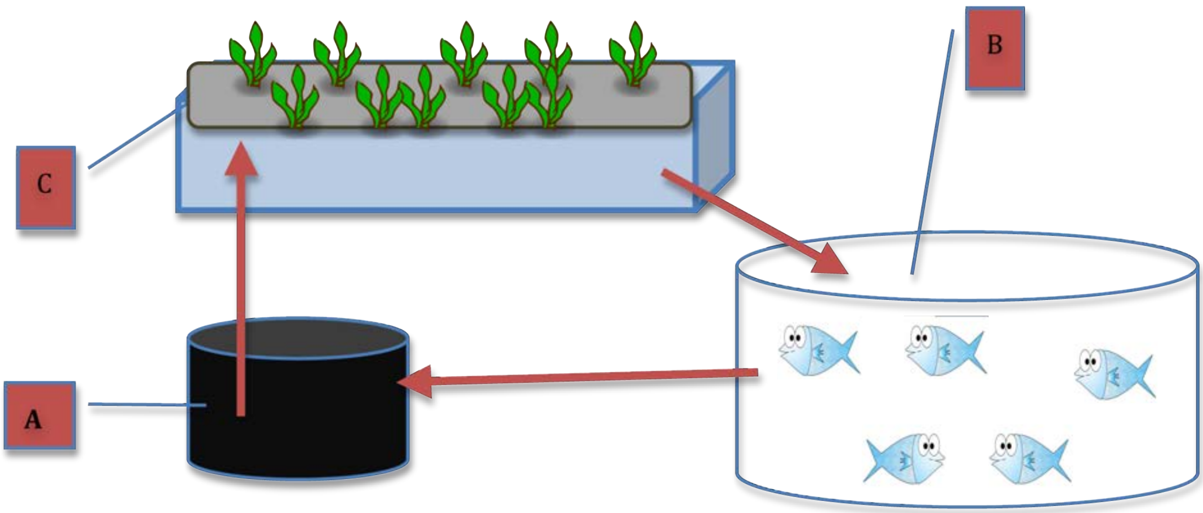
2. A bell pipe placed over the standpipe. The bell pipe is freestanding, slightly taller than the standpipe it covers, and is fitted with an end-cap. Additionally, the base has pieces cut out to allow the free movement of water.

3. Small air holes are drilled near the bottom of the bell pipe to break 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 draining the water out of the container. When the water level drops to the level of the air holes, the siphon is broken, and the process begins again.



Raft /Deep-Water
Aquaponics System



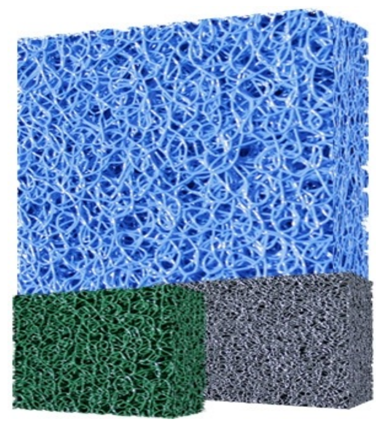
A. Mechanical / Biological Filter
B. Fish Tank
C. Growing Raft

Raft or Deep Water Culture (DWC) is the most frequently used technique for large-scale, commercial aquaponics. With this technique, the plants are grown on perforated rafts, usually made of Styrofoam or similarly buoyant material, which float in dedicated water tanks. The roots of the plants are often bare and constantly in the water. This is a highly productive method, which requires good aeration and intensive filtration to keep the water clean and clear of solids waste.

FILTRATION AND CYCLING

Overview of Filtration

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



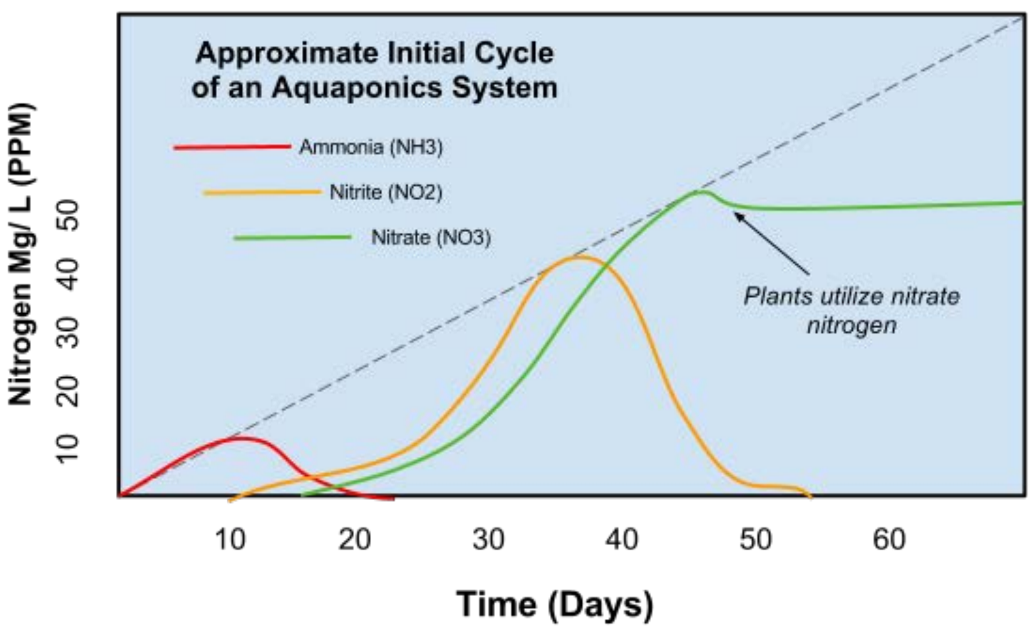
Biological filtration or bio-filtration is the most critical for providing proper water quality, and enhancing the well-being of the fish. In bio-filtration, naturally occurring aerobic bacteria convert the toxic ammonia (NH3) produced by fish, decomposing fish waste, uneaten food, and dead plant matter into nitrite (NO2) (also toxic) and then to relatively non-toxic nitrate (NO3). Bio-filtration is achieved in a number of ways in these systems, but all work on the same basic principal of moving oxygenated water through an inert material with high surface area in which the nitrifying bacteria colonize. One type of bacteria, Nitrosomonas, converts ammonia to nitrite, then a second type of bacteria, 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.

Mechanical filtration is the removal of solid waste before being 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. The mechanical filter 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 filter, reducing the amount of oxygen used by bacteria in the mineralization and nitrifying processes. This is important, as your fish need oxygen as well. If there is too much solid waste in the system – uneaten food, plant matter, etc., the dissolved oxygen may drop to dangerously low levels.

The Initial Cycle

These beneficial bacteria are ubiquitous and will eventually colonize where there is adequate oxygen and nutrients. Similar to the set up of an aquarium, a new aquaponics system must first be “cycled” prior to 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 initially adding a few fish to the system. 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, the second type of bacteria (Nitrospira) begin to convert the nitrite to nitrate. The cycle naturally stabilizes in about four 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, which can help bolster and speed up the cycling process



Water Flow

In aquaponic systems, a water pump is used to move water from the fish holding tank through the filters to the plant roots and back to the tank. If multiple tanks or barrels are used, the 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 provide an even, strong flow through all of the tanks and to the roots of the plants. Providing strong water movement through the fish tanks reduces dead spots and improves overall oxygenation.

BASIC PARTS AND SUPPLIES

- Fish Tanks
- Grow Trays or NFT Channels
- Growing media
- Plumbing
- Biological Filter
- Mechanical Filter
- Water Pump
- Water Heater (if needed)
- Air pump / Diffusers
- Net Pots (for NFT)
- Lighting (if indoors)

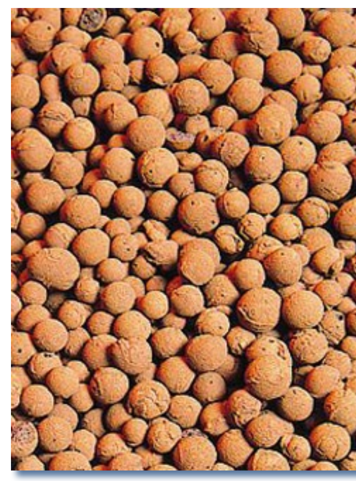
Fish Tanks, Ponds, and Barrels

A variety of containers may be utilized to hold fish, including aquariums, plastic storage barrels, pond liners, etc. ECOLIFE's indoor barrel system uses four interconnected 55-gallon plastic food-grade storage barrels to hold fish. We have had good results with modified water storage tanks and raised concrete beds with pond lining.

Grow Trays and NFT Channels

Specialty growing trays and NFT channels are available through hydroponic and agriculture equipment suppliers. Plastic cement mixing trays and plastic storage containers of appropriate size can work well as growing trays, and rain gutter downspout can be easily adapted to accommodate growing pots. Both items are readily available through hardware supply retailers.

Grow Media



Hydroton ™ LECA (lightweight expanded clay aggregate) is a popular hydroponic grow media used for aquaponic growing. 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 quartz gravel and rockwool – a specialty product for hydroponic growing. Ideally, the media should be inert and composed of varying pebble sizes to ensure that there is interstitial space necessary for water flow and root growth.

Biological Filter Media

This is the material used to provide a growing surface for beneficial nitrifying bacteria. There are many specialty plastic and ceramic bio-media products 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. Plastic onion bags and polypropylene strapping can also serve as inexpensive and effective bio-media. We have had great results using 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

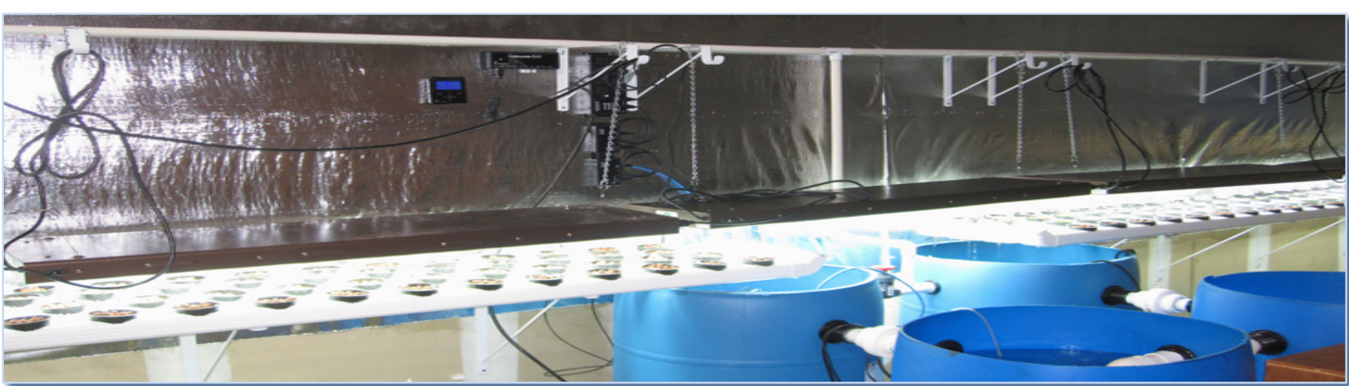
making it an effective bio-media. It is available in four densities, which may be stacked from less dense to most dense for optimum filtration.

Mechanical Filters

As discussed earlier, mechanical filtration functions 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 can also be 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, but positioned above the water line to catch water as it flows from the growing channels back to the fish. The sponge may then be removed, cleaned, and replaced on a regular basis. For larger systems, sand filters, settling tanks, and other commercial filters are a good investment and will go a long way in providing stable water quality.

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 most of our NFT channel systems.



Lighting for Indoor Systems

The sun is the finest light source for aquaponics. For growing indoors, however, there are a number of artificial light options for indoor gardening, including high output fluorescents, metal halides, mercury vapor bulbs, LEDs, and plasma lights. We use T5 high output fluorescent fixtures and LEDs with relatively low heat output and minimal power consumption. This has worked very well for leafy greens like basil, lettuce, and chard. Some vegetables may require more intense lighting when growing indoors.

Water 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's capacity and ambient temperature of the surrounding area. For tabletop units of 10 – 40 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. 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. As an alternative, passive solar heating systems may be employed to manage water temperature. These units are a bigger up front investment but will save a great deal of electricity in the long run.

Air Pumps and Air Stones

Aeration is vital to maintaining adequate oxygen levels for fish respiration. Providing extensive water surface area, along with water surface agitation helps to increase the dissolved oxygen in the water. Supplemental air pumps and diffusers, along with airline tubing and gang valves to manage flow can also be used to provide supplemental O2. Like much of this equipment, air pumps and peripheral 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 best 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.

WATER QUALITY

Rainwater and clean well water are ideal sources for filling an aquaponic system. Many of us, however, are limited to municipal water to charge the system. While in some regions water may be ready to use right out of the tap, many municipal sources add chlorine and chloramine to the water for disinfectant purposes. These compounds make the water safe for humans to consume but are toxic to fish and the bacteria in the bio-filter. 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. Medical grade carbon filters may also be used to safely remove these harmful compounds from tap water. Replacement water, (water that is added to the system for a water change or due to evaporative loss) will require little water treatment in established systems.

pH	**6.5-8**
Ammonia	**0 ppm**
Nitrite	**0 ppm**
Nitrate	**5-80 ppm**

- **pH:** A neutral pH (7.0) is ideal. This is a compromise between the optimal ranges for the fish, the plants, and the bacteria. Fish typically thrive best in a pH of 6.5 to 8.0. For plants optimum pH ranges from 5.0 to 7.0. 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 to keep track.

- **Ammonia and nitrite** levels should be less than .25 ppm. High ammonia and nitrite levels are the number one killers of fish in an aquaponic system. Ideal ranges for your system are included in the table below.

RESOURCES

Food Grade Barrels and Containers:
- *San Diego Water Recycling* - www.sandiegowaterrecycling.com
- *Hydrofarm* - www.hydrofarm.com

Grow trays, Bell siphons, and Other Specialty Supplies:
- *The Aquaponic Source* - http://www.theaquaponicstore.com
- *Growers Supply* - http://www.growerssupply.com
- *Aquatic Warehouse* - http://www.aquaticwarehouse.com
- *Innovative Growing Solutions, Inc.* - www.igshydro.com
- *API Water Quality Test Kit* - http://www.apifishcare.com/product.php?id=580#.WKuL6RIrLUY

LECA, Grow Pots, Lighting, and Indoor Growing Supplies
- *Greentrees Hydroponics* - www.hydroponics.net
- *Innovative Growing Solutions, Inc.* - www.igshydro.com
- *Peaceful Valley Farm Supply* - www.groworganic.com/

Water Pumps, Bulkhead Fittings, and Plumbing Supplies
- *Grangetto's* - www.grangettos.com
- *Pentair* - http://pentairaes.com

Fish & Bulk Fish Food
- *Tilapia Mama* - www.mybackyardfishfarm.com
- *Alpine Fisheries* - www.alpinefishery.net
- *Aquaponic Source* - www.theaquaponicstore.com
- *Brine Shrimp Direct* - www.brineshrimpdirect.com
- *Angels Plus* - www.angelsplus.com

Workshops
- *Green Acre Aquaponics*, Colorado - http://greenacreaquaponics.com/
- *International Aquaponics and Tilapia Aquaculture Course*, University of the Virgin Islands: http://www.uvi.edu/research/agricultural-experiment-station/aquaculture-home/aquaponics-workshop/default.aspx
- *Nelson and Pade*, Wisconsin - Workshops & Training; Aquaponics, Hydroponics
- *Eden Aquaponics*, California - http://edenaquaponics.com/
- *Nor Cal Aquaponics* - California - http://norcalaquaponics.com/