Design and Implementation of Hybrid Automated Aquaponics System

A report submitted in partial fulfilment of the requirements for the award of the degree of

Bachelor of Technology

in

Electronics and Communication Engineering

by

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2020-2021

<u>Declaration by the Students</u>

We hereby declare that the project work presented in this report entitled "***Design and Implementation of Hybrid Automated Aquaponics System***", submitted in partial fulfilment for the award of the degree of Bachelor of Technology in Electronics and Communication Engineering during the academic year 2020-2021, has been carried out by us and that it has not been submitted in part or whole to any institution for the award of any other degree or diploma.

Date: 29/06/2021

Place: Tezpur

Students' name with signature

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   (Bhaskar Taye)
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CERTIFICATE

This is to certify that the report entitled '***Design and Implementation of Hybrid Automated Aquaponics System***' submitted to the Department of Electronics and Communication Engineering, Tezpur University in partial fulfilment for the award of the degree of Bachelor of Technology in Electronics and Communication Engineering, is a record of project work carried out by ***Bhaskar Taye (ELB17029) and Suraj Kumar (ELB17046)*** under my supervision during the period from January 2021 to June 2021. All support received by him/her/them from various sources have been duly acknowledged. No part of this report has been submitted elsewhere for the award of any other degree or diploma.

Date:29/06/2021

Place: Tezpur

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Date: **(Type your internal supervisor's name here)**

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<u>CERTIFICATE</u>

This is to certify that the report entitled "***Design and Implementation of Hybrid Automated Aquaponics System***" is a bonafide record of project work carried out by ***Bhaskar Taye (ELB17029)*** and ***Suraj Kumar (ELB17046)*** and submitted in partial fulfilment for the award of the degree of Bachelor of Technology in Electronics and Communication Engineering during the academic year 2020-2021. They have carried out their project work under the supervision of ***Prof. Soumik Roy, HoD, Electrical engineering dept. , Professor ECE Dept,*** **(and affiliation of your supervisor here.)**

This approval does not necessarily endorse or accept every statement made, opinion expressed or conclusion drawn as recorded in the report. It only signifies the acceptance of this report for the purpose for which it is submitted.

Date: 29/06/2021 (S. Sharma)

Place: Tezpur

Certificate by the Examiner

This is to certify that the report entitled ***"Design and Implementation of Hybrid Automated Aquaponics System"*** submitted by ***Bhaskar Taye (ELB17029)*** and ***Suraj Kumar (ELB17046)*** in partial fulfilment of the requirements for the degree of Bachelor of Technology in Electronics and Communication Engineering has been examined by me and is found satisfactory for the award of the degree.

This approval does not necessarily endorse or accept every statement made, opinion expressed or conclusion drawn as recorded in the report. It only signifies the acceptance of this report for the purpose for which it is submitted.

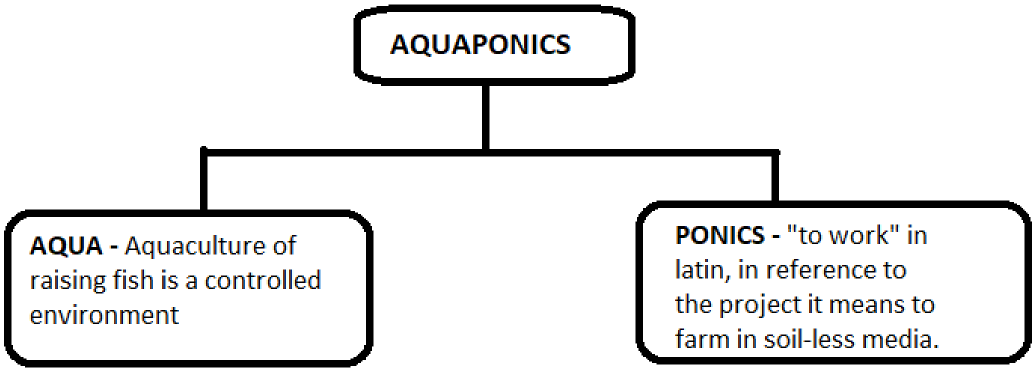
Date: 29/06/2021 (Examiner)

Place: Tezpur

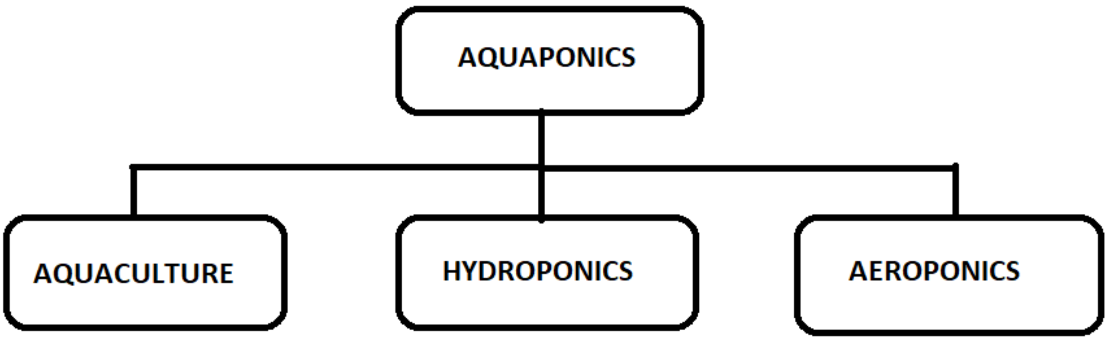
Contents

1. Introduction

The term **Aquaponics** is basically divided into two parts **Aqua** and **Ponics** where
Aqua means aquaculture is raising fish in a controlled environment and
Ponics means is Latin “to work”,in reference to this it is growing in soil-less media.



Aquaponics consists of 3 parts mainly , **aquaculture** (fish farming) , **hydroponics** and **aeroponics**. **Hydroponics** is basically the process of growing plants in water and **Aeroponics** is the process of growing plants in air or usually moist environments.So, an aquaponics system is combinedly growing plants and practicing aquaculture at the same time using the hydroponics system as well the aeroponics system.



Basic processes of an Aquaponics system. -

a. Freshwater fish are put in fish tanks and a supply of oxygen is provided to regularly oxygenate the water for the fish to survive.
b. The fish produces waste from the food provided in regular intervals. The excretory products of the fish contain high amounts of ammonia which gets mixed into the water the fish are in.
c. The water then goes into the media beds as well the mediums in which the plants are grown.
d. The bacteria that grows in the media beds and the medium used for growth of the plants converts the ammonia into nitrites and the nitrites are then taken up through the roots by the plants as nutrients.
e. In the process of absorbing the nutrients, by the plants it purifies the water to an extent. The purified water is then pumped into the fish tanks.
f. This is the cycle that continues till we feed the fishes and as a result the plants receive nutrients.

2. Aquaponics system

The fish kept in the tanks are fed with food required for the fish to survive. The fish consumes the food and as an excretory product it gives out ammonia and various bacteria convert ammonia into nutrients for the plants. Then the plants absorb the useful nutrients produced by the fish which reach the plants through the water cycle of the system. One key feature of an aquaponics system is that it replicates a natural ecosystem favourable for the fish and the plants to grow and survive.
An aquaponics system depends upon the natural relationship of the bacteria, water, aquatic life, nutrient dynamics, and plants. Each of the elements helps each other in their own process of growth. In this system there is exchange of waste by-products of the fish from the tank which is considered as a perfect fertilizer for the plants, as a result clean water that is favourable for the fish is returned into the tank. There is less waste in the system in comparison to another individual way of farming.
It uses the best of all the farming techniques , utilizing the waste of one element to benefit the growth of another , just like the natural environmental process.

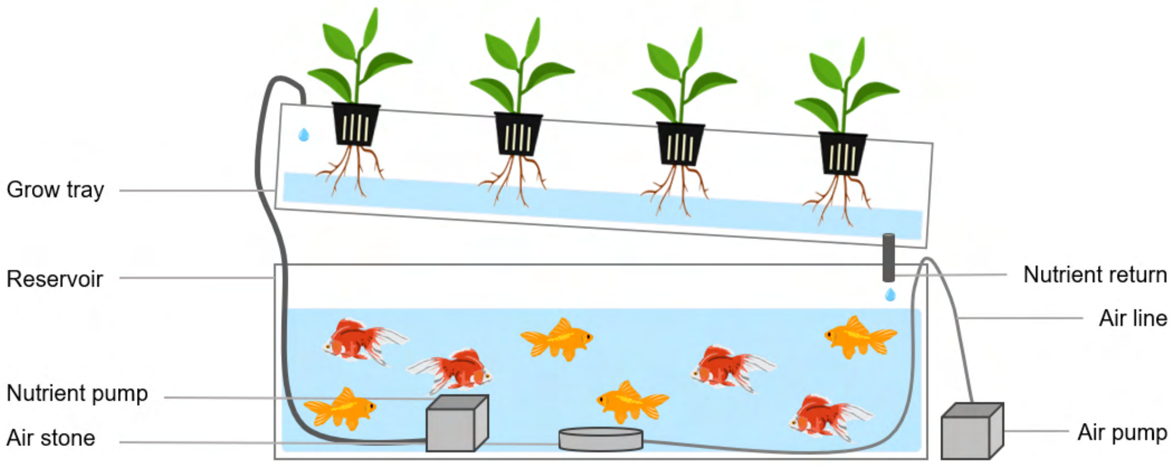


Fig-1 :- A typical aquaponics system.

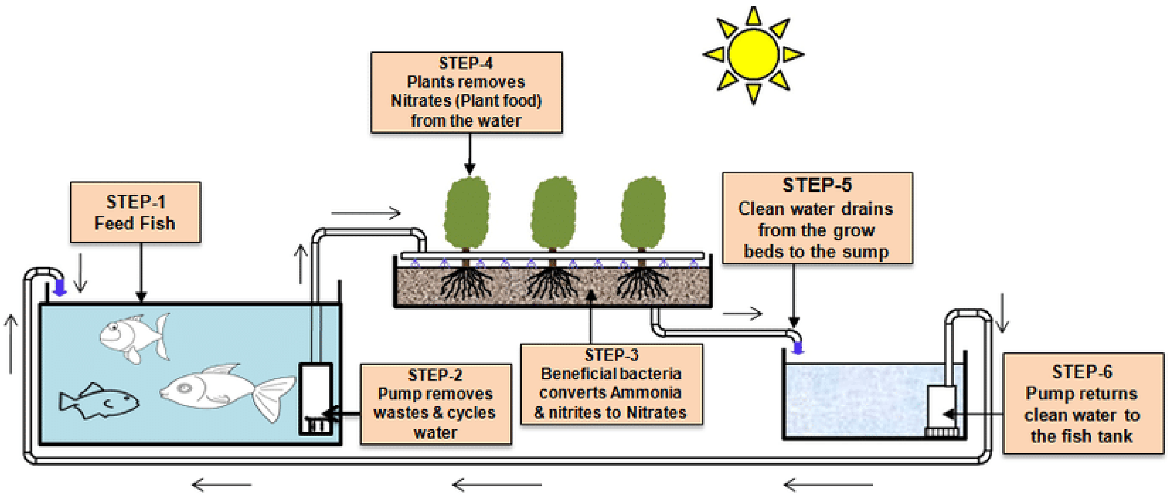


Fig-2 :- Various processes involved in an aquaponics system.

3. Aeroponics System -

An Aeroponics system is basically the simplest of all the hydroponic farming systems. It is fairly easy to build an aeroponic system. This type of system can be built to maximize the usage of an available space. This system typically uses little to no growing media. The roots of the plants that are grown get maximum oxygen, and as a result the plants grow very rapidly in this system.
This type of growing uses very little water for their growth as the water is not stagnant, and its water consumption is literally very less in respect to other hydroponic growing environments.

Growing root crops in an aeroponic system seems to be beneficial ,also harvesting is easier in comparison to other systems.

Fig-3 :- An aeroponic farming system.

Aeroponic systems have several advantages, including the fact that they often utilise little or no growth material.As a consequence, the roots receive the greatest amount of oxygen and the plants develop more quickly. In addition, aeroponic systems require less water than any other form of hydroponic system (especially true aeroponic systems). Harvesting is frequently easier as well, particularly for root crops.
Aeroponic systems, on the other hand, have a few drawbacks. Aside from being a little more expensive to construct. The dissolved mineral components in the nutrition solution might cause the mister/sprinkler heads to clog. So make sure you have extras on hand in case they clog up while you're cleaning them. Also, because the roots of the plants in aeroponic systems are suspended in mid-air by design, they are considerably more susceptible to drying out if the watering cycle is interrupted. As a result, even a brief power interruption (for whatever reason) might kill your plants far faster than in any other form of hydroponic system. In aeroponic systems, especially real high-pressure systems, there is also a less margin for error with nutrient levels.

Components required to build an aquaponics system.

- The nutritional solution will be held in a container hence ,we require a reservoir.
- Pump for submersible fountains and ponds.
- Tubing to transport water from the reservoir pump to the growth chamber's mister heads.
- The root zone is enclosed in a growth chamber.
- Heads of the mister/sprinkler.
- The root systems of the plants will be in a watertight container in the growth chamber.
- Excess nutrient solution is returned to the reservoir through tubing.
- To switch on and off the pump, use a timer (ideally a cycle timer).

It's a simple notion to understand how an aeroponic system works. The roots are suspended in mid-air for two reasons. First, they need all of the oxygen they can get. The large volume of oxygen available to the roots helps the plants to develop more quickly than they would otherwise, which is the major advantage of this sort of hydroponic system. Second, very little, if any, growth material is often utilised, exposing all of the plant's roots. Small baskets or closed cell foam plugs that compress around the plant's stem are used to hang the plants. These baskets or foam plugs fit into little holes on the growth chamber's top. The roots dangle within the growth chamber, where they are misted with nutrition solution on a regular basis by mister heads. Watering at regular intervals keeps the roots moist and prevents them from drying out, as well as providing the nutrients that the plants require to thrive.The roots' growth chamber should be light resistant and almost airtight. It must allow fresh air in so that the roots receive adequate oxygen, but it must not allow water or bugs to enter. You also want the root chamber to maintain a constant level of humidity. Ultimately, you want lots of moisture, fresh oxygen, and nutrients for the roots. At the same time, a well-designed aeroponics system delivers a healthy balance of all three of those components to the roots. Finally, the size of the water droplet is an important consideration in aeroponic systems. Roots sprayed with a fine mist will grow significantly quicker, bushier, and have a larger surface area to absorb nutrients and oxygen than roots sprayed with little streams of water, such as from tiny sprinkler heads.As a result, the plant canopy is expanding at a faster rate. The size of the water droplets determines the sort of aeroponic system.

Advantages of an Aquaponic system.

One wouldn't have guessed that bare roots could live, It turns out that removing the growing medium is extremely liberating for a plant's roots: the increased oxygen exposure leads to quicker development. Aeroponics systems similarly use very little water. Closed-loop systems use 95% less water than plants grown in the ground. The nutrients are also recycled since they are stored in the water. Aeroponics' eco-friendly image is strengthened by the capacity to grow huge quantities of food in tiny places, in addition to these efficiency. Indoor vertical farms, which are becoming more widespread in cities, use this method to reduce the environmental costs of delivering food from field to plate. Furthermore, because aeroponics systems are completely enclosed, no nutrient runoff pollutes neighbouring rivers. Rather than using harsh chemicals to combat pests and diseases, the growing equipment may simply be sterilised as needed.

Disadvantages of an Aquaponic system.

To work efficiently, aeroponics systems require a little finesse. The water's nutrient concentration must be kept within strict limits, and even a little fault of your equipment might result in crop loss. Those hanging roots will swiftly desiccate if the misters aren't sprayed every few minutes—perhaps because the power goes out. And, to avoid being blocked by mineral deposits in the water, the misters must be cleaned on a regular basis. Aeroponic systems rely on electrical power to pump water through the small misting devices, which has one big disadvantage in terms of environmental impact.

Products of an Aquaponics system.

In principle, you could do anything. Aeroponics systems are mostly utilised for the same things as hydroponics systems: leafy greens, culinary herbs, chillies, strawberries, tomatoes, and cucumbers. One exception is root crops, which are problematic in a hydroponic system but ideal for aeroponics since the roots have ample area to develop and are easily harvestable.

4. Hydroponic System.

Hydroponics is a method of growing plants in a nutrient-rich solution that is based on water. Instead of soil, hydroponics uses an inert material like perlite, rock wool, clay pellets, peat moss, or vermiculite to support the root system. The primary idea of hydroponics is to allow

the roots of the plants to come into direct touch with the nutrient solution while simultaneously allowing them access to oxygen, which is necessary for healthy growth. Nutrients for hydroponic systems can originate from a variety of places, including fish faeces, duck dung, and chemical fertilisers purchased at a store.
Hydroponics is a basic process that is similar to growing plants in soil in many aspects. Plants require food, water, and oxygen to survive. It's easy to feed plants simply what they require when you reduce it down to those three items. The science of growing plants without soil is known as hydroponics. The plants may survive only on the nutrient solution; the medium serves just to sustain the plants and their root systems.

Advantages of a Hydroponic system.

Our plants would not have to work as hard to get nutrients, they will grow larger and quicker. Even a little root system will offer everything the plant needs, allowing the plant to concentrate on developing upward rather than extending the root system beneath. All of this is made possible by maintaining a tight grip on your nutrition solution and pH levels. Because the system is enclosed, there is less evaporation, hydroponic systems require less water than soil-based plants. Because it eliminates waste and pollutants from soil drainage, hydroponics is healthier for the environment.

Growing using hydroponics has a number of benefits, the most important of which is that your plants will develop at a much faster rate. Your plants will mature up to 25% quicker and produce up to 30% more than plants grown in soil with the right setup.

Disadvantages of a Hydroponic system.

The biggest danger with a hydroponics system is that anything as simple as a pump failure, depending on the size of our system, might kill all of our plants within hours.
Because the growth medium, unlike soil, cannot retain water, the plants are reliant on a constant supply of water.

Despite the many benefits of a hydroponics system, there are a few drawbacks. For most individuals, the most important consideration is that a high-quality hydroponics system, regardless of size, will cost more than a comparable soil system. Dirt, on the other hand, isn't exactly cheap, and we get what we pay for. If we aren't the most skilled grower, setting up a big scale hydroponics system might take a long time. Plus, maintaining our hydroponics system will require a significant amount of time. On a daily basis, we will have to monitor and balance our pH and nutrition levels.

Products of a Hydroponic system.

Leafy greens, culinary herbs, strawberries, tomatoes, cucumbers, lettuce, spring onions, peppers, Spinach, Coriander, and other plants are grown in hydroponics systems.

5. Media Bed.

The most popular design for small-scale aquaponics is media-filled bed units. For most developing regions, this approach is highly recommended. Because of their simplicity, these designs are space-efficient, have a cheap initial cost, and are appropriate for novices. The medium is used to support the roots of the plants in media bed units, and it also serves as a mechanical and biological filter. The next sections show how NFT and DWC techniques both require discrete and more sophisticated components for filtering, despite the fact that media bed units are the simplest. On a wider scale, however, the media bed approach can become cumbersome and costly. If fish stocking numbers exceed the carrying capacity of the beds, the media might get clogged, necessitating separate filtration. With increased surface area exposed to the light, water evaporation is higher in medium beds. Some media have a lot of weight to it. Media beds come in a variety of forms, and this is perhaps the most versatile method. Bumina, for example, is an aquaponic method used in Indonesia that employs a network of tiny media beds linked to an in-ground fish tank. Furthermore, salvaged items may be simply reused to contain media and fish.

Implementation of a Media Bed.

Plastic, fibreglass, or a wooden frame with water-tight rubber or polyethylene sheets on the base and within the walls can be used to create media beds. Plastic containers, modified IBCs, and even disused bathtubs are among the most popular DIY media beds. All of the aforementioned can be used as beds and other types of tanks as long as they satisfy the following criteria:

- able to withstand the weight of water and growth medium without breaking;
- capable of withstanding adverse weather conditions;
- constructed of food-grade plastic that is safe for fish, plants, and microorganisms to eat;
- Simple plumbing pieces allow it to be readily linked to other unit components, and it may be positioned close to them.

Here, we used a circular bed in the project of around 0.5 m of radius and a depth of around 50 cm. A rectangle with a width of roughly 1 m and a length of 1–3 m is the usual shape for media beds. Larger beds can be used/made, but they will need additional support (such as

concrete blocks) to sustain their weight. Longer beds may also have uneven solids distributions, which tend to collect near the water entrance, increasing the danger of anaerobic areas. The beds should not be so broad that the farmer or operator cannot reach halfway across.
The quantity of root space volume in the unit influences the sorts of vegetables that may be produced, thus media bed depth is crucial. If you're growing large fruiting vegetables like tomatoes, okra, or cabbage, the media bed should be 30 cm deep; otherwise, the larger plants won't have enough root area, will have root matting and nutritional shortages, and will most likely collapse over. Small leafy green vegetables only require 15–20 cm of media depth, making them an excellent choice for small media beds. Nonetheless, some experiments have shown that if nutrient concentrations are sufficient, even bigger crops may be produced in shallow beds.

Medium used in a Media Bed.

Several common and fundamental characteristics will apply to all suitable growth mediums. The medium must have sufficient surface area while being water and air permeable, allowing bacteria to thrive, water to circulate, and plant roots to breathe. The medium must be inert, non-toxic, and dust-free, with a neutral pH to avoid affecting the water quality. Before inserting the medium into the beds, it is important to properly wash it, especially volcanic gravel, which includes dust and other particles. These particles might block the system and damage the gills of the fish. Finally, working with material that is pleasant for the farmer is critical.
Bacterial growth can take place over a wide surface area. pH neutral and inert. Drainage characteristics are excellent. There is enough room for air and water to circulate freely within the medium, and it is both available and cost-effective.

Clay Pebbles.

Lightweight Expanded Clay Aggregate (LECA) is a highly effective grow medium made from clay balls that have been treated at a super-high temperature. It is, without a doubt, one of the most widely utilised media in both hydroponics and aquaponics.Clay pebbles are light yet hefty enough to provide a plant adequate support. They're also pH-neutral, non-degradable, and don't provide a lot of nutrients to the water. Their porous nature and spherical shape assist to maintain a healthy oxygen-to-water ratio while also offering a smooth working surface for gardeners.

Gravel.

Gravel is the cheapest aquaponics grow media, but it's also the most difficult to work with. For starters, it has a higher density than the alternatives. This is okay for taller plants, but not so much for smaller ones. Finding the right size gravel might be difficult, but pea size and river gravel are the best alternatives. Other disadvantages include the fact that it does not retain water well and has a considerably smaller surface area than the alternatives, making it harder to colonise bacteria and reducing bio-filtration capacity. Finally, because limestone is commonly contained in gravel, we should always conduct a vinegar test before putting it in our system. If we're going to use gravel, we'll need to keep an eye on it.

6. Suitable Conditions for Growth of Aquatic life.

Since they create profit, the aquaponics system's aquatic habitat and floral habitat are the two most important elements. Furthermore, because these regions support the majority of the system's life, with just bacterial life remaining, the specifications they establish tend to define the system's overall circumstances. While there are some parallels in terms of the conditions that must be met, each ecosystem has its own set of requirements.

The pH of the water in the system is an excellent example of a common specification, as various pH values are required for plant and aquatic life to thrive. Because plants prefer acidic conditions and fish prefer alkaline conditions, these levels frequently contradict each other. For example, a certain breed of fish may require a pH of around 8, while a species of plant may require a pH of closer to 6, as plants prefer acidic conditions and fish prefer alkaline conditions. To get a pH that is more acceptable to both plants and animals, it is ideal to combine plant and fish kinds so that the needed pH may be taken into consideration more fully, therefore balancing the system.

The ammonia level must be kept below 0.98 ppm in the fish habitat, since prolonged exposure can be fatal to fishes like tilapia. Although extremely brief periods of time at higher ammonia levels, such as 4 ppm, can be tolerated, the ammonia level should be kept as near to 0 ppm as feasible. The quantity of dissolved oxygen in the system, which should be between 4 and 5 milligrammes per litre, is another important factor in the fish habitat. Some fish 4 species may require higher levels, but this is a good place to start.It's usually a good idea to conduct some research on whatever topic you're working on.

Nitrite levels should be kept at 0 ppm, whereas nitrate levels can range from 20 ppm to 100 ppm. The temperature of the water is influenced by the type of fish chosen, but it must be taken into account as well.

Another essential consideration when choosing a fish to grow is the feed conversion ratio, or FCR, which determines how much of the food is turned directly into mass gained in the fish. It is a unitless number computed by dividing the mass of the food provided to the fish by the mass acquired by the fish. As a result, a greater FCR is less optimum since more food is required to develop the fish to harvest weight, resulting in higher production costs.

Another problem is the amount of water per pound of fish, because the less water available per fish, the faster chemical levels might change, potentially making the water poisonous without notice. For less experienced aquaponics farmers, a stocking density of about eight gallons per pound of fish is advised, while some more experienced farmers may be able to reduce the stocking density down closer to two gallons per pound of fish. A lower stocking density is ideal since the more fish that are successfully grown, the more money you will make when it comes time to harvest. Conversely, if a farmer aims for a stocking density that is below their capacity, they may lose a large percentage of their crop, because they were unable to effectively offset the variation in nutrient levels, they lost much, if not all, of their harvest.

Another element that must be controlled is the amount of light in the tanks. When fish are exposed to insufficient light, they get agitated. If the fish aren't happy, they won't consume as much and won't develop as fast. On the other hand, if the fish tanks are exposed to too much light, algae may begin to develop on the top of the water, depleting the oxygen levels in the water and perhaps killing the fish.

Even with such a diverse set of requirements, there are almost no limits to the number of fish that may be housed.55-gallon industrial barrels and 275-gallon intermediate bulk containers (IBCs) perform nicely.In smaller aquaponics systems, concrete troughs or aquarium tanks might be utilised to hold the fish. 300-gallon stock tanks, or any size and form of container made of fibreglass or plastic, may be employed. Bathtubs and swimming pools are also excellent options. While all of the exact criteria must be followed, the containers must also be deep enough for the fish to survive and not too tiny for them to move about freely.

7. Suitable Conditions for Growth of Plants.

Plants are less complicated than aquatic life, thus they should have less restrictions than marine life. As previously stated, the pH level of the system's water acts as a balance point for the two habitats, with plants preferring a pH of approximately 6. Cool-season plants thrive in cooler temperatures (50°F to 70°F), but warm-season plants require somewhat higher temperatures (60°F to 80°F). As a result, keeping the air temperature at 65°F should satisfy both types of plants, allowing for a wider variety of crops to be produced at the same time. Plants like light that is blue or red in colour. Many grow lights are specifically designed to emit light in these ideal spectrums in order to augment any ambient lighting.

There are additional requirements for the other nutrients that must be present in the water, in addition to all of these environmental parameters. The plants will already be receiving nitrates, as mentioned in the bio filtration section, but they will also require phosphorus, potassium, calcium, magnesium, and sulphur. Other nutrients such as iron, manganese, boron, zinc, copper, and molybdenum are also required in small levels. While they may occur naturally in the system due to the fish or the environment, it is strongly advised that these levels be checked or, at the absolute least, supplements be given to ensure that the essential levels are equal to or surpass the requirements. Because the necessary amounts differ per plant species, it's essential to do some study before planting a new crop.

8. Essential Nutrients Circulation.

A pump of some type is required to circulate water throughout an aquaponics system, much as a heart pumps blood throughout the body. The water in the system must be entirely "turned over" or cycled through the whole system a certain number of times each hour, according to the main specification for the 8 pump. The number of times the water must be turned over is governed by a variety of elements, including aquatic life forms, plant kinds, and system size. In general, a reasonable estimate of one or two times per hour for turning over all of the water in the system is adequate. Electric pumps, air pumps, and gasoline-powered pumps are all capable of doing this duty. Each kind has its own set of benefits and downsides, and there are undoubtedly additional ways to move water through the system that haven't been mentioned.

9. Aeration

Aeration is the process of forcing air into the water to raise the dissolved oxygen levels. The fish require around 4 to 5 milligrammes per litre of dissolved oxygen in general. The requirement for smaller bubbles to develop farther down in the tank is crucial. As the bubbles float up from a greater depth, the surface area to volume ratios increase, allowing the bubble to be absorbed faster and the oxygen to have more time to be absorbed by the water, because of the higher pressure at lower depths, the bubbles will be smaller. Any bubbles that make it to the surface aren't useful for aeration, and the energy needed to create them was squandered, resulting in lost production expenses. Aeration is straightforward to do in its most basic form, as there are various ways to create bubbles in water.

The oxygen bubbles up from the bottom of the tank thanks to air stones attached to a pump. Venturis have also been used to produce bubbles in a constricting flow. Although oxygen saturation cones substantially oxygenate the water, they require pure oxygen to operate, which raises expenses. A Bakki shower is a structure in which water is pushed to the top of a six to ten foot structure, filling a shallow depression. The bottom of the trough contains holes that allow the water to drain into another trough below that also has holes. The water continues to sink to the bottom, oxygenating the air and degassing the water as it does so.

Spray bars can also be used to provide water to the grow beds, allowing tiny volumes of water to fall into the beds and create bubbles. Mechanical aeration devices, such as propellers, can also be employed, although they are more costly and less common. Any method that involves splashing water will produce bubbles, and hence oxygen.

10. Degassing

There are beneficial nitrification bacteria in the bio filter section of the tank, but there are also sulphate reducing bacteria that create hydrogen sulphide under anaerobic circumstances, which is toxic to fish. Degasification removes carbon dioxide, hydrogen sulphide, methane, and nitrogen gas from the system, which helps to avoid hydrogen sulphide build-up. Removing nitrogen may be detrimental depending on the plants cultivated, as leafier plants require more nitrogen. As a result, most systems aren't large enough to require a separate degassing tank; instead, aeration is used in conjunction with degassing because the bubbles created during aeration also serve to degasify the system. The grow beds may also be used to degas the water by allowing the water to interact with lots of open air, allowing the hazardous chemicals to escape

The presence of a rotten egg odour from hydrogen sulphide is typically a sign that a degassing tank is required; there are a variety of solutions available. To allow the hydrogen sulphide to bubble out and aerate the water, a separate tank with air stones may be used. A Bakki shower, as mentioned in the aeration section, can be utilised if a less traditional approach is desired. The aim of aeration is for no bubbles to reach the surface, signifying optimum efficiency. Degasification, on the other hand, relies on a large number of bubbles reaching the surface to remove the hazardous gases, resulting in a trade-off. Regardless of how many or how big the bubbles that escape are, most systems nevertheless allow enough water to be released to the atmosphere to degas the system.

11. Removal of Solid Waste - Clarification

Clarification is the process of removing solid waste from the water flow between the fish and the plants. If the solid waste is not removed, it might block the system's pipes, causing it to collapse catastrophically. Alternatively, poisons in the solid waste might injure the foliage if it made it through the pipes to the plant environment. Heterotrophic bacteria might be added, depending on the clarifying technique employed, to break down the solid matter in the waste.

Even if the bacteria are present and no additional clarifying is employed, the amount of waste produced would be too enormous to break in any but the smallest systems, necessitating the addition of a separate chamber to handle the solid waste. This work can be accomplished in a variety of ways. Swirl filters are popular because they are simple to make. Water enters a circular barrel at an angle that is almost tangent to the barrel's curve. This creates a weak vortex in the water, causing the solid waste to sink to the bottom. After that, the cleaner water leaves the barrel. A baffle filter, in which the water is delivered into a tank perpendicular to a flat plate, removes the majority of the water and waste's momentum in the hit, is another way employed. As a result of their inability to acquire enough speed to escape the tank, the solids drop to the bottom. As a third alternative, settling tanks are typically used in septic systems to collect human solid waste, but smaller versions may easily be used in aquaponics systems. A drum filter, which works like a reverse sieve and has a larger container that houses a smaller, internal container with holes in it, can be employed. The water enters the bigger container, settling the sediments in the outer container, before being suctioned into the inner container and delivered to the plants. There are a variety of mechanical separators that may be utilised as well. The more dense solids might be forced to the outer edge for extraction using centripetal force. Aggregate grow beds might be utilised to offer a habitat for bacteria to break down the minute quantity of solid waste if there are enough fish for the number of plants. A revolving baffle filtration system might be created by inserting an auger screw into a pipe with wastewater running through it. There is no one ideal technique of clarity; each has advantages and disadvantages, and the method of clarification is highly reliant on each unique system, the available space, the ability to undertake maintenance, and a variety of other considerations.

12. Biofiltration

The other filtering stage that must be completed is biofiltration. The bio filter eliminates the ammonia emitted by the fish, while the clarifying stage removes the big solid debris.
Even at levels as low as 0.98 ppm for long periods of time, ammonia is worthless to plants and very harmful to fish.The ammonia passes through the bio filter, where microorganisms convert it to nitrite. Unfortunately, nitrite is still extremely hazardous to fish, and even low levels of 0.1 ppm can kill certain catfish, but other aquatic life has a better tolerance. Fortunately, a secondary bacterial mechanism changes nitrite to nitrate, which is not hazardous to fish until it is present in high amounts (about 20 ppm to 100 ppm depending on the source) and which the plants may take as nutrients to grow and prosper.

13. Design of the Aquaponics system

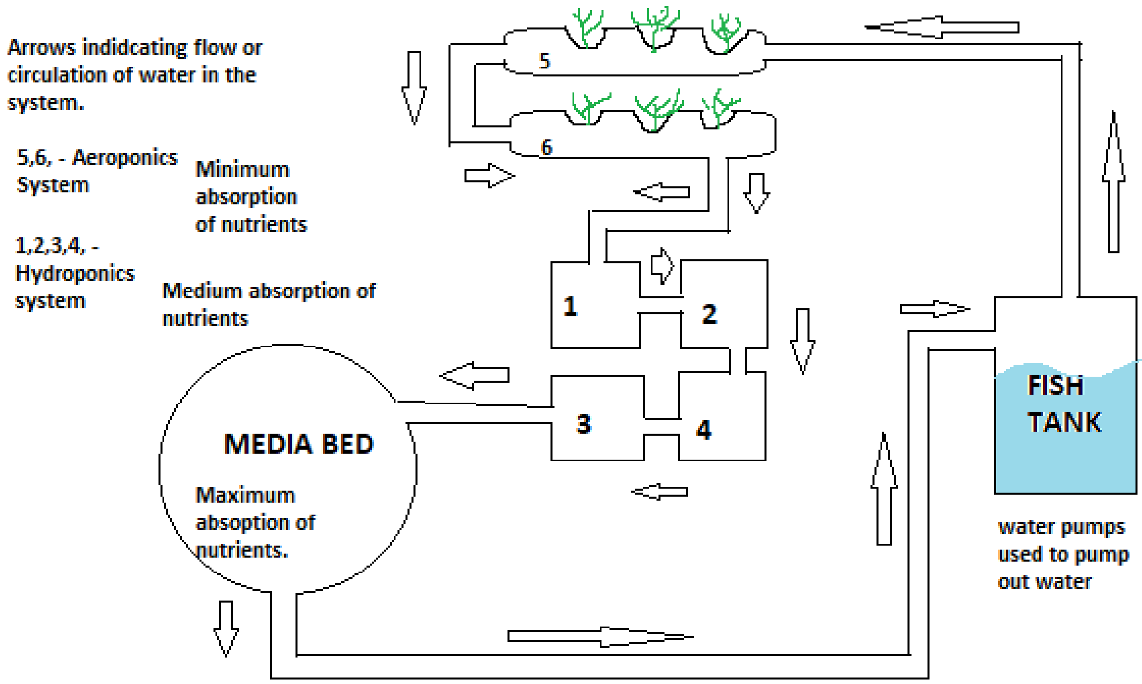


Fig - Initial design of the Aquaponics System.

The water from the fish tank is injected into the Aeroponics system at regular intervals. Wastes are absorbed the least in the Aeroponics system. Water from the aeroponics system goes to Hydroponic bed A and then to the other beds B, C, and D through gravity. Wastes and nutrients are absorbed at a medium rate here. The water subsequently flows through the media beds A and B due to gravity. The highest absorption of wastes and hence nutrients by plants occurs here. In this stage, the water is hard filtered, and ammonia-free water is returned to the fish tank. As a result, this design is very efficient since it only needs a small number of water pumps to move the water. The effect of gravity causes water to flow naturally at most phases.

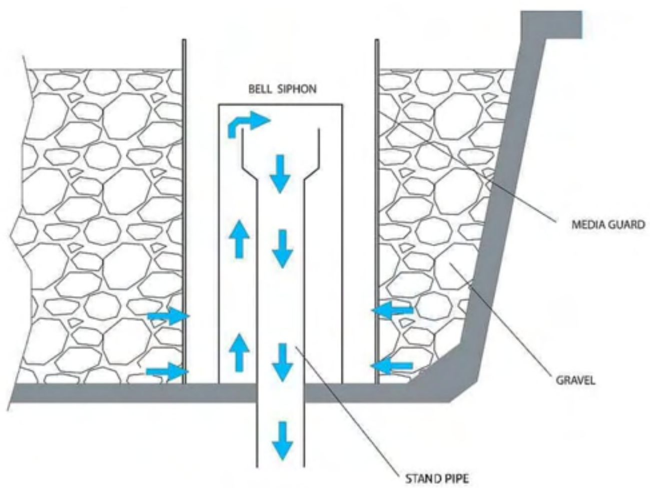
Siphon -

A Siphon is used in the Media Bed with gravel and pebbles to drain out in case water overflows into the media bed. A Siphon is a simple instrument that easily and efficiently controls water flows via aquaponic and hydroponic systems, without human involvement.

The syphon allows the bed to fill initially, and then drains the water out mechanically when it reaches a specific level. The siphon also keeps a low water level, because there is an overabundance of dry water. During the flood and drain cycle, siphons prevent the need to switch the pump on and off by hand. The flood and drain cycles are conducted so that the plants may absorb more food and increase their oxygenation. The cycle therefore serves a critical function in maintaining proper plant growth and growth.

Working of a Siphon -

First of all, the drained bed is filled with water by the water pump.
If the water level reaches the top of the standpipe in the syphon pipe, the water starts to flow via the reducer on the top of the standpipe and into the fish tank at a low pressure through the stand pipe.
Water rises up inside the bell and pushes out air via the stand pipe, while water slowly drains out of the pipe. This finally results in a drop in pressure inside the bell.
Due to the ensuing low pressure in this bell, the bell differs from the environment and causes the syphon to ignite. So the syphon quickly drains the water out and empties the pipe at a much higher pressure till the water level reaches the bottom of the bed.
The air entering the bell through the slits at the bottom of the syphon pipe reaches the base of the Siphon pipe, relieving the pressure differential between the bell and the atmosphere which causes the syphon to break up and stop the water drain.



A schematic diagram of working of a Siphon.

14. Components and equipment required.

1. Thermocol boxes
2. Circular container for another mediabed
3. PVC 4 inch pipes
4. PVC 1 inch pipes
5. Level pipes
6. Pipe connectors/ couplers/ elbow joints etc
7. Water pump
8. Wooden frame to elevate the system
9. Water tank to store the fish and water
10. Plantation pots and trays.
11. 2 submersible water pumps
12. Gravel
13. Clay pebbles
14. Arduino uno, arduino mega microcontroller.
15. Relay module
16. Aerator
17. Connecting wires
18. pH meter
19. Coco peat
20. Fish feed
21. Power supply

15. Initial implementation process

Initially, we constructed a wooden platform to store all of our components or beds. We utilised two 4” diameter PVC pipes for the aeroponics system. Then we drilled the appropriate number of holes for the plantation pots. Connected the two pipes and drilled a hole for the Aeroponics system's outlet. We have added level pipes connected to water pumps that pump water into the Aeroponics system from the fish tank at the inlet.

The outlet from the aeroponics system goes into the first hydroponics grow bed, followed by the remaining three beds. CPVC pipes link them all together. The last hydroponic bed's outlet is made, and water flows into the media bed. Gravity causes the water to flow from one bed to the next.

The media bed is made on a circular container made of PVC (large 300 litre water tank cut into half) containing gravel and hydroton, that holds the minerals as well as essential nutrients for the plants.

Image of Gravel.

Image of Hydroton in a Media bed.

The cleaned water then goes back to the fish tank through an exit from the second media. As a result, the water is forced to circulate across all of these beds. The growth pots for the plants have now been installed on all of the plant beds. Coco peat, derived from coconut, is used to fill the pots. Coco peat is a great substrate for plant growth. It can keep water for a longer period of time. It also aids the denitrifying bacteria in the breakdown process by keeping a neutral pH level in the water. It also provides superb root aeration. As a result, it can be used as a soil substitute. Then we plant seedlings of fast-growing green crops such as cabbage, lettuce, Knol Khol, and others. For testing purposes, we used Catfish in the fish tank. Catfish was chosen because it is relatively resistant to temperature fluctuations and can thrive under harsh environmental conditions.It also creates a lot of ammonia from waste, which is beneficial to plant development. As a result, the hardware portion is finished.

Image of Coco peat derived from Coconut.

16. Designed System.

Image of the designed system.

17. The electronics and the softwares used.

For regulating the water and oxygen pumps in a certain order, we used an Arduino-UNO and an 8-channel relay module. We also utilised an ultrasonic water level sensor to keep track of how much water is in the fish tank. The ultrasonic sensor ensures that the fish tank is dry at all times. It monitors the water level and directs the pumping of water from the reservoir tank to the fish tank. Water must be pumped by the two water pumps, however they are not all switched on at the same time. As a result, an 8-channel relay module is being used to turn on one pump while leaving the other off. The Arduino board is powered by a 12V DC converter, and the water and oxygen pumps are coupled to a direct 220V ac supply through a relay.

First and foremost, before pumping water from the fish tank, make sure the water level is correct. As a result, a 22-inch threshold restriction has been set, meaning that any distance larger than 22 inches recorded would result in water being pumped from the reservoir tank to the fish tank. This procedure is continued until the distance between the two points is less than 22 inches. One of the two water pumps is therefore installed near the reservoir tank for this reason.

The pump at the reservoir has been switched off for the water pumping cycle from the fish tank. The other water pump will be kept in the fish tank. The oxygen pumps are situated in an open area with adequate weather protection. The two oxygen pumps and one water pump are now turned on for 3 minutes using the relay module. Before turning them on for another 2 minutes. For the next 10 minutes, everything is switched off.

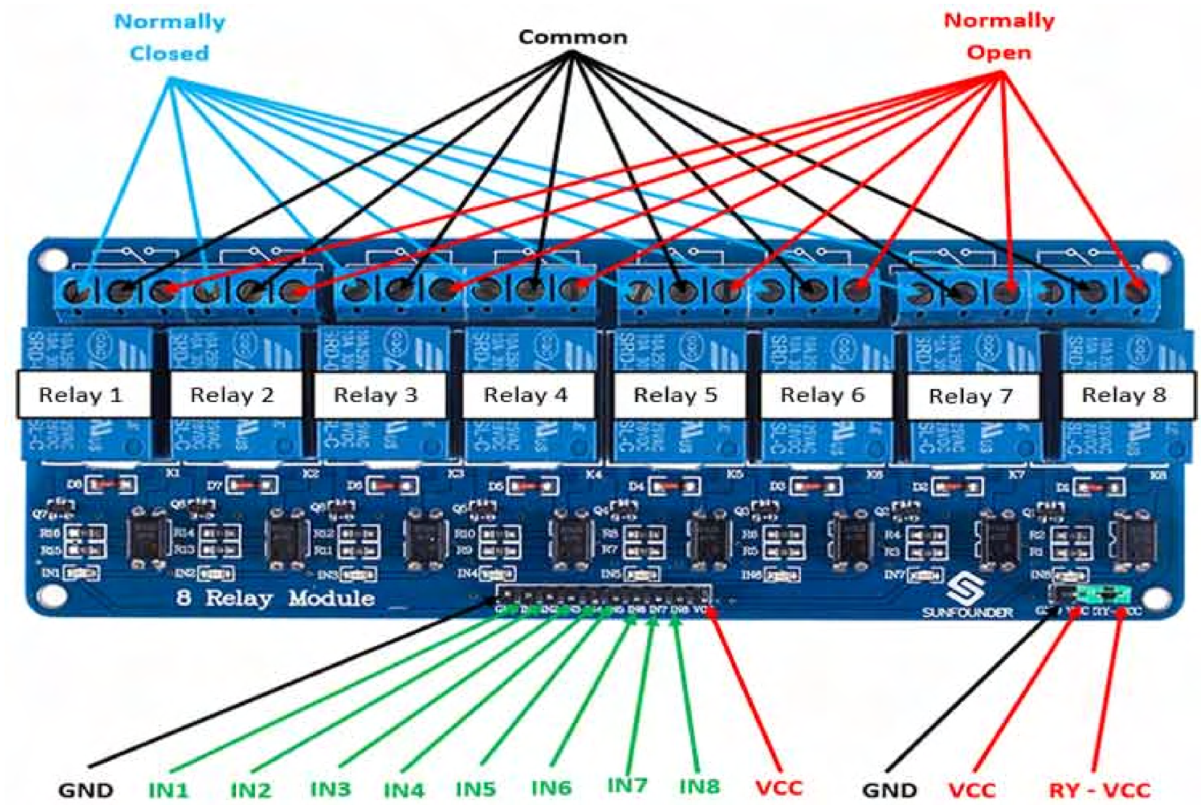
The identical procedure is followed again, except this time the second water pump is turned on while the first remains off. After that, everything is switched off for 15 minutes. The cycle comes to an end here, and the procedure of checking the water level resumes. This entire procedure repeats itself.

1. **Arduino UNO / Arduino Mega.**

Image of an Arduino UNO

Image of an Arduino Mega

2. Relay Module (8-Channel)



3. Ultrasonic Water level sensor

4. **Submersible water Pump.**

5. **Oxygen pump**

6. **Sandstone fixed with Oxygen supply to pump.**

7. **12V DC Power adapter for arduino.**

18. Arduino Code for water flow controller and the oxygen flow.

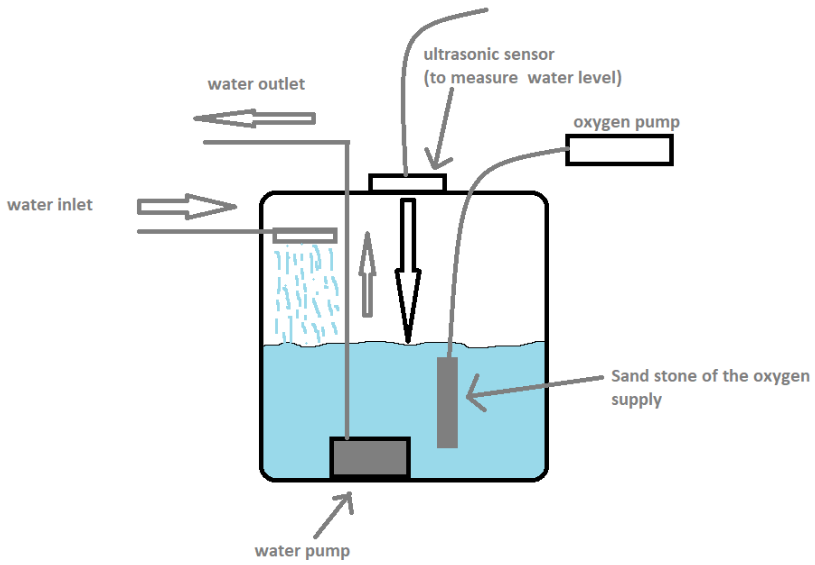
```
int trigPin = 7;
int echoPin = 6;
long duration, cm, inches;

#define VCC2 5
#define GND2 2
#define RELAY1 13
#define RELAY2 12
#define RELAY3 11
#define RELAY4 10
#define RELAY5 9
void setup() {
Serial.begin (9600);
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);

pinMode(VCC2,OUTPUT);
digitalWrite(VCC2,HIGH);

pinMode(GND2,OUTPUT);
digitalWrite(GND2,LOW);

pinMode(RELAY1, OUTPUT);
pinMode(RELAY2, OUTPUT);
pinMode(RELAY3, OUTPUT);
pinMode(RELAY4, OUTPUT);
pinMode(RELAY5, OUTPUT);
}


void loop() {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(5);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);


  pinMode(echoPin, INPUT);
  duration = pulseIn(echoPin, HIGH);
```

```
  cm = (duration/2) / 29.1;
  inches = (duration/2) / 74;

  Serial.print(inches);
  Serial.print("in, ");
  Serial.print(cm);
  Serial.print("cm");
  Serial.println();

  if(inches>22){
    digitalWrite(RELAY1, HIGH);
    digitalWrite(RELAY2, HIGH);
    digitalWrite(RELAY3, LOW);
    digitalWrite(RELAY4, HIGH);
    digitalWrite(RELAY5, HIGH);
    delay(3000);
}

else
{
    digitalWrite(RELAY1, LOW);
    digitalWrite(RELAY2, LOW);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, LOW);
    digitalWrite(RELAY5, HIGH);
    delay(180000);

    digitalWrite(RELAY1, LOW);
    digitalWrite(RELAY2, LOW);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, HIGH);
    digitalWrite(RELAY5, HIGH);
    delay(10000);

    digitalWrite(RELAY1, LOW);
    digitalWrite(RELAY2, LOW);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, LOW);
    digitalWrite(RELAY5, HIGH);
    delay(120000);

    digitalWrite(RELAY1, HIGH);
    digitalWrite(RELAY2, HIGH);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, HIGH);
    digitalWrite(RELAY5, HIGH);
    delay(600000);
```

```
    digitalWrite(RELAY1, LOW);
    digitalWrite(RELAY2, LOW);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, HIGH);
    digitalWrite(RELAY5, LOW);
    delay(120000);

    digitalWrite(RELAY1, LOW);
    digitalWrite(RELAY2, LOW);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, HIGH);
    digitalWrite(RELAY5, HIGH);
    delay(10000);

    digitalWrite(RELAY1, LOW);
    digitalWrite(RELAY2, LOW);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, HIGH);
    digitalWrite(RELAY5, LOW);
    delay(180000);

    digitalWrite(RELAY1, HIGH);
    digitalWrite(RELAY2, HIGH);
    digitalWrite(RELAY3, HIGH);
    digitalWrite(RELAY4, HIGH);
    digitalWrite(RELAY5, HIGH);
    delay(1500000);
  }

  }
```

19. Implementation of the Reservoir Tank.

In a short period of time, the water level in the fish tank begins to drop owing to leaks or evaporation. As a result, extra caution should be exercised to ensure that the fish tank never runs out of water. If the amount of water in the fish tank drops, a reservoir tank is required to fill it up. This may be done automatically by using an ultrasonic sensor mounted on the top of the fish tank to measure the water level, as well as a water pump to pump water from the reservoir to the fish tank.
One transmitter and one receiver make up the ultrasonic sensor module. The transmitter can broadcast ultrasonic sound at a frequency of 40 kHz, whereas the maximum receiver can only receive sound at that frequency. Once the module encounters any object in front, the ultrasonic receiver sensor kept adjacent to the transmitter should be able to receive reflected 40 KHz. As a result, anytime the ultrasonic module encounters any barriers, it estimates the time it takes from sending the signals to receiving them, because time and distance are linked for sound waves travelling at 343.2m/sec through air.
The ultrasonic transducer vibrates throughout a specified frequency spectrum and creates a burst of sound waves when a high-voltage electrical pulse is delivered to it. When an obstruction gets between the ultrasonic sensor and the sound waves, an electric pulse is generated. It calculates the time it takes for sound waves to be sent and an echo to be received.When the water level in the fish tank drops to a certain level, the arduino is programmed to automatically pump water from the reservoir into the fish tank.



Schematic design of the Reservoir Tank.

20. pH Measurement and water filtration.

Here , if the pH of 8.5 or above, the water becomes extremely alkaline as it accumulates a large amount of fish waste. Fish development is hampered by acidic water with a pH less than 5. It is therefore necessary to maintain neutral water or water with a pH of 6.5 to 7.5. Furthermore, in unclean water, the amount of dissolved oxygen (DO) decreases, making it difficult for fish to survive. Fish require a DO level of 5ppm. In such instances, hard filtration in the medium bed is insufficient. As a result, new filter media must be designed through which water may travel and therefore be cleansed. Filtration mediums range from single-stage to multi-stage filtering depending on the pH level.

The pH measurement is implemented in 3 stages -

One stage filter -

The one-stage filter is a basic bio filter (with microorganism growth) with a duckweed and conserved water storage tank. If the pH level of the water flowing out of the media bed is found to be in the range of 7-7.5 or 6.5-7, the water is pumped into this tank first, then returned to the fish tank.

Two stage filter -

The bio filter and a mechanically constructed charcoal filter will be included in the two-stage filter design. Water with a pH of 7.5-9 or 5-6.5 is sent first through the charcoal filter, then through the bio filter.

Three stage filter -

Another level of filter, known as the resin filter, will be included in the three-stage filter process. Water that is very acidic or alkaline, with a pH of more than 9 or less than 5, is forced to pass through all three stages of the filter. Water from the media bed first passes through the charcoal filter, then the resin filter, and finally the bio filter or reservoir tank.

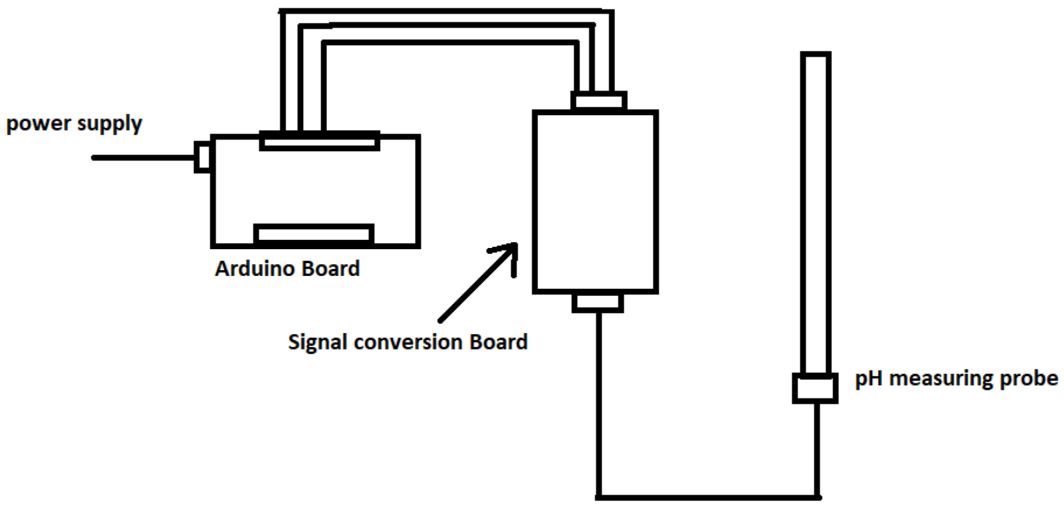
21. Implementation of pH sensor (Measurement of pH)

The pH sensor has two electrodes that produce voltage proportional to the pH of the fluid. One of the two electrodes is a measuring electrode made of ion selective glass. The hydrogen ions are separated from the huge flock of ions in the solution by this barrier hen. At any given temperature, the reference electrode maintains a constant potential. A millivolt signal proportional to pH is generated when the reference potential is compared to the potential of the pH electrode, allowing for the measurement.

A neutral pH buffer solution is used to make the reference electrode, which is permitted to exchange ions with the process solution through a porous separator, resulting in a low resistance connection to the test liquid. This electrode establishes a reference that it strives to maintain and against which potential measurements from the measuring electrode may be compared. Wet chemical interfaces are used because they create less voltage across the contact interface, allowing for more precise measurements.

At 25 °C, almost all pH sensors are designed to provide a 0 mV signal with a slope of 59, 16 mV/pH at neutral pH of 7. This theoretically perfect slope symbolises sensitivity, and the point is generally an isopotential point, where potential remains constant as temperature varies. When the isopotential point is known, it may be combined with theoretical knowledge of electrode behaviour to allow pH measurement correction at any temperature by comparing it to the reference temperature.

The pH sensor, along with equipment such as the temperature sensor, a preamplifier, and either an analyzer or a transmitter, make up the actual pH measurement loop. In terms of electrical calculations, this loop may be thought of as a battery, with the positive terminal serving as the measuring electrode and the negative serving as the reference electrode. When the measuring electrode generates potential from hydrogen ions, it is compared to the measuring electrode's liquid's stable potential.



Schematic diagram of the pH sensor setup.

22. Arduino code for pH measurement

```
#define SensorPin A0      // the pH meter Analog output is connected with the Arduino analog

unsigned long int avgValue; //Store the average value of the sensor feedback

float b;

int buf[10],temp;


void setup()

{

  pinMode(13,OUTPUT);

  Serial.begin(9600);

}

void loop()

{

  for(int i=0;i<10;i++)                    //Get 10 sample value from the sensor for smooth the value

  {

    buf[i]=analogRead(SensorPin);

    delay(10);

  }

  for(int i=0;i<9;i++)        //sort the analog from small to large

  {

    for(int j=i+1;j<10;j++)

    {

      if(buf[i]>buf[j])

      {

        temp=buf[i];

        buf[i]=buf[j];
```

```
      buf[j]=temp;
    }
  }
 }
 avgValue=0;
 for(int i=2;i<8;i++)                    //take the average value of 6 center sample
   avgValue+=but[i];
 float phValue=(float)avgValue*5.0/1024/6; //convert the analog into millivolt
 phValue=3.5*phValue;                    //convert the millivolt into pH value
 Serial.print("    pH:");
 Serial.print(phValue,2);
 Serial.println(" ");
 digitalWrite(13, HIGH);
 delay(800);
 digitalWrite(13, LOW);
}
```

23. Flow of water through different stages of the filter.

There are three phases to the filtration process,because of which the water must be guided according to pH requirements. This is accomplished by installing three solenoid valves that open and close as needed. The water from the media bed is first collected in a small bucket, where the pH is measured with a pH sensor. Three solenoid valves are connected to this bucket. These valves are typically closed, but when the requirements are met, they open, allowing water to pass to the various filtering stages stated before.

Solenoid valve -

Inside the solenoid valve is an enclosed chamber with vented openings at various locations. Each hole is linked to a network of oil pipes. A piston is located in the centre of the chamber. Two electromagnets are used on each side. The valve body will be drawn to one side by the electrifying magnetic coil, allowing various oil outlets to be opened or closed by regulating the valve body's movement. The oil intake, on the other hand, is always open.

Different draw-off pipelines will receive the hydraulic oil. The oil pressure will drive the piston of the oil cylinder, which will subsequently drive the piston rod, and finally the mechanical device. The mechanical movement will be regulated in this way by regulating the current of the solenoid valve. Let's also take a quick look at the two major types of solenoid valves and how they function.

The solenoid coil provides electromagnetic force to raise the closure member off the valve seat and open the valve when the power is turned on. When the power is turned off, the electromagnetic force vanishes, and the spring closes the valve by pressing the closure member against the valve seat.

A solenoid valve

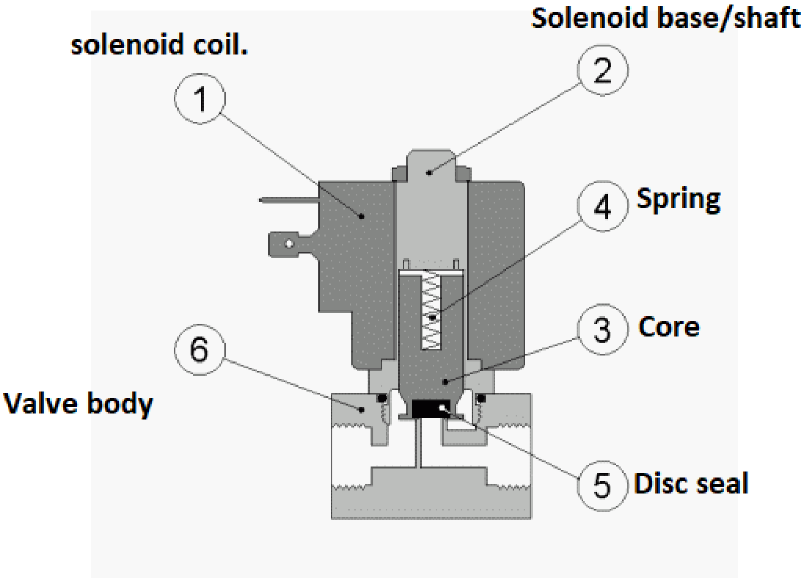
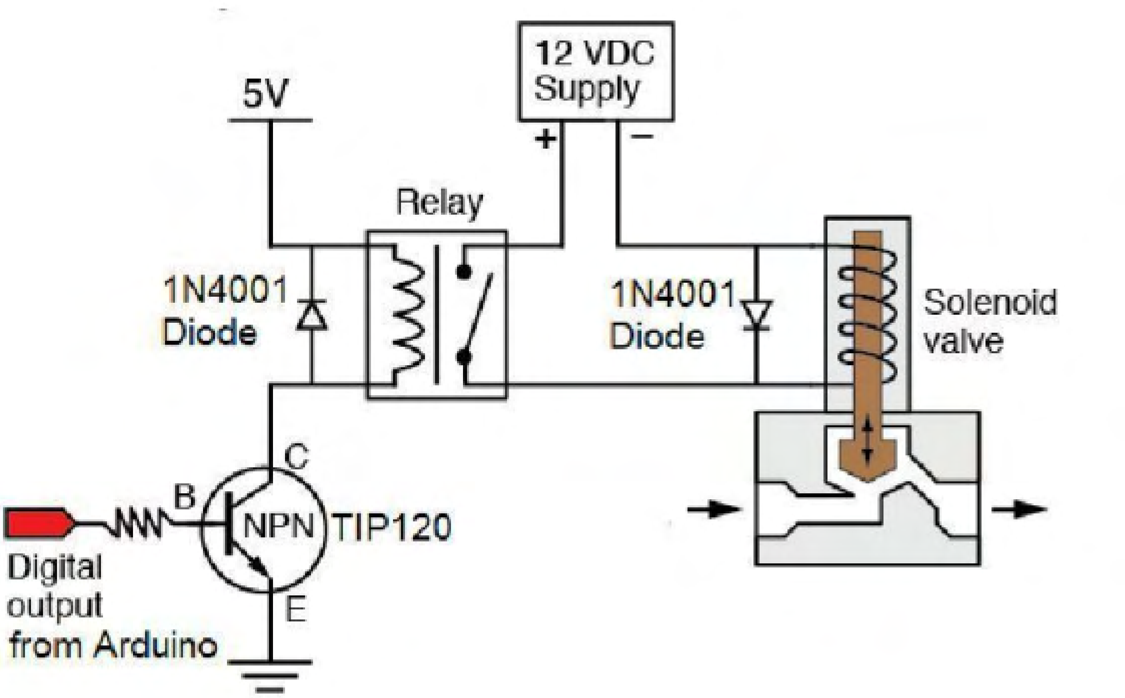


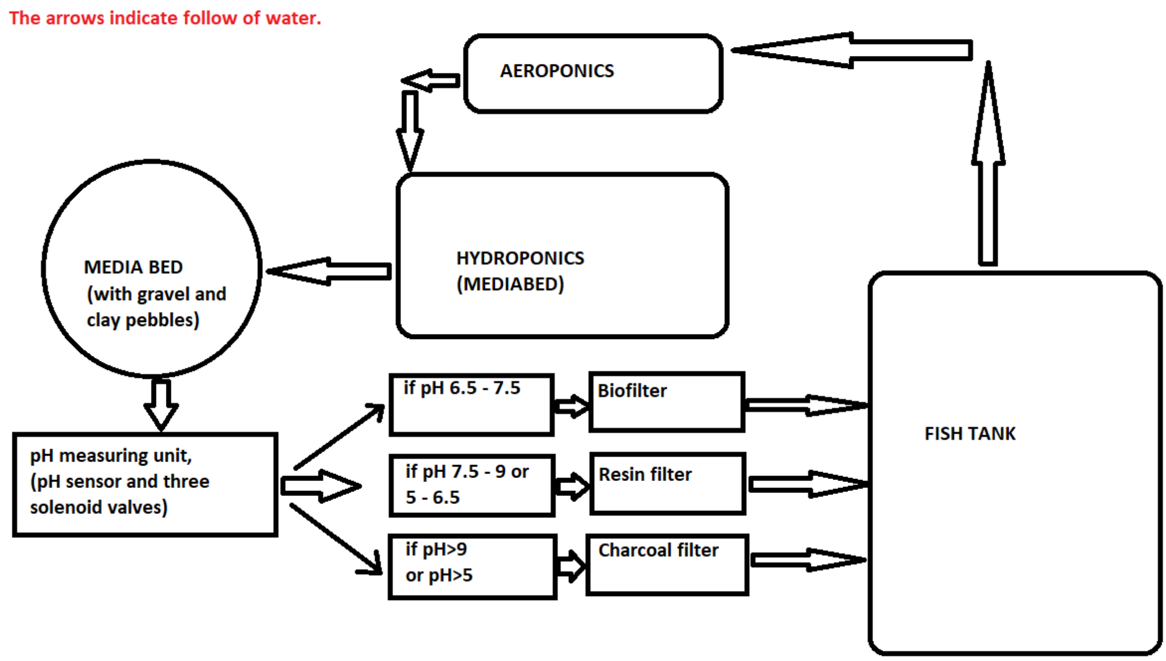
Diagram of a Solenoid valve.



Wire connection of a solenoid valve

24. Final workflow

The water from the media bed falls straight into the fish tank in the previous process, but in the new design, the water from the media bed is made to flow through several filtration stages as illustrated below. -



Final workflow of the project.

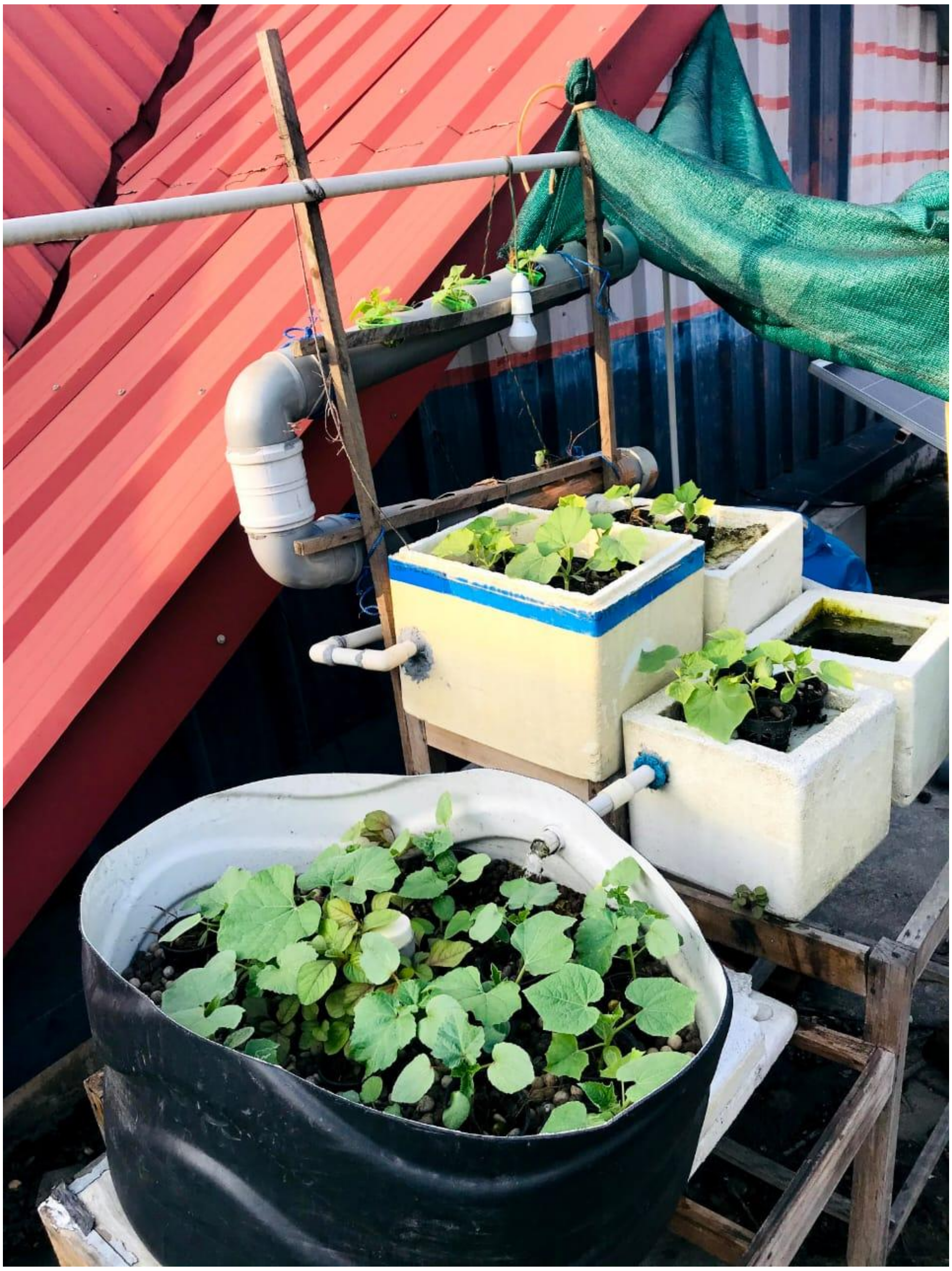
25. Results of the Project.

Growth of the Catfish in the Fish tank

Initial stage of growth of saplings before moving them to the growing cups.

Initial stage of the project setup.

Growth after a week.



Growth after 2 weeks.

Growth after 4 weeks.

26. Using the internet to monitor the system.

Monitoring the system via IoT (Internet of Things) will be the next stage. The pH value, temperature and humidity level, and water level in the tank are all monitored in real time by the IoT-based Aquaponics Monitoring system. The database server and application server can be configured to link the sensors to the internet and show information about the sensors. These data may be accessed and transmitted through the internet using the Raspberry Pi microcomputer. The water within the tank is monitored in real time to ensure that the fish and plants in the system thrive and survive in a healthy environment. Plants and fish will develop faster if the system's fundamental parameters are monitored. This will also assist the user in keeping track of the system and, if necessary, making modifications. The Internet of Things network will also aid in the formation of a network of interconnected systems by linking a large number of devices via fog computing.

27. Fault tolerance

Fault tolerance is the ability of a system to continue to function normally even if any of its components fail or cumulative failures of the system. In a big scale farming approach, a huge number of our tiny systems may be linked together. The fault tolerance is great since such tiny systems operate independently in expansion. Any flaw in a tiny system has no impact on other systems. This is a significant benefit of this kind of system design.

28. Conclusion

The job of integrating all of the systems, including aeroponics, hydroponics, and aquaponics, is difficult. Many elements have a role in the natural growth of plants and fish, all of which must be monitored in this system. Individuals who want to farm on a smaller scale and with less human interference will benefit greatly from such a system. We attempted to keep the cost of this system as low as possible while still making it modular. By incorporating an electrical method into the system, the current issues in the traditional aquaponics system may be alleviated. This may inspire individuals to grow organic, nutritious plants in their own homes for everyday use or consumption.

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