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## Why Aquaponics?

Aquaponics is basically the holy grail solution for the trio of sustainable aquaculture, sustainable agriculture and recycling of organic waste. Before humans, the world used aquaponics naturally and after we invented farming, it has been set aside for a long time.

When we create civilizations on the moon or on Mars, it is almost guaranteed aquaponics will be used to produce the food and recycle the waste of the residence. Even NASA is developing systems for aquaponics. So it is not only a return to nature, but also a modern and rapidly advancing research topic.

## Learning

As an engineer I had some learning to do about plants and fish and I wanted to challenge myself to see if I could reproduce the project from concepts. One great resource I recommend is your state's local agriculture extension most state universities in America have a sizable agriculture research team that delivers free information for local growers to successfully harvest crops in their region, including backyard farmers.

## Initial test

Before I designed this project, I decided to build a miniature version my 10-gallon aquarium to see if it's really true that fish poop can make plants grow. I built a basket on top of the aquarium with a metal mesh bottom and some cups of porous rocks. Then I added some herbs like basil and I added one 5-Volt DC pump to circulate the water over the plants roots. I was amazed at the results; the plants grew very well and the water of the fish aquarium no longer accumulated ammonia, which I tested just like many aquarium keepers do.

A little background: nitrogen is a general term for an element that takes on a cycle in normal ecosystems. The fish excrement contains a form that slowly converts into ammonia which is more volatile then solid waste the bacteria in the water convert those nitrates into nitrites and something must evacuate the nitrites because they are toxic to the fish after they reached some level. This is where the plants roots come into play; plants are lovers of nitrates.

### Visiting the Agrilife Learning Greenhouse

I visited the AgriLife extension greenhouse in a small town in Texas and I learned a lot about growing basil and how to start an aquaponic system. Doctor Joe Massabni led the workshop and he has published a huge amount of worksheets and YouTube videos to help other people get started.

## The Problem I Solved

I spent a couple of years learning about hydroponic systems and aquaculture systems and what I saw was they aim for sustainability but the practical applications tend to include a weakness related to high cost, or non-renewability. For example, most full scale hydroponics greenhouses (hydroponics = plants and water, no fish) are sourcing non-renewable fertilizers continuously to feed the plants, and most high tech aquaponics systems use expensive LED lighting with extremely high electrical consumption.

The most promising operation that I saw so far was a local aquaponics greenhouse which grew goldfish and utilized sunlight, but the lettuce production was not so stable, no fruiting plants were successful, (in this case as well as common cases for aquaponics), and the goldfish were not harvested because we don't eat goldfish in the US.

The Greenhouse also creates a problem because pollinating insects cannot enter the greenhouse to support fruiting plants like tomatoes, and if a bacteria pathogen arrives inside the greenhouse it spreads quickly without the balancing elements that show up in a and open air farm.

I wanted to create a model that uses minimal electricity, utilizes sunlight, allows wind and insects to pollinate the plants, and uses and edible fish to produce the plant food. Also, I wanted to eliminate the high cost of having specialized containers for the plants as you usually see in hydroponic setups.

# Features

These are the features of my aquaponics design and the problems they solve.

## Overhanging structure:

This system could be built with no upper frame, but I used inexpensive landscaping beams. This allows us to tie ropes up high and let tomato vines grow larger.

## Shade Cloth

The wood structure gives us a place to add a shade cloth in extremely hi radiation so the plants do not overheat.

## Mesh Enclosure

The mesh is surrounding the structure to prevent birds from eating the fruit but still allow pollinating insects to come and go.

It also allows wind to pollinate the plants, and allows the air to perform evaporative cooling.

As a result, my garden continued to grow in mid summer when most gardens are retired in Texas.

## Swirl filter

The swirl-filter is a simple design, low cost, and does not require replacement of any filter media. How it works – the solid fish waste is pulled into the center, and it is retained in the swirling reservoir while bacteria break it down into plant-available, liquid fertilizer.

The circulation filter also reduces energy consumption drastically from a pump that must force water through a filter media.

## Single-pump gravity system

The entire system can be modified or expanded, but the height of each item is critical. That’s why I made the 3D model of this system (not just for fun) – it solves the requirements for a low-energy pump, gravity-fed water tubes, and pumpless return of the water into the aquarium from the plant bed.

## Below-ground aquarium

When I visited an aquaponics farm, they told me they shut down the system in mid-summer. This is because the water temperature rises too high.

The first solution was to use goldfish, which survive fairly high temperatures, but market-desired fish like tilapia need cooler temperatures. The below-ground aquarium allows the water to remain much cooler. I was successful in raising crappie and catfish, although some died without a clear cause (I need a veterinarian to participate next time).

## Aquarium cover

The aquarium cover is made of wood, with one layer of ½ inch insulation foam. This cover shades the aquarium, suppressing algae and sunlight. It is absolutely necessary for an outdoor system. It also reduces the evaporation rate over the aquarium, and the cost of re-filling with RO (reverse osmosis) water.

## Cinder block retaining wall

Cinder blocks have 3 key advantages over other structures:

1) They are cheap and available everywhere
2) They cool down the system when they get wet, due to their high porosity and thermal mass
3) They allow us to build the system and reconfigure/dismantle it without any fasteners or glue, due to their solid weight

## 5-gallon net cups

These became popular and available this decade as many backyard growing systems use a media + water reservoir inside of a 5-gallon bucket. They can be replaced by other solutions, but this is the only specialty product in this whole system.

The “net” cups allow 360 degrees of water drainage and air cooling, to keep roots cool.

The cups also allow roots to hang down lower if they grow very large.

## Net Cups hanging planks

The net cups are suspended by cedar planks, which are weather-resistant and mold resistant compared with other wood. The 5-gallon net cups allow rearranging of plants (required since we use sunlight instead of controlled LED lighting),

## Porous media

Expanded shale is the selected media, and is an innovation when combined with their containers.

The media is the most affordable option currently available, and is available in bulk unlike coco-fiber media in hydroponics stores, and compared with expanded clay pellets found in stores.

The media does not leach harmful toxins for the plants or fish, like many other stones.

## Suspended-media method

Suspended media method is the name I would like to give to this unique method created here compared with most popular aquaponics solutions.

The porous media gives the plants a place to set their roots. The media spreads the water flow (a novel solution compared with DWC (deep water culture) method and eliminates a pump from the Flood-and-drain method, and reduces the number of parts in the system.

The media also protects the roots from sunlight compared with omitting root media (per the aeroponics method or gravity-tube method), and the media supports larger plants like tomatoes, compared with the sponge media in the common Floating-Raft method.

The suspended media gives us control of the spacing of the plants (in this trial the spacing is broad) and gives us the option to remove one type of plant depending on the season.

This method also allows us to put multiple plants in one container if it is small like basil, while retaining the grid spacing, and supporting planning.

For research situations, this method allows us to isolate plants from one another if we wish to perform an experiment with separate treatments (unlike the large monolithic beds in many flood-and-drain systems).

## Pressure-regulating outlet pipe

The end of pumped water network is a very important feature: a vertical pipe for overflow.

This outlet solves several engineering requirements:

- The outlet tower regulates the pressure in the system, forcing the flow to each plant to be equal. It eliminates deviations in pressure which often accompany evaporative water losses, or debris and algae build-up in the tubes
- The outlet tower has no adhesive, so the height can be changed as required.
- The outlet tube permits the farmer to add or reduce the number of plant-feeding tubes without concern for changing the water flow to the other plants, by maintaining a constant pressure in the main feed line.
- The outlet tube expels any excess water if there is a change in flow entering from the swirl filter.
- The outlet gives a free path for exit of any large particles that may enter from the swirl filter on occasion.
- The outlet tube prevents pressure increases that would then demand more power from the pump, thereby reducing energy and pump size requirements.
- The adjustability of this tube gives the operator flexibility on setup (by a few inches) on the height of the swirl filter or the flow rate of the pump, allowing the user to purchase any available parts rather than the exact specifications of this particular design.

## Reverse Osmosis filter

This is not a very sustainable element but it's necessary to start the system with clean water – the tap water in Texas contains too much chloramine

## 150-gallon aquarium

This aquarium is sold at farm stores as a watering trough for livestock. But it's very tough and it is safe for fish.

## PVC water distribution

The water distribution system is made without glue, which disqualifies a farm from "organic" food production in the USA. The pipes fittings operate with low pressure (less than 3 PSI) so there was never more than a tiny leak here and there. Leaks are no problem.

## Plastic liner

Below the plants, and inside the cinder blocks I used a cheap outdoor tarp to line the bed. With one hole in the tarp, I feed the return pipe into the lowest area of the plant bed.

The tarp also allows us to perform a simple grading of the floor of the plant bed, by pouring in some gravel and then forming it to a slope towards the return pipe. This ensures no water sits stagnant in the plant bed.

### Shower curtain hoops

The front of the plant bed is accessible by hanging the front net on shower curtain hoops, which you can get at a dollar store.

### Boat

If you accidentally overfill the water, it pours out of the tank and into the pit below the tank.

Then if your circuit breaker trips at the same time, and the water circulation pump turns off, and then it turns back on later, the tank level will drop as the water spreads through the system. Then, there will be more water outside of the tank than inside.

This makes the aquarium buoyant, which allows the aquarium to turn into a boat. Be careful that your fish do not sail away.

### Electronics and IoT sensors

This contraption is another project, so I won't go into details here. But, many hackster projects focus on smart farms, which pairs great with an experimental farming setup. I was able to control my pumps remotely and monitor some aquarium sensors while I am away.

## Results

### Tomatoes

These grew on the first try, and I couldn't believe it! No added nutrients were necessary. Admittedly, I used store-bought feed for the fish, so it's not a completely closed cycle yet.

I was really proud to learn that I can produce tomatoes with this setup.

### Goals of the Challenge:

Using the term "we" in this discussion points to myself as an open source Hackster contributor as well as all of the supporters and knowledge-offerers from Texas Agrilife Extension service, a few local aquaponics farms, and some local biologists and farmers who offered tours and inputs. Also the aquaponics stores in Austin Texas who had real working demos for their hydroponics products. This also includes youtubers who developed example systems from which many of the ideas are derived, so the only thing left to do was engineering those ideas into functional plans.

### Recycle Electronics

We use low-cost pumps to make a robust system, instead of expensive hydroponics supplies. We engineer the water cycle with an innovative gravity flow plan, accommodate such a pump, whereas typical aquaponics systems require stronger pumps or multiple pumps.

### Make energy harvesting more efficient

Food is energy. We can harvest two kinds of energy from this system, more efficiently than existing published plans for gardening, aquaponics, or hydroponics. The efficiency comes from thermal regulation that supports edible fish species, and innovative ambient air/light capture that eliminates the need for costly air circulation systems and LED lighting, along with the electricity demanded from them.

## Contribute to the sustainability movement

We finally bridge the gap between sustainable aquaculture (a huge step of enclosed systems that don't over-fish the wild populations in the oceans) and sustainable agriculture (having backyard gardens, having gardens fed organically, and having gardens fed by wasted produced in the same home.

The connecting of these two innovation areas gives us aquaponics, which is not entirely novel, but in this project we make it so that the backyard hacker can build this from affordable and available materials.