Palestine Polytechnic University

College of Engineering and Technology

Mechanical and Computer Engineering Departments

Mechanical Automotive Engineering

Computer Systems Engineering

Graduation Project

Project Title
Smart Aquaponics Monitoring System Via IoT Techniques

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Abstract

Smart Aquaponic System is the combination of fish and plant production in an integrated recirculation alongside using IoT technology to build a prototype of aquaponic system to perform it functions as much as possible without external interference from the user. In natural waters ammonium is converted rather rapidly to nitrite and further to nitrate by aerobic bacteria from the genera Nitrosomonas (AOB) and Nitrobacter (NOB)**,** through a process called nitrification. Ammonia (NH3) is the waste product of the fish and extremely toxic to fish**.** First nitrifying process is by Nitrosomonas bacteria. Nitrosomonas bacteria is cultured in the grow beds (gravel). This bacteria feed on both oxygen' and ammonia and with their biological activities. Reaction of Nitrosomonas bacteria excretes a chemical called nitrite (NO2)**.** Nitrite is toxic to fish but not toxic as ammonia. Second of nitrifying process is by Nitrobacter bacteria. Nitrobacter bacteria also cultured in the grow beds (gravel). These bacteria utilize oxygen in its respiration, and act in a similar way as Nitrosomonas bacteria. Reactions of Nitrobacter bacteria have changes the nitrite into a relatively harmless chemical called nitrate (NO3). Nitrate is the primary source of plant nutrition. Plants take in the converted nitrates as nutrients. The nutrients are a fertilizer, feeding the plants. This system produces clean water to fish tanks and is ready for next cycle. And uses the internet of things techniques to monitor, adjustment and control all system parts and parameters needed to maintain a water quality and life of both fishes and plants organisms, and to gain a high-quality production from hydroponic with without any human intervention**.**

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Introduction

1. Overview

In our country, we have been living under the unjust Israeli occupation for more than 70 years, which restricts and hinders any attempt to develop Palestinian society in all aspects of life, and also one of the areas most affected by the occupation practices is the economic and environmental situation, and that is through economic restrictions. Impact on the working class and restrict movement from one place to another, as well as confiscating agricultural lands and destroying their contents such as trees and crops, controlling and raising the prices of agricultural and industrial products, as well as exploiting the natural resources of the Palestinian lands, through controlling groundwater and artesian sources in Palestine and imposing restrictions on it, thus raising the price of water doubly.

Based on that, we decided to work on adapting and employing technology through the aquaponic System, in order to serve the Palestinian community and try to reduce the restrictions imposed by the Israeli occupation, and this is represented by the increasing agricultural production in Palestine At relatively low cost and without relying on traditional method and employment of recent discipline disciplines.

Also, the aquaponics farming method comes into as a solution to improve farming productivity. Aquaponics is defined as the process of growing aquatic organisms and plants symbiotically, it is a combination between aquaculture (farming of fish) and hydroponics (growing plants without soil), which also means an integration of aquaculture and hydroponics environment. This farming method promises to be a good alternative against the food and environmental problems our community and world is facing as all. Our Aquaponic system will be smart and an automated system by using what is known as the Internet of Things (IoT).

2. Motivation

We have been thinking about this system for several reasons, including the attempt to reduce the effects and damages resulting from the Israeli occupation, especially on the agricultural sector in Palestine, and also the attempt to adapt technology to reduce or solve the economic and environmental problems in our society.

Exploiting and using Internet of Things technology to build smart and remotely controlled and automated aquaponic systems, such that we need to use the internet of things in our world and for most fields of our life to be a better and easy life, this tends in the future orientation for most computer science and networks.

Intelligent system meets the system input and output with the main block containing the processing and gets a high level of system based aquaponic.

Thinking about an alternative to the traditional farming system, so that this alternative is available to anyone and anywhere, and that it has a productivity level or better than traditional agriculture. Certainly, after integrating fourth generation technology and Internet of Things technologies, a system can be obtained that saves time and effort and gives the best results

3. System Importance

The importance of the aquaponic systems lies in the following steps:

1. The Aquaponics system is a good alternative against the food and environmental problem that the world is facing. Where this system began to be applied in many countries of the world, and it showed that it can be relied upon as an alternative system for traditional agriculture**.**
2. Aquaponic system has a high-water use efficiency, thus saving the water consumption**.**
3. Reducing the use of pesticides and fertilizers, which can be considered as a green technology**.**
4. Aquaponics systems have a lesser environmental impact**.**

4. Problem Statement

Traditional plant cultivation has been mainly performed in the soil. It is known that a series of drawbacks can be found in such a way. For example, regular watering and fertilizing has to require more time and labor, and consume a large amount of water.

The traditional system needs to be followed up. You need a regular presence of the farms to be monitored and taken care of, and for this you need and consume time, effort and money.

So, we need an overall automated system remotely in this case, to solve and process all system needs and requirements by itself without regular farmer intervention.

5. Short Description of The System

An aquaponic refers to two basic definitions one of them is aquaculture and the second contain of hydroponic completed the cycle with water live, no plans can't live without water but, there are a lot of plants can live and grow up without Agriculture soil, at the same state of point, there is any fish can live without water, of course not so, if we contain two basic systems with one system and explained this hybrid system by the name of aquaponic, it's just need from us to integrated this two basic systems with monitoring parameters and smart system to successful our project, and that's my meaning of the plants without soil, water made of fish and plants together, each one successful the other one, moreover here is the best way to description the project by the meaning of smart aquaponic system remotely controlled by commands so my final words in main important sensors reading and commands taken by the reading of sensors and that's all.

6. System Objectives

1) Design an independent real time smart aquaponic monitoring prototype that combines between hydroponics system and aquaculture system**.**

2) Using and exploiting the internet of things technology as tools to achieve a remote monitoring of the system and make the aquaponic system more efficient and smarter**.**

3) Compare between traditional aquaponic systems without smart and automated controlling and the smart aquaponic monitoring system in terms of efficiency and productivity**.**
4) Produce a high-quality production from the hydroponic system as much as possible.

5) Ability of the system to deal with any system failures, whether in sensing elements or in aquaponic and hydroponic components**.**

7. Problem Analysis

Traditional plant agriculture has been mainly performed in the soil. It is known that a series of drawbacks can be found in such a way. For example, regular watering and fertilizing has to require more time and labor and consume a large amount of water.

The traditional system needs to be followed up. You need a regular presence of the farms to be monitored and taken care of however for this you need to consume time, effort and money. So, we need an overall automated system remotely in this case, to solve and process all system needs and requirements by itself without regular farmer intervention.

8. Aquaponics System Main Components

Aquaponic system combined between two main system components, which include the following:

1) **Aquaculture Components:** Fish tank aquarium**.**
2) **Suspended Solid Filtration Part:** Remove some solids impurities from fish water
3) **Biofiltration Part:** Process that converts fish waste into a nutrient solution for plants.
4) **Hydroponic Components:** Growing plants without soil.
5) **Internet of things techniques:** Remote monitoring and controlling
6) **Hydroponic Solution Tank.**

We will explain these components in chapter 2 in detail**.**

9. List of HW Requirements

Hardware components classified into two parts:

1) Water monitoring sensors for both aquaculture and hydroponic parts.
   - pH sensor**.**
   - Water Temperature Sensor**.**
   - Dissolved Oxygen sensor (DO)**.**
   - Water Flow Sensor (Flowmeter Device)**.**
   - Water Electrical Conductivity Sensor (EC)**.**
   - Total Dissolved Solids Sensor (TDS)**.**

2) Environmental sensors and devices to monitor and control environment parameters for both water and hydroponic components**:**

- Temperature and humidity sensor (DHT22 Sensor)**.**
- Camera to monitor plants fish and health and based on artificial intelligence**.**
- Fan to control relative humidity in the hydroponic system**.**

3) Arduino and Raspberry pi microcontrollers to monitor and control all system components and parameters, and exploiting the internet of things technique**.**

4) PVC pipes, water pumps, and water tanks (Water Sump)**.**

5) Specific types of plants to be used in the system and also, we need specific types of fish**.**

10. List of SW Requirements

Software requirement in the aquaponic system represented in the internet of things application that can be used for remote monitoring and ability for remote controlling via internet or via local mesh network between sensors and microcontrollers**.**

As an example of this software is a “Blynk Internet of Things Platform”, this platform came with android application and website server that can connected to the cayenne client on each microcontroller, and receive and display all system parameters on the website server, and also ability to remote control via android app or via website server**.**

11. Expected Results

1. The availability of the IoT system for all times, and for all users**.**
2. Getting accurate readings from highly sensitive sensors for making real time controlling and monitoring without any delay or suspension, and getting plant productions of high quality and to have a high quality of a growth rate**.**
3. Ability to adapt with any variation of the system in any place or any time based on all parameters that are adjusted for the system**.**

12. System Limitations

System limitations may be having influence on the system performance o, or can affect the the of the system implementation, and we need to explain some of limitations that we can faced throughout system implementation**:**

1. The cost limitation, it may have the biggest impact on the project implementation**.**
2. Electrical usage in the system, and it may be related to the cost limitation, and it depends on the system design manner**.**
3. Type and amount of organisms (fish and plants) used in the system, because this will have impact on implementation of the system**.**
4. Availability of some important sensors used in the system in the markets, and ability to purchase these sensors because of the very high cost of some sensors**.**
5. Ability to find the suitable alternatives components and solutions for the system when not available**.**
6. Ensure that the system will be capable of handling different failure scenarios, and it performs warning and appropriate action without user intervention**.**

13. Overview of The Rest of the Document Sections

Chapter two (Background), we will discuss an overview of the aquaponics system history and its evaluation in the last years. Explain main system parts in detail, system parameters, and types of the aquaponic systems in terms some standards used the aquaponic area.

Chapter three (System Setup), will consist of the design of the system, block diagrams, and design each part of the system how it works, determine the main important parameters values will be used in the system.

Chapter four (Software and Mechanical Implementation), in this chapter we will review all software environments used in the system implementation and development.

Chapter five (Validation and Conclusion), will check and review the expected results and experimental implementation of the system results to get best results and better performance.

Chapter 2
Background

1. Introduction

The aquaponic system contains fish release solids wastes. In aquaponics, we need to treat these fish waste solids as nutrients to plants, and reuse the nutrients for plant growth. This literature review will discuss an aquaponics cycle, biofiltration, suspended solids, fish species and plants adapted to the aquaponics system, and use of IoT technology in the system.

2. Literature Review

Aquaponics is a relatively recent trend in agriculture, in which combining aquaculture and hydroponics systems into one cohesive closed loop system that cycles nutrients and water to the mutual benefit of the plant and fish species within the system. The first scientific papers on aquaponics were published in the 1980s, but the research on the subject only really became widespread after 2010. As water and food scarcity became more widespread with climate change, aquatic systems were one of the technologies that scientists began looking for as a potential solution for stable and sustainable food production with potential for reducing water usage as compared to traditional farming methods.

- **Roots of the Aquaponic system**

There is a widespread debate among scholars about the exact origin or the beginning of the aquaponic system as a concept, or as the earliest form of aquatic system throughout history. The scholar found that the earliest concept is believed to have started in 1000 AD among ancient Aztecs civilization people in central Mexico, and these people did not have places to farm and grow their food because the places they inhabited, as they lived on the shores of the fresh**. (**farmingaquaponics.com/the-history-of-aquaponics/).

The exact origin of aquaponic systems also remains under debate, even to this day. While the Aztecs chinampas in Mexico are believed to to be the basis of modern aquaponic**.** People of the eastern Asia, especially in South China, Indonesia, and Thailand, were also thought to be among the earliest aquaponics practitioners, so we can conclude that the growing fish and plants together as a concept is made by ancient people of Central America and Eastern China (J. E. Racoky, 2003).

- ## The Development of the Modern Aquaponic Systems

Aquaponics term was coined in the 1970s, but the practice has ancient roots although there is some debate on its first occurrence as we mentioned earlier. According to some researchers, the first aquaponic research was held at the research station in Lethbridge city Alberta province in Canada**.** It was the beginning of researchers work on existing aquaculture research at a research station in Lethbridge, where the main objective of these scientific research is in effort to manipulate or eliminate the waste of fish from the water in the aquaponic system, such that the aquaponics system evolved from aquaculture to achieve this goal. (Love et al., 2014). The transition to aquaponics systems began in Alberta in the mid-1990s, such that a number of fish growers in Alberta adapted this system by building greenhouses and growing various types of vegetables. (Cătălin - Costin ONIGA,2018). The development of modern aquaponics is often attributed to the various works of the New Alchemy Institute and the works of Dr. Mark McMurtry at North Carolina State university.

As a modern concept, the earliest application of the aquaponic system as a research area and concept, was in the 70s and 80s from the last century, and was the main purpose of these research is improving the quality of water by removing the excess ammonia in the RAS aquaculture system. Also, aquaponic research started to grow after 2010. Nowadays aquaponic systems are more popular in many countries, and it’s being practiced in at least 43 countries in the world, but 84% of the practitioners use this technology as a hobby.(Love et al., 2014). What is distinguishes the Aquaponic system is its ease to implement within urban areas or as local food production because of the adaptable size of the system and its freedom from soil, so it is possible to create an aquaponics system in any place without dependability on requirements that is needed in a traditional farm.

3. Types of Aquaponics Systems in Term of Grow Bed

When designing the hydroponic component three different choices can be made for the grow bed or classified based on types of grow bed used, known as**:**

1) **Nutrient film technique (NFT)**.
2) **Floating-raft (deep water culture).**
3) **Media filled (flood and drain).**

Figure **2.1** explains these three types and how it works in detail. (Engle, 2015).

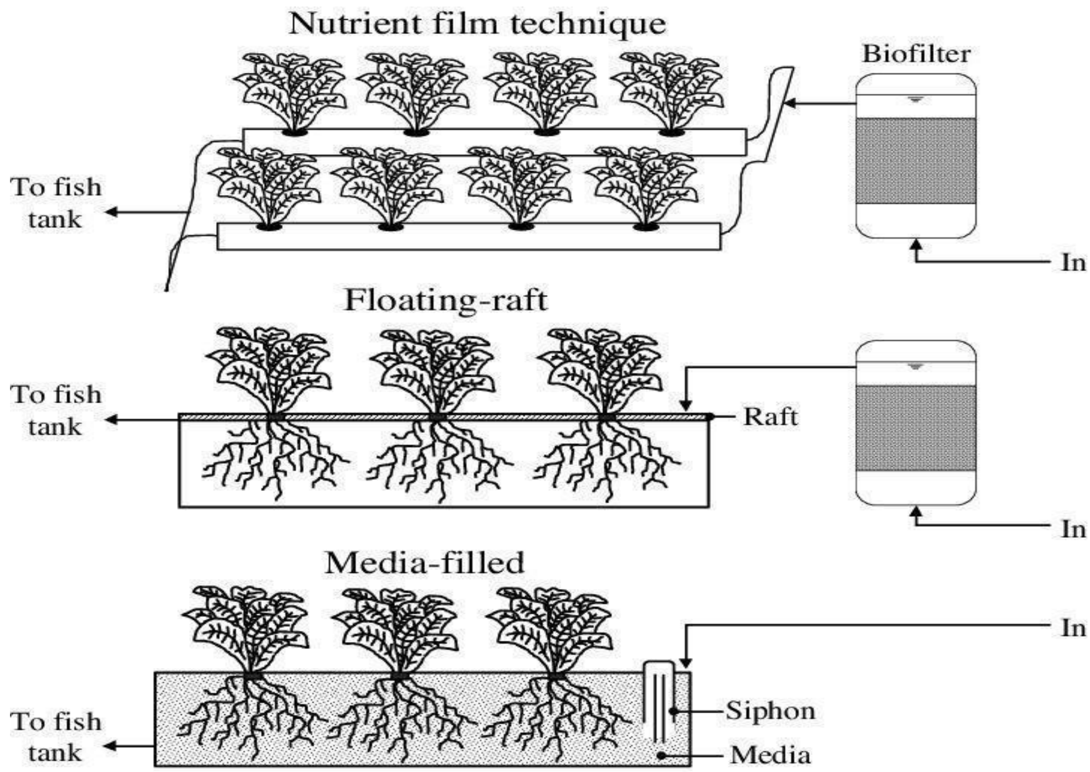

Figure 2.1 Aquaponic System Types (Love et al., 2015).

Note: In our project we will adopt type 2 [Nutrient Film Technique] as a basic design.

4. Aquaponics System Main Parts

The aquaponic system involved four main parts, as the following**:**

- **Aquaculture Components.**
- **Hydroponic System.**
- **Biofiltration Part.**
- **Internet of Things Tools.**

1) Aquaculture Components: -

It is a part in which aquatic organisms (e.g. fish) produce nutrients from its waste by the chemical and a biological process called nitrification, such that aquatic animals excrete waste, then bacteria convert the animal waste into nutrients, we will explain this process later in this chapter.

2) Hydroponic System: -

The hydroponic system is a technique of growing plants without soil, and the plants make use of the nutrients that are exerted by the aquaculture part to grow, thus improving the water quality for the aquatic animals. In this part we will adopt Nutrient Film Technique as a basic design**.**

3) Biofiltration Part: -

It is the removal of waste harmful chemicals that result from fish waste that may cause an increase in ammonia in the water, and that removal is done by using living organisms, bacteria, algae, etc., by absorbing and dissolving pollutants biologically, and the common use of these filters in sewage treatment, in which harmful substances or silt are removed from the water by the surface runoff process through the sedimentation process. In this case of air pollutants, harmful organic materials and biological organisms are eliminated by oxidation of those pollutants. The water of fish tanks contains high toxic dissolved in the water resulting from fish waste, so this water will be directed to the biofilter, where this biofilter contains bacteria that convert the fish waste into nutrients fertilizers for plants by a process known as nitrification.

4) Internet of Things Tools: -

One of the main goals is to design a smart system to exploit computer technology in agricultural environments, because this will facilitate the maintenance, development and use of aquaponic systems. In this part we will exploit the internet of thing technique for smart monitoring and measurements of all system parameters, and adjustment of all critical values of the system main parts, without any intervention from the system user, and gain the high quality of products.

5. Aquaponic System Cycle

Aquaponic is a system of production of vegetables and fish which live in a symbiotic relationship. In this section we need to answer the question that says, how aquaponic system work?

Firstly, fish are raised in a tank. Fish are fed food and, this food contains a percentage of protein, so ammonia is a dissolved gas produced by the waste exerted by fish and plays an important role in the aquaponics system, such that 10% of the protein in fish feed will converted into ammonia in system water (Tyson et al., 2008)**.** Also, ammonia is highly toxic for fish in small amount, so too much waste substance is toxic for fish, in this case we need to use this waste as a nutrient for the hydroponic part**.** Secondly, water from the fish tank is pumped to the biofilter to make the nitrification process that converts fish waste to nitrate as nutrients for plants**.** So that the bacteria which is culture in the biofilter and as well as the fish tank, breaks down this ammonia into nitrites and the nitrates. The Plants take in the converted nitrates as nutrients fertilizer, feeding the plants**.** Also the plant's roots help filter the water for the fish**.** Third, plants absorb the nutrient rich water**.**

Fourth, filtered water as clean water is returned to the fish tank and ready for the next cycle.

Water in the system is filtered through the grow medium in the grow beds. The water also contains all the nutrients for fishes. all the nutrients for the fish. Oxygen enters the system through an air pump and during dry periods. This oxygen is essential for plant growth and fish survival. figure 2.2 and figure 2.3 shows how aquaponics cycle will be.

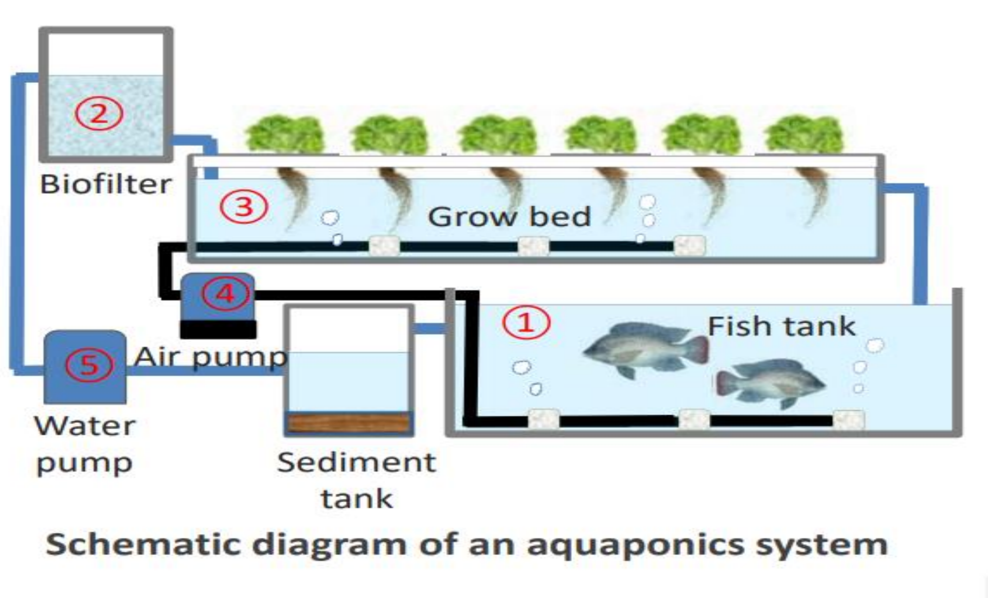

Figure 2.2 (Hye-Ji Kim, Assistant Professor of Sustainable Horticulture Crop Production)

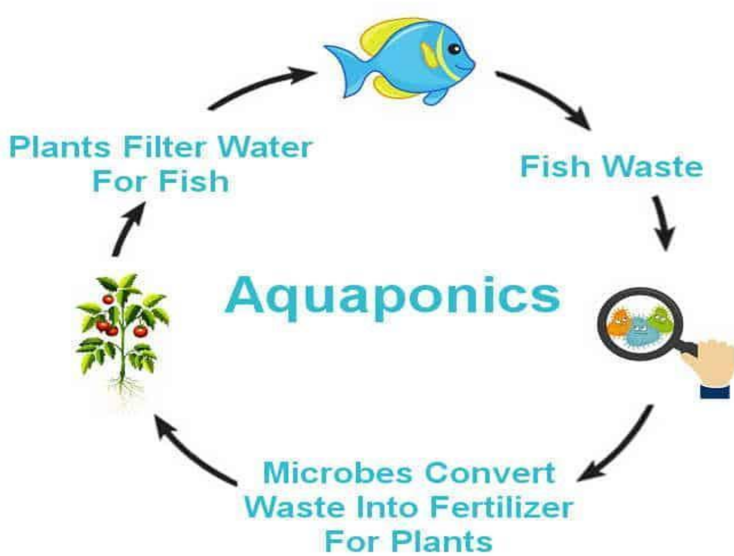

Figure 2.3 Water cycle in Aquaponic system, aquaponicsexposed.com/the-nitrogen-cycle/

6. Fish Species Adapted to Aquaponic System

Aquarium fish, tilapia, yellow perch, trout, catfish, bass, bluegill, carp, koi, goldfish and freshwater prawns are included as several warm-water fish and cold-water fish species are adapted to the aquaponic system. However, catfish are used in many research. Catfish species can grow well in a recirculating system and like temperatures around 80° C. But catfish is more sensitive to temperature, pH, and water quality than other species. So, we must check water quality and add water or do partial water changes if necessary. Have a few factors that must be considered to keep fish healthy. Most fish like **pH between 6-8.**

In aquaponic fish tanks, a water pH of 6.5 to 7.0 is maintained (Nelson, 2008). We must maintain the water pH in the fish tank to keep fish survival. Potassium hydroxide (KOH) and calcium hydroxide are often used in the system in order to maintain a pH of 7. Besides that, ammonia and nitrites are very toxic to fish but nitrates are fairly safe for fish and great for plants. So, the aquaponics system will remove this ammonia to produce clean water for fish. Furthermore, fish are sensitive to light. We must avoid direct sunlight on fish tanks, cover the top to avoid algae and make fish happy**.**

7. Nitrification Process

The essential element for all life forms is the chemical element Nitrogen (N), which is present in All amino acids that compose proteins, this being essential for many key biological processes and Functions for animals (Somerville et al., 2014). Also, the nitrogen element is considered as an Essential element for all living organisms (Pratt and Cornily, 2014). And are the most important Organic nutrients for the plants. The major source of nitrogen input in the aquaponic system is fish feed, which is exerted to a form of ammonium-nitrogen. One of the forms of nitrogen that plants can uptake is the Nitrates ($\mathbf{NO^{-}_3}$) (Anthemises et al., 1976; Ebeling et al., 2006). Ammonia is a dissolved gas produced by the waste exerted by fish and play an important role in the aquaponics system, since it will serve as an initial component for plant growth nutrients, is the base of the nitrification process in the aquaponic system, it's a form of nitrogen found in organic and many fertilizers**.** (Tyson et al., 2008) (Stone and Thomforde, 2004)**.**

- Ammonia it can be found in the water in the form of:
  1) Ammonia [$\mathbf{NH_3}$]**.**
  2) Ammonium **[$\mathbf{NH_4}$].**

Where the concentration of both ammonia and ammonium in a water solution is a function of the pH, the **temperature**, and the **salinity**.

The sum of both is known as [Total Ammonium-Nitrogen concentration] **(TAN)**, such that **TAN** forms this equation TAN **= [NH_3] + [NH_4].**

- There is a different kind of the bacteria that contribute in the nitrification process, which Include:

  1. Ammonium Oxidizing Bacteria (**AOB**): TAN is oxidized into Nitrite **NO^-_2 .**
  2. Nitrite Oxidizing Bacteria (**NOB**): Nitrite broken down into Nitrates **NO^-_3 .**

  So form the preceding information we can define the nitrification process as: the process that transforms **TAN** into Nitrates **Nitrates** (**NO^{--}_3**), which is form of nitrogen that plants can uptake as a nutrient in the hydroponic system.

❖ We can conclude the nitrification process in the following steps:

1. The fish produce waste from its feeds**.**
2. The fish waste produces **TAN** in the water**.**
3. **TAN** oxidized into **Nitrite NO^-_2** by Ammonia Oxidizing Bacteria (**AOB**).
4. **Nitrite NO^-_2** oxidized into **Nitrates NO^-_3** by Nitrite Oxidizing Bacteria (**NOB).**

Figure 2.4 explain the nitrification process in the system:

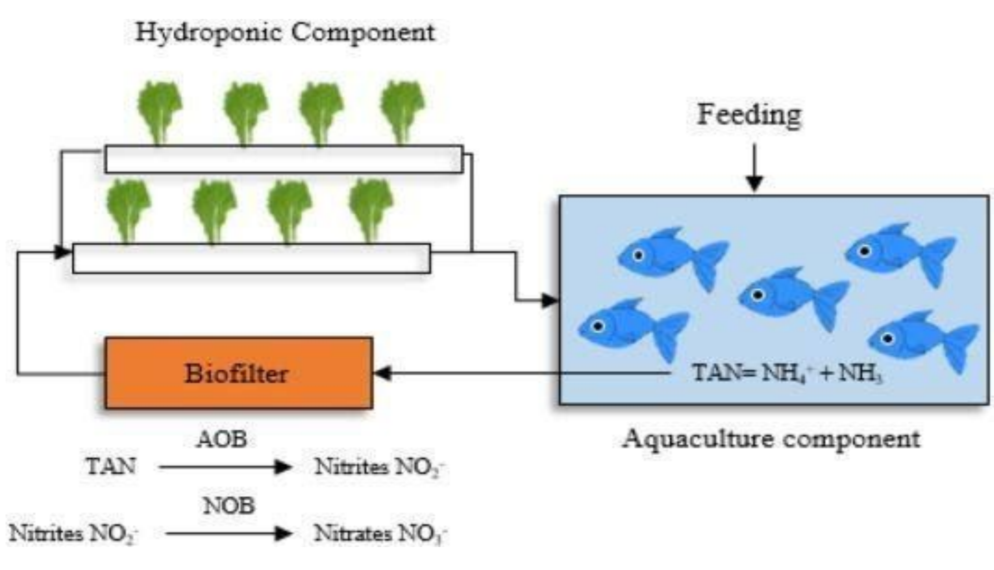

Figure 2.4 Overview of Nitrification Process with NFT design (Love et al., 201)

We need to point out that the ammonia s a highly toxic for fish in small amount, and it is Predominant (relative proportion increases) in the water solution when it becomes strongly Acidic or alkaline, so the researcher creating equation to compute the relative proportion of the total ammonia nitrogen TAN generated in the aquaculture component, and calculated from the following equation**:**

$$P_{TAN} = F*PC*c$$

Where:

P_{TAN} : The production rate of TAN

F : Represent the feeding rate (Kg/day).

PC : Is poutine content (fractional).

c : Is the constant amount of excreted TAN per protein input based upon the feeding rate.

The **c** constant is empirically obtained, and for aquaponics system **c = 0.092(Ebeling et al.2006).**

Research papers for (Stone and Thomforde) mentioned that the desirable range of TAN for fishes in the aquaponics systems of **TAN** is **from 0 to 2 mg/L** (Stone and Thomforde, 2004). Somerville et al. make a difference between (**warm water fish)** and (**cold water fish)** (Somerville et al., 2014).

- **For the (warm water fish):** the optimum TAN range is **< 3 mg/L.**
- **For the (cold water fish):** the optimum TAN range is **< 1 mg/L.**

For bacterial activity, namely AOB and NOB, the optimum value is **< 3 mg/L** for the fish and less than **30 mg/L** for plants (Somerville et al., 2014)**.**

8. Types of Aquaponic System in term of Cycle Technique

In the aquaponic system there are different design in term of system cycle and steps used in the system and these techniques are**:**

1) **Coupled aquaponic system.**
2) **Decoupled Aquaponic system.**

Each design has pros and cons, in the following page we will explain these types works and its advantages and disadvantages**.**

1) Decoupled Aquaponic System

In this design the aquaponics farms that are designed with the flexible manner to decouple the aquaculture part from the hydroponic part, and this separation technique allow the two systems to be operated independently from one another. So, this work by separating the water and nutrients loop of the both system aquaculture and hydroponic, which each system has its own water loop, to provide more ability to control the water chemistry and control water parameters for each part independently. Figure 4.5 provides a block diagram of a two-loop decoupled aquaponic system. (Alyssa Joyce, 2019)**.**

Decoupled systems commonly consist of two independent recirculating units: a recirculating aquaculture system (RAS) for fish and a hydroponic unit for the plants as shown in (Figure 2.5).

Disadvantages of this design represents that this system design is more complex that requires Greater capital investments, space, technical expertise, and management. Because this design contains two-loop water, it is difficult to provide adequate levels of nutrients for plant growth solely from the aquaculture component, because maybe there is a decrease of nutrients level concentration befor hydroponic water loop, so we need more nutrient adjustment tank to ensure to control nutrients level. (Rossana Sallenave and R. Charlie Shultz) (Alyssa Joyce, 2019).

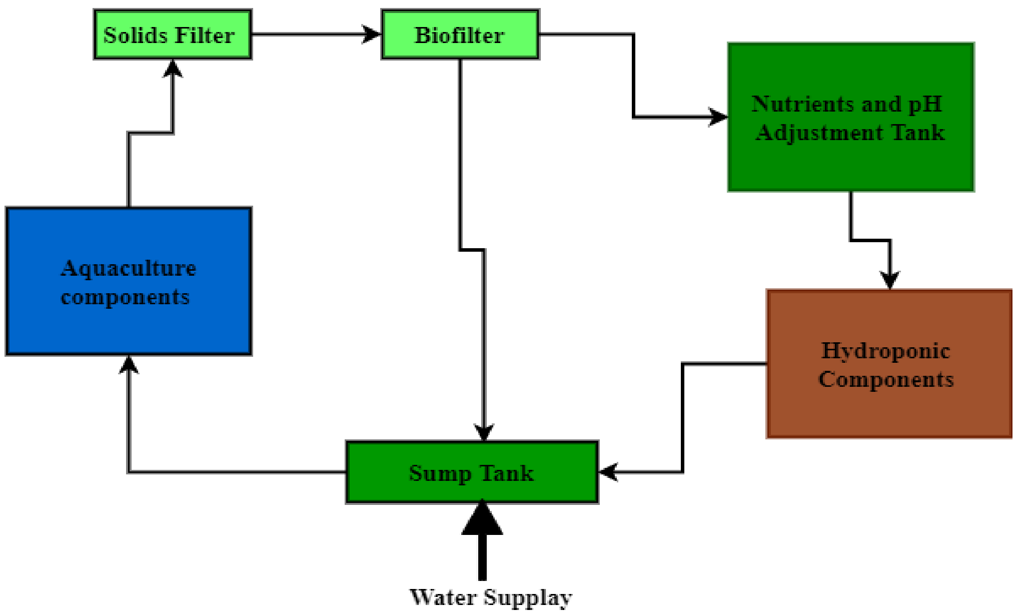

Figure 2.5 Decoupled Aquaponic System

(This design will be adapted in our project.)

2) Coupled Aquaponic system (Single loop Design)

As we explained earlier, the water serves as a medium of nutrient transport, mainly from dissolved fish waste, which is converted into nutrients for plant growth by bacteria. In single-loop or balanced aquaponics systems, the water from the fish tanks flows through a series of filtration tanks and then into the hydroponic portion of the system. The filtered clean water is then returned to the fish tank via a pump. So, the concept of a coupled one-loop system is that water recirculates freely in a one loop between the aquaculture and hydroponic units, while nutrients rich sludge is discharged. (Rossana Sallenave and R. Charlie Shultz).

The concept of a coupled one-loop aquaponics system as shown in Fig. 4.6, is a one loop system design

that combines three classes of organism as any aquaponic system:
1) aquatic organism.
2) bacteria.
3) plants that benefit from each other in a closed recirculated water body.

One of the key drawbacks of such systems is that it is necessary to make trade-offs in the rearing conditions of both subsystems in terms of pH, temperature, and nutrient concentrations.

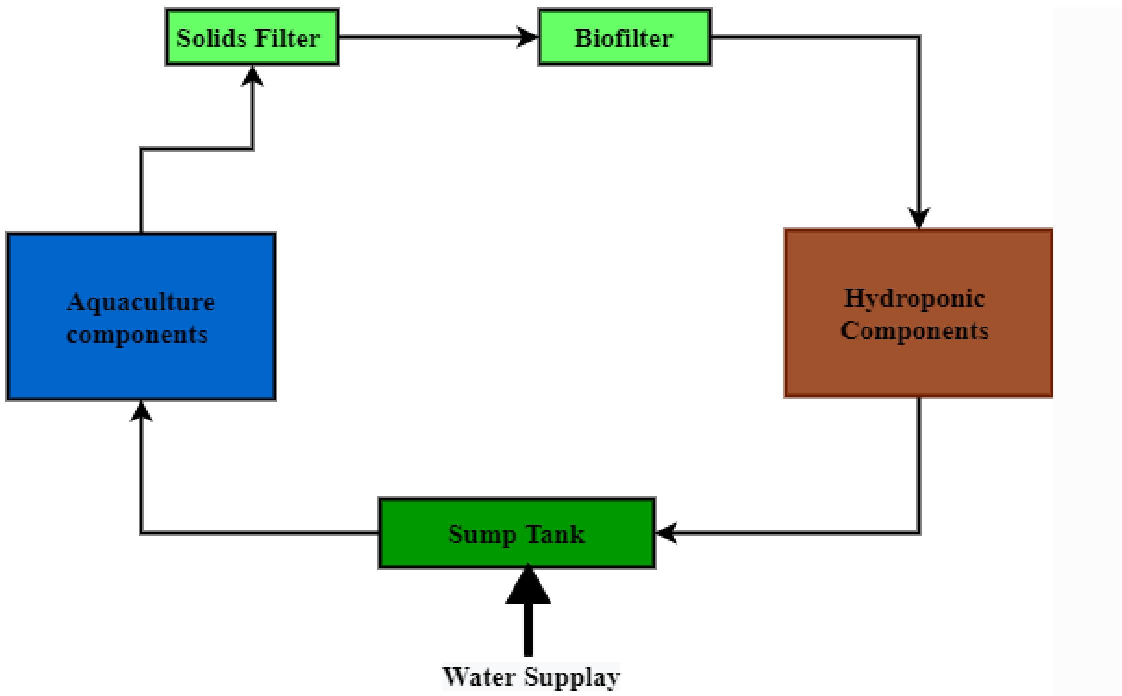

Figure 2.6 Coupled Aquaponic system

9. System Monitoring Parameters

The monitoring parameters in the system are defined and classified based on the following factors (Yanes a ,2020):

1) **Water Parameters.**
2) **Environment Parameters.**

In this section we will discuss the importance and effect of each parameter and the suitable values that can be used as a standard in the aquaponics systems based on multiple research papers in this field, and how we can measure them in the automated aquaponic system. (Yanes a ,2020).

❖ Water Parameters

The quantity of water is the most important parameter in this system, where the water is important for fish life and as a nutrient for plants in the hydroponic system part, and any error or defect in these parameters, non-equilibrium system or lead to fail the system at all. So, to ensure an ideal quality standard in the system, we need to maintain, monitor and adjust and correct the amount of these parameters continuously. (Odema et al., 2018) (Yanes a ,2020).

Note: All parameters and values in this section are variables, and subject to change according to many other factors, such as system design, fish and plant types that will be used in the system.

1. pH

pH is a measure of hydrogen-ion concentration in the water, usually known as the measure of acidity and alkalinity of solution. The aquaponic system is sensitive to changes in the pH measurements. So, the pH value affects fish health, plant growth and rate of nitrification process.

- For aquaculture components the desirable range for the water pH is goes from **6.5 to 9.5,** but in general the acceptable range is from **5.5 to 10**. However, this range can slightly vary with fish species (Stone and Thomforde, 2004).
- In the hydroponic component the optimum range of pH is around **6.0-7.0**. A higher than **7.0** will cause precipitation of Fe and Mn, and lower than **4.5** can cause root injury (Wada. 2019)(Summer ville et al.,2014).
- For the nitrification process the required pH range goes from **7.0** to **9.0.** (Stone and Thomforde, 2014) (Yanes a ,2020).

2. Water Temperature

The temperature in the water is related to many other factors in the system, and linked to most other water-related parameters. So, it is important to monitor and maintain its values in specific parts of the system. (Summer ville et al.,2014).

- For the nitrification process, the optimum temperature is around **17-34 C,** if the water temperature below this ranges the productivity of bacteria will tend to decrease and the nitrification process will not be successful. (Summer ville et al.,2014).

- For the hydroponic components the suitable temperature range is **18-30 C,** out this range (Summer ville et al.,2014)**.**
- For the aquaculture components, the maintaining correct temperature will decrease the risk of disease, and the appropriate temperature it depends on the fish species used in the system as the following (Summer ville et al.,2014)**:**
  - ★ For tropical fish for example, the optimum temperature is **22-32 C**.
  - ★ For cold water-fish, the required temperature range is from **10 - 18 C.**
  - ★ For some other fish a wider range of suitable temperature is **5-30 C.**

3. Dissolved Oxygen (DO)

Is a measure of how much dissolved oxygen in the water available to aquatic organisms

Is an important parameter for the three organism (fish, bacteria, and plants) that share the aquaponics environments. It is a high importance to monitor dissolved oxygen in any aquaponics system, because its level changes dramatically in a short period of times, less than 24 h (Sallenave, 2012)**.**

- The optimum range of DO for nitrifying bacteria is **4-8 mg/L.**
- For the hydroponic component, typically **> 3 mg/L.**
- In the aquaculture components DO concentration is **>5 mg/L.**

4. Total Dissolved Solids (TDS)

Total dissolved solids are naturally present in the water. TDS levels represents the content inorganic salts, organic matters and other dissolved material in the water**.**

- For fish life, typically the optimum amount of TDS is **1000 mg/L.** Also, below **2500 mg/L** is acceptable for some fish species**.** But the proper value will differ between fish species used, where a high amount of **TDS** > **1000 mg/L** will be toxic for most fish species (Stone and Thomforde, 2004) (Yanes a ,2020)**.**

❖ Environment Parameters

Are the parameters related for both aquaculture and hydroponic parts, we need to obtain a high quality of plants and maintain balanced and safe optimal crops in the system, to ensure the stable and healthy growth of fish and vegetables. So, it is necessary to monitor and control some environmental parameters, and these parameters are explained as the following**:**
(Stone and Thomforde, 2014) (Yanes a ,2020).

1. Air Temperature

The air temperature is important to maintain the health of plants in the hydroponic system. The suitable temp for most types of the vegetables is in the range **18-30 C.** The air temperature can be measured using DHT22 sensor, this sensor has high resolution and very sensitive to small change in temperature**.** (Somerville et al., 2014).

2. Relative Humidity

Air humidity can be expressed as the proportion of the air water saturation or relative humidity. So, the relative humidity is defined as the moisture in the air. Humidity is an important factor to maintain the health of plants. To control and maintain the level of humidity, we need control over ventilation and heating systems, which allows the ventilation systems to exchange moisture inside the greenhouse with the drier air from outside**.**

- The optimum level of RH is depending on type of crops and the growth stage of the Plants**.**
- In general, the suitability of RH ranges from 50% to 80% but also this depends on indoor temperature in the greenhouse**.**

10. Smart systems

Intelligent or smart systems is a concept related to the industry 4.0 generation technology, are now broad in the world and the research area, this is due to technological development in our time. The "smart" concept involves complex logical processes, algorithms, and it's not limited to basic logical operators**.** There are different between smart systems and automated systems in the technology area, which the machines that work under input signal, and compare and process these signals, make triggers and resulting output, it's called automated but not smart**.** The adoption of smart system technology in the farming or in the aquaponic systems will helping to minimize the production time, reduce the need for labor, lowering the expertise needed to regulate the systems and for the improvement of quality of products**.**

- **Some application of smart aquaponics systems represents in the:**

1) Parameter prediction

The smart components in the systems depends on the application of the regression analysis techniques to predict the future values for some parameters as pH and nitrates. Regression is a data mining technique used to predict a range of numeric values or continuous values as sensors values, and using a deep neural network for prediction and decision making have been made, and this trained neural network was installed in the Arduino microcontroller or on raspberry pi to control the outputs depending on the sensed values.

2) Quality and growth rate monitoring.

There is a different manner to monitoring quality and growth rate of plants in computer science, one of these methods is using "Convolutional Neural Networks" technique, that are commonly used in quality assessments of the crops. A monitoring growth rate of lettuce using deep convolutional neural networks was implemented in a hydroponics system by Lu et al. (2019). Other techniques are monitored and controlled by artificial intelligence techniques and image processing, such that for example, we can monitor plants' growing rate and health by live and direct monitoring by camera, process and analyses the captured image, and perform actions according to the data analyzed. Moving forward, this image analysis and prediction models can be used to monitor some parameters in the aquaculture component, e.g., the health of the fishes based in the known physical reactions of some parameters, (i.e., red areas in the eyes when the level of ammonia is dangerous), turbidity of the water for triggering the filter or cleaning, etc. The image processing and prediction techniques based on images is not found often in the literature of Aquaponics.

11. Internet of Things Techniques

The Internet of Things is a recent technical term, which symbolizes the new form in which the technical devices began to communicate with each other through the Internet.So, the term Internet of Things is a description of the situation in which the communication between technical devices is done via the Internet without human intervention. You now find washing machines capable of sending a notification, for example, to a supplier sending a laundry freshener if it runs out, as well as refrigerators capable of making similar communications without any interference from humans. (Shiny Abraham,2017).

- **How IoT Works?**

The establishment of the Internet of Things system depends on the various main components, which are the smart devices that support the web for the purposes of harnessing them for processing data and sensors, as well as communication devices of various kinds for the purpose of collecting data from their environment and transmitting it to be used, as the secret of working in it lies in the extent of interconnection and connection of all devices The Internet of Things with special sensors to attract the necessary data and analyze it, in order to then obtain the important information returning from the various devices, without the need for any human intervention, and special protocols must be in place to connect to the network and devices supported by the web**.**
(Shiny Abraham,2017)**.**

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Chapter 3

Design

1. Aquaponic Project Design

Aquaponic is mixing between two main programming system, those two main systems integrated together, aquaculture science with hydroponic science, those two main systems required control as startup of the aquaponic system design, providing control of nutrients solutions from fish water before moving the water through plants media to absorb the nutrients from water and support the growing stages and help fish with freshwater.

A) Mechanical system design

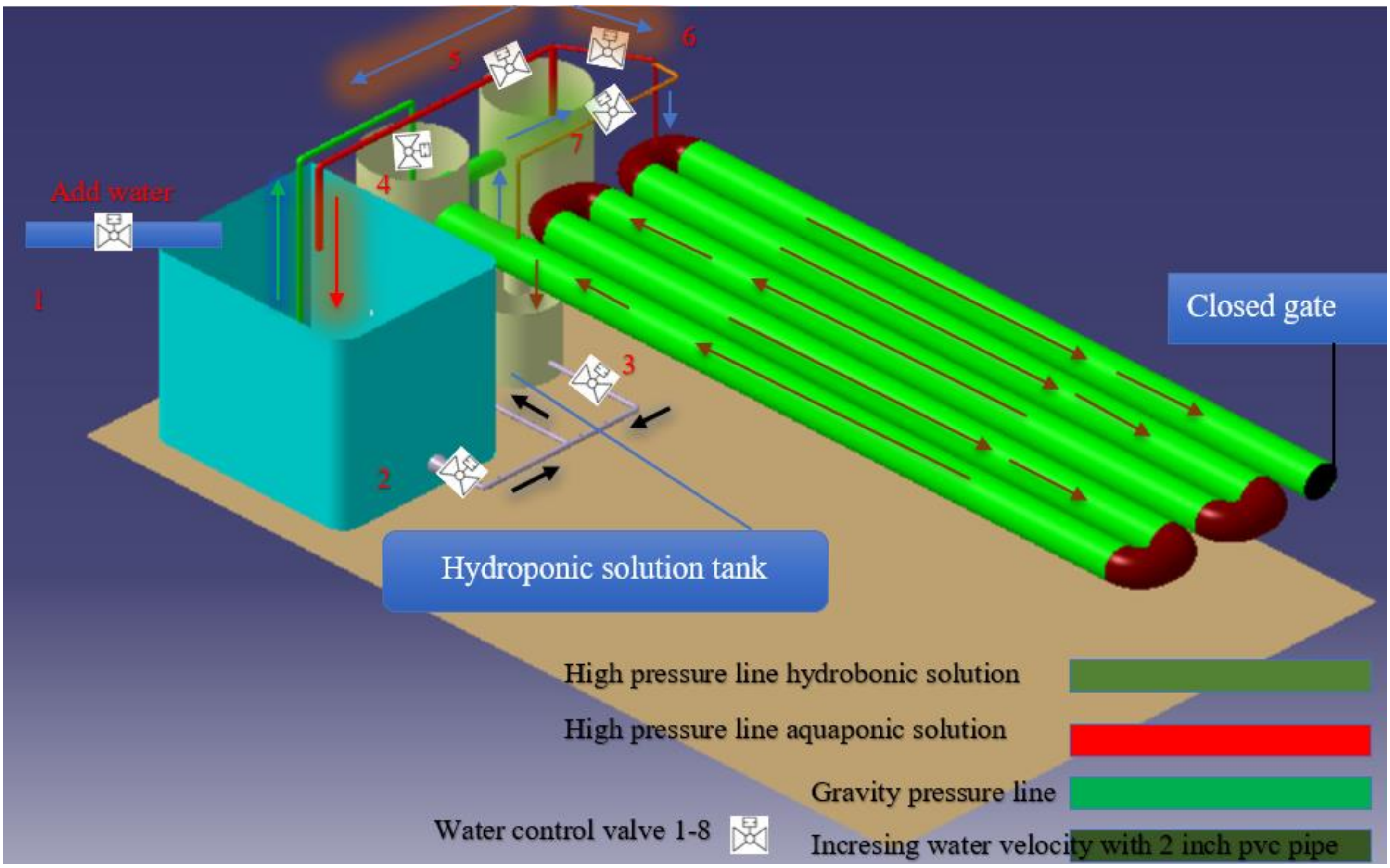

Figure 3.1 explained the hydroponic tank with all fluid motion directions with water controller's valves.

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Plumping setup

1. Design of the Aquaponic system

a. Fish tank water flow

Design explains the water flow system from start add water point until plants absorb water, it explained, as shown at the figure below start point of fish tank, where fishes produce main Key Nutrients for plants as discussed in chapter there, from fish tank to mechanical filter water…

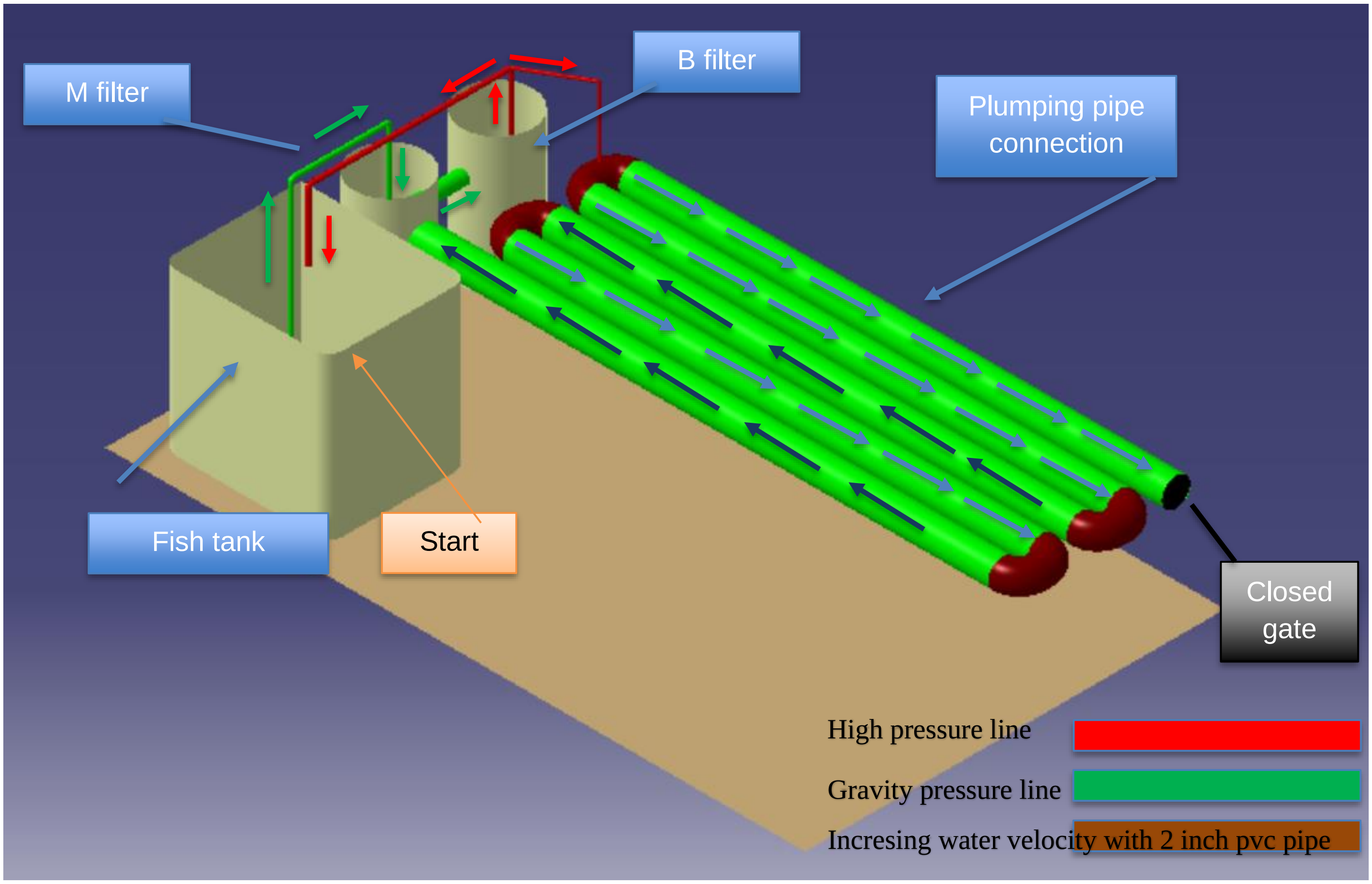

Figure 3.2 Explanation view of aquaponic design for the water flow

b. Fish tank, Pascal pressure calculation

moves from the lowest tank level of water, where high pressure water produced by density and maximum water level under the atmospheric of water, that's law lets the water goes from high pressure water part to low pressure part applied to Bernolie equation. According to (MUNSON 2009)

$$p + \frac{1}{2}\rho v^2 + \rho g h = constant\ along\ streamline \qquad (1)$$

$$p_1 + \frac{1}{2}\rho v_1^2 + \gamma h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \gamma h_2 \qquad (2)$$

P, P1: static pressure of fluid at the cross section; g: acceleration due to gravity

ρ: density of the following fluid in; v: mean velocity

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h: elevation head of the center of the cross section with respect to a datum.

From figure of fish tank to understand the flow of water by gravity and the continuity of flow water for the flow rate example

$$P = p1 + \gamma h1$$

while H1; the distance from the water top level.

ρ= 998.2 kg/m3 (density)

γ= 9.789 kN/m3 (specific weight)

Fluid application based of fluid fundamental and application of Bernali equation.

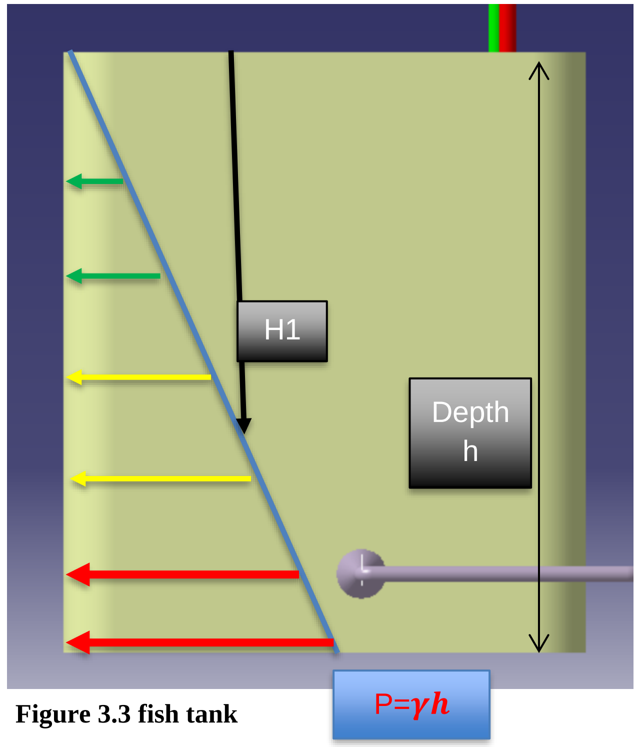

Figure 3.3 fish tank

Note: all pressure is the same for constant h, and if any increasing or decreasing of h, increases or decreases the pressure. It's based of hydrostatic principles.

important to know:

there is no changing of pressure if we increase or decrees the diameter of the tank or the pipe its changing occur

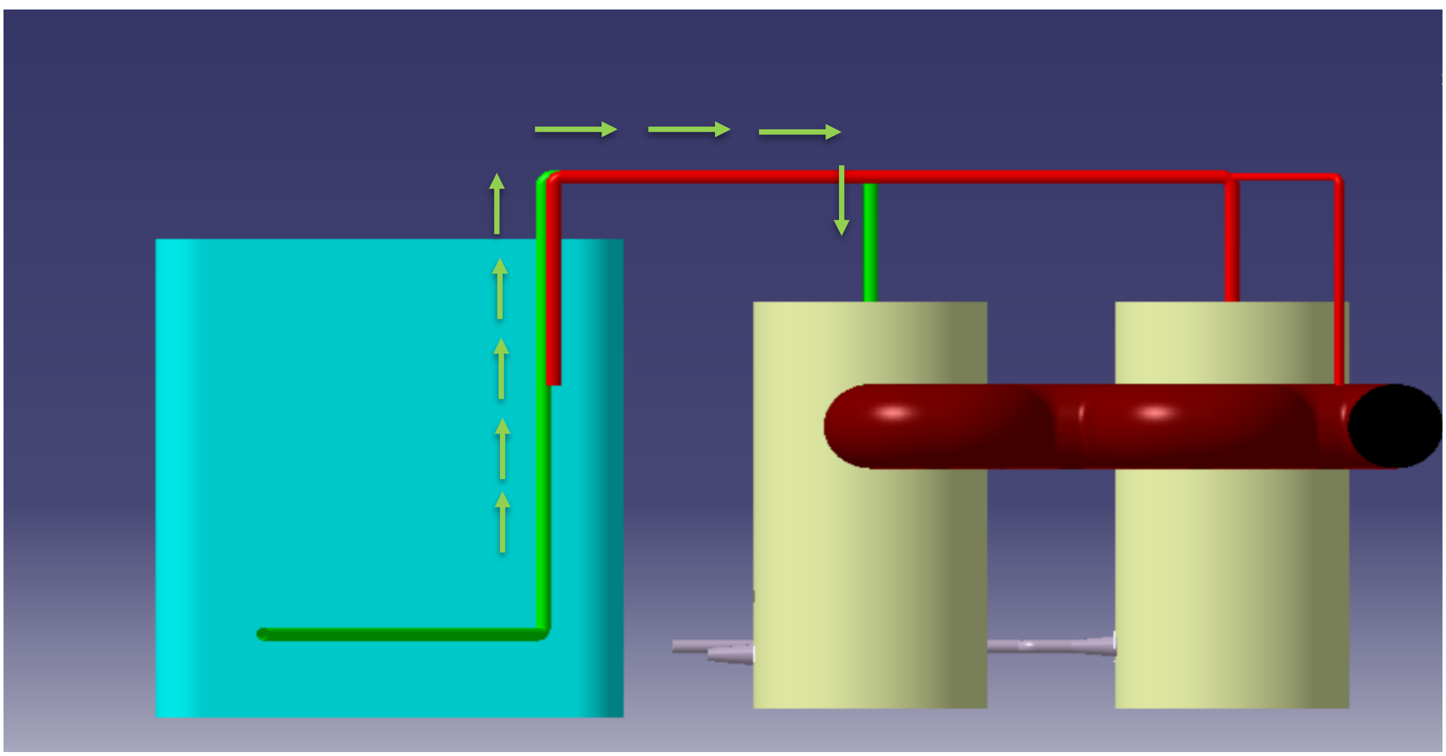

Figure 1.4 fish water tank section to view the flow water from fish tank to filters

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on the high of h level, so if we put into fish tank a small filter to filtrate the water fish from small particles, into the pipe of 2 inch used into fish tank to filtrate the fish water small particles, we can use PVC 15mm – 20mm to move water from high pressure to low pressure part accruing due to atmospheric pressure at the fish tank surface level of water, so it's important to not fully close the fish tank and to not put fish tank below the level of moving water it must have high level surface above the surface needed to 15mm – 20mm to move water from high pressure to low pressure part accruing due to atmospheric.

pressure at the fish tank surface level of water, so it's important to not fully close the fish tank and to not put fish tank below the level of moving water it must have high level surface above the surface needed to wove water, mean you should put rising level of rock before add water at the fish tank to raise the level of height and to rise gravity acceleration for the flow water to the filter.

(Should to create initial vacuum to make the continuity of flow water from high pressure to low pressure)

explanation of waste flow water that goes to soil plants earth if there is no need to use water produced from fish or extra water produced from fishes, however it has all nutrition of fishes like nitrogen and Phosphorus and Potassium NPK as mentioned in chapter 3, moreover you can create more PVC pipe and more plants from fish water like hydroponic and it's so efficient to save water.

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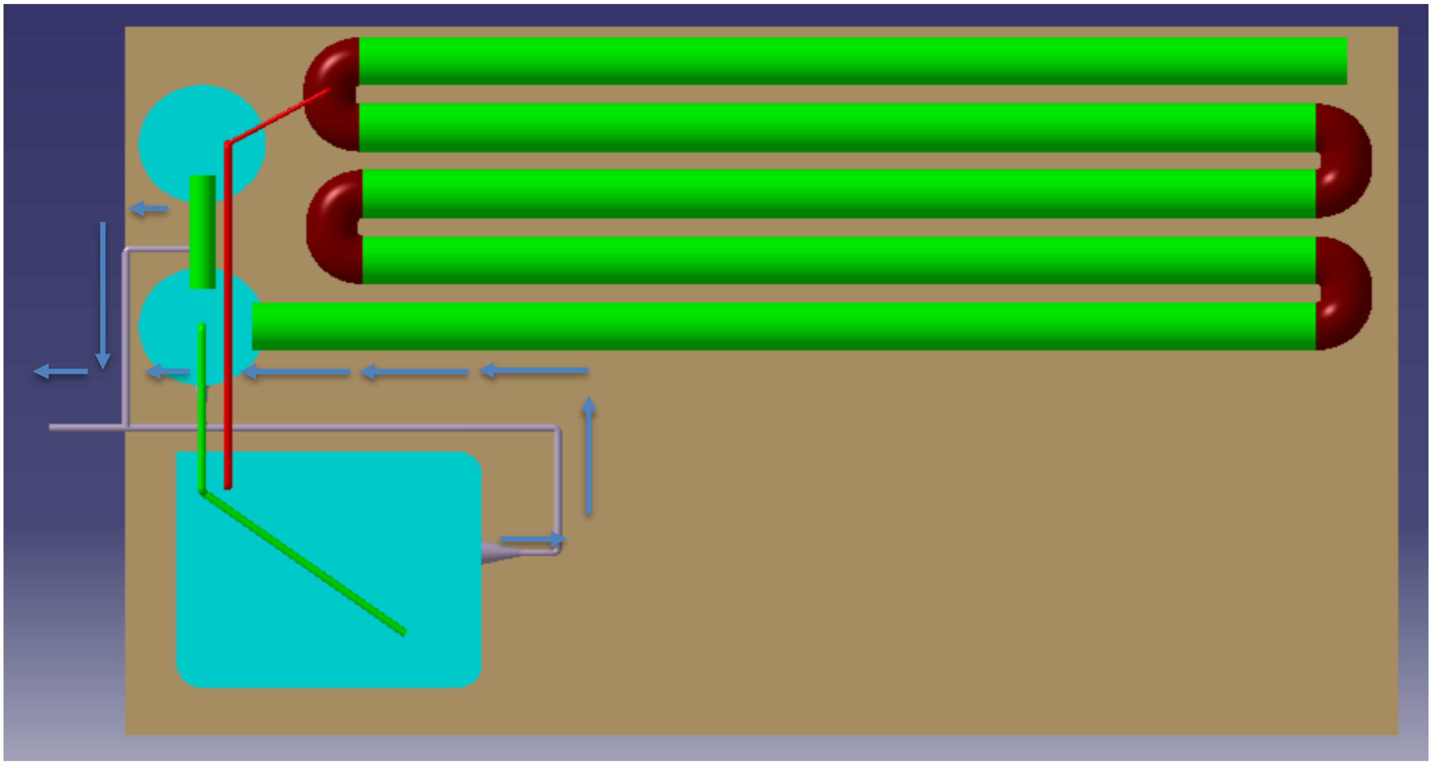


Figure 3.5 view the waste water flow that not needed to plants or fishes.

2. Water flow rate calculation

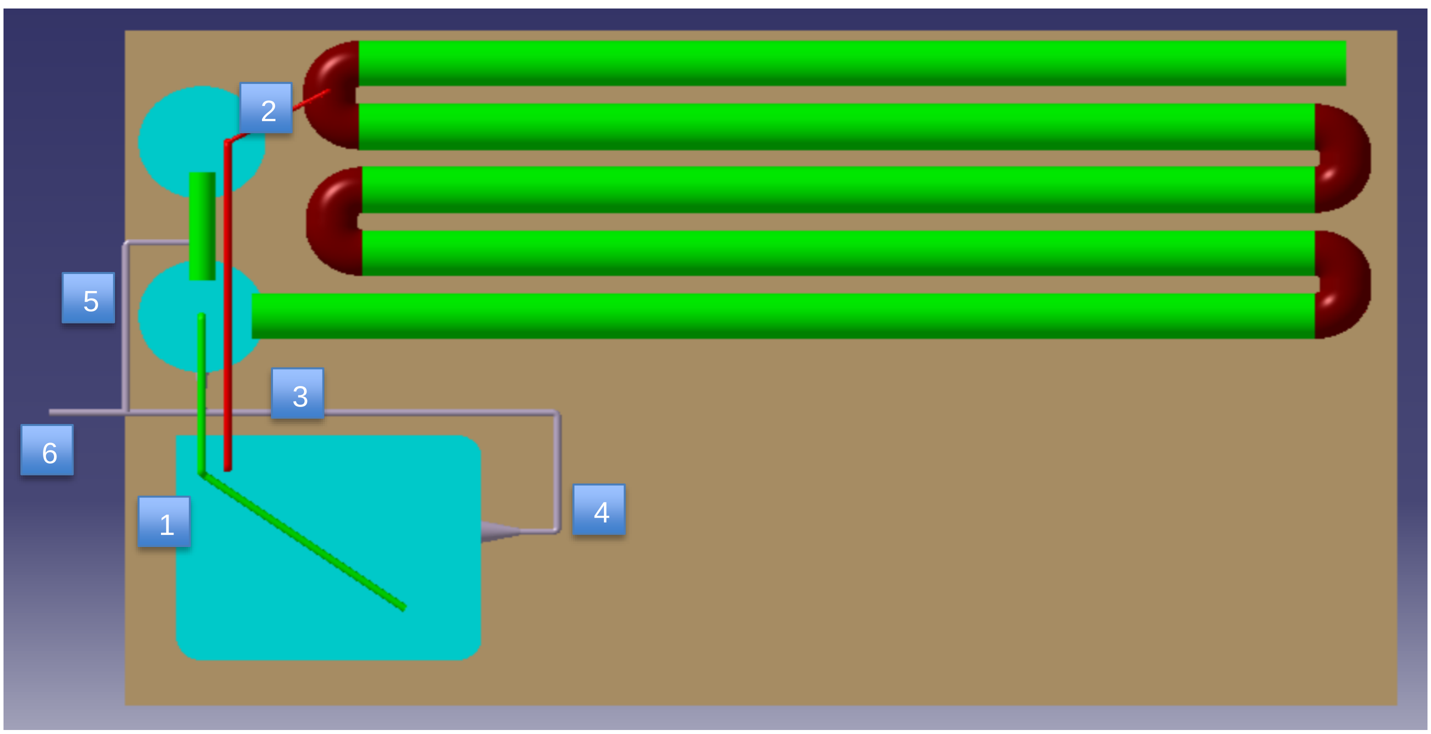


Figure 3.6 flow rate pipe diameters.

1. Fishes water to MF 15mm PVC pipe
2. BF to plants 15mm
3. From MF to fish's tank (25 mm)
4. PVC pipe to waste
5. PVC pipe to waste
6. PVC pipe to waste(15mm

`

For water flow rate of fish tank applying to figure

Applying to equation number 2 we got table of pressure and velocity

$$p_1 + \frac{1}{2}\rho v_1^2 + \gamma h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \gamma h_2$$

p1 equal the pressure inside the tank

p2 for the pressure at the waste valve fish water

simplify the equation (2) to

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

So, by calculation Z1=Z2, P2=zero opened to surface, V1= zero.

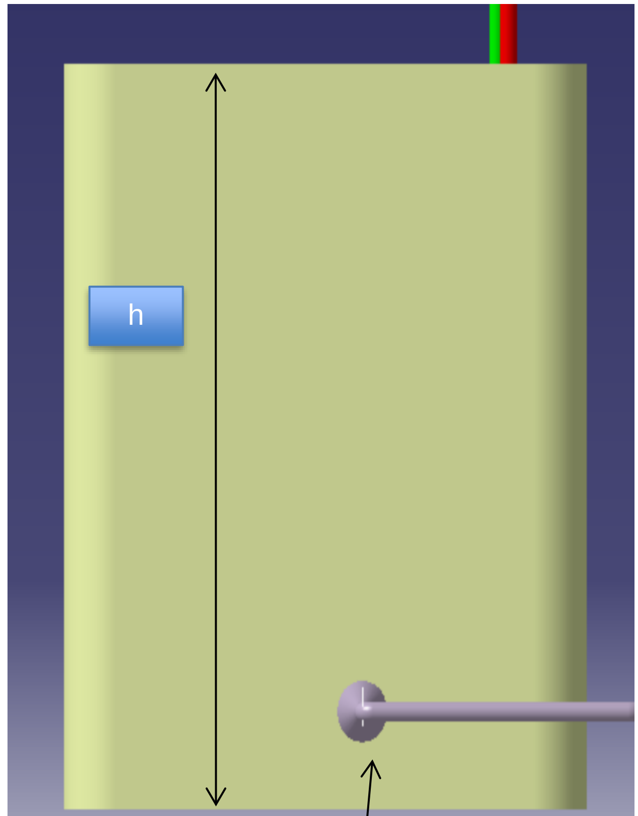


Figure 3.7 fish tank

Table 3.1 shows the high and pressure parameter of the fish tank.

	Pipe diameter (mm)	**15**		
	Density (Kg/m3)	998.2		
	Specific weight γ (KN/m3)	9.78		
Pressure(a) (Kpa)	Depth h (m)	Velocity (2) (m/s) Velocity exits the tank	Flow rate(m3/h)	Flow rate(L/h)
0	0	0	0	0
1.956	0.2	1.979660147	1.258766904	1258.766904
3.912	0.4	2.799662229	1.780165228	1780.165228
5.868	0.6	3.428871956	2.180248233	2180.248233
6.846	0.7	3.703605006	2.354937243	2354.937243
7.824	0.8	3.959320294	2.517533809	2517.533809

$$P = p1 + \gamma h$$

$$V = \sqrt{\frac{2P}{\rho}}$$

9.78	1	4.426654661	2.814688366	2814.688366

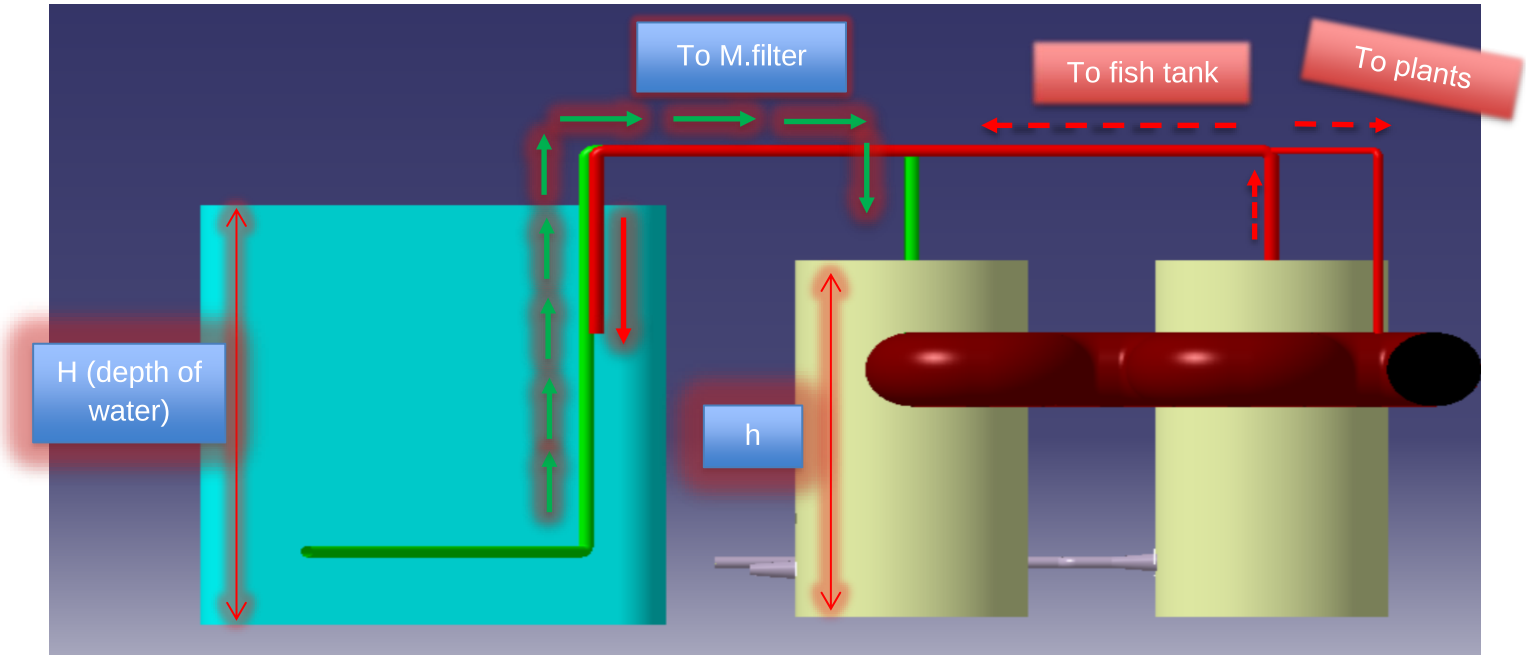


Figure 3.8 calculation fish water tank to view the flow water from fish tank to filters

Table 3.2 shows velocity and flow rates of the water gravity moving from fish tank to mechanical filter.

	gravity (m/s^2)	9.8		
	pipe diameter (mm)	15		
	Density (Kg/m3)	998.2		
	Specific weight (KN/m3)	9.78		
	h (m)	0.6		
Pressure(a) (Kpa)	Depth h (m) water into fish tank	Velocity (2) (m/s) For water goes from fish tank to filter by gravity	flow rate(m3/h)	flow rate(L/h)
5.868	0.6	0	0	0
6.846	0.7	0.98	0.623133	623.133
7.824	0.8	1.96	1.246266	1246.266
9.78	1	3.92	2.492532	2492.532

$$P = p1 + \gamma h$$

$$V = \sqrt{2g(H - h)}$$

Note: negative sign means, there is no flow rate accepted by the gravity and there is no moving water from fish tank side to another side, we recommended to rise up the fish tank to accept the gravity more range for moving water from gravity acceleration.

3. Pipe flow rate calculation

By water flow dynamic according to fundamental and principle of fluid text book ((MUNSON 2009) shows two types of water flow dynamic 1st series water flow, 2nd parallel water flow and we used the second type of water flow in order to achieve the best result of flowing the water.

Water flow in = water flow out -----------------------------(1)

Q1=Q2+Q3 --(2)

$A_1V_1 = A_2V_2 + A_3V_3$

where: A: area of the pipe = πr^2 mm^2

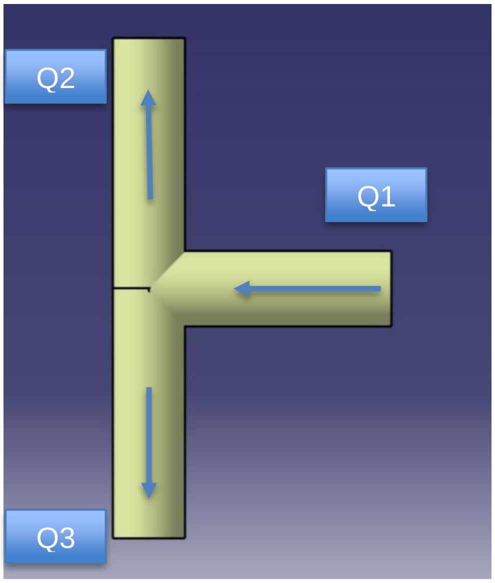


Figure 3.9 T connection to parallel flow rate

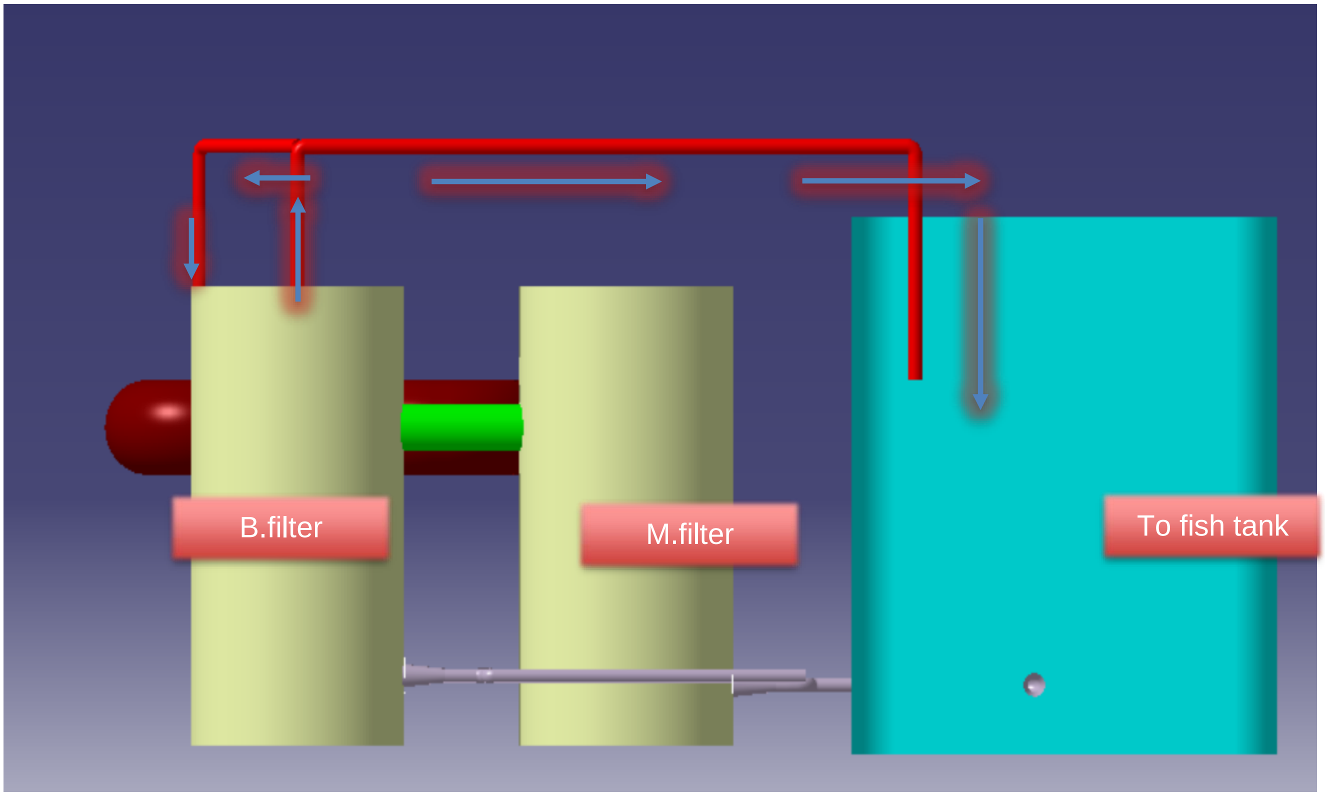


Figure 3.10 water flow pump from biological filter

We used water pump with 2100l/h and max high is 2 from biological filter through plants and through with tank with electrical water valve to control the flow loop, we can calculate the flow rate by the previous law, $A_1V_1 = A_2V_2 + A_3V_3$ by d=15mm and Q1=2100l/h (recommended pump used in our project).

4. Water flow system

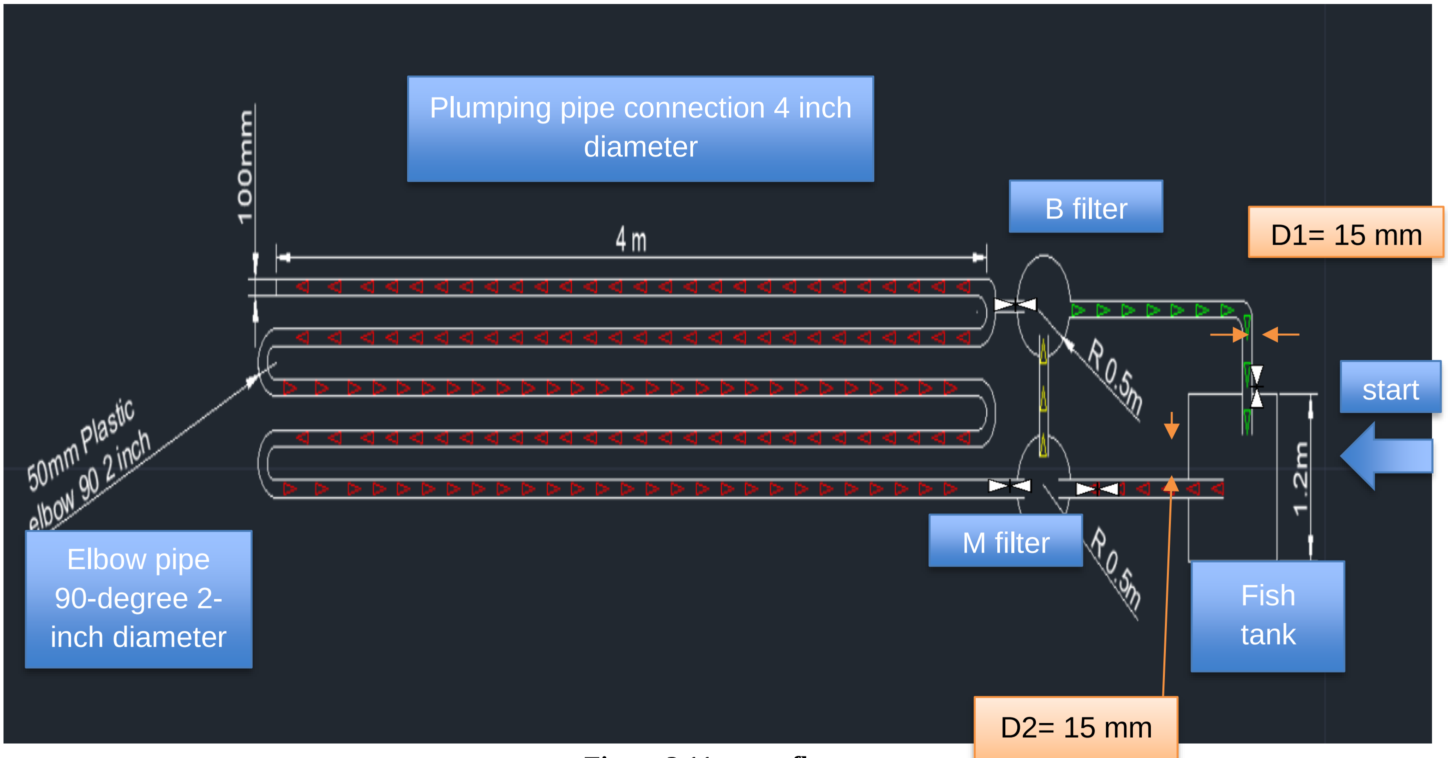


Figure 3.11 water flow system

⋈ : is flow control valve with water flow meter

Figure above explained system motion from the add point of water until plants absorb water and get new fresh water to complete the fish life and save fishes life that's all system must be control.

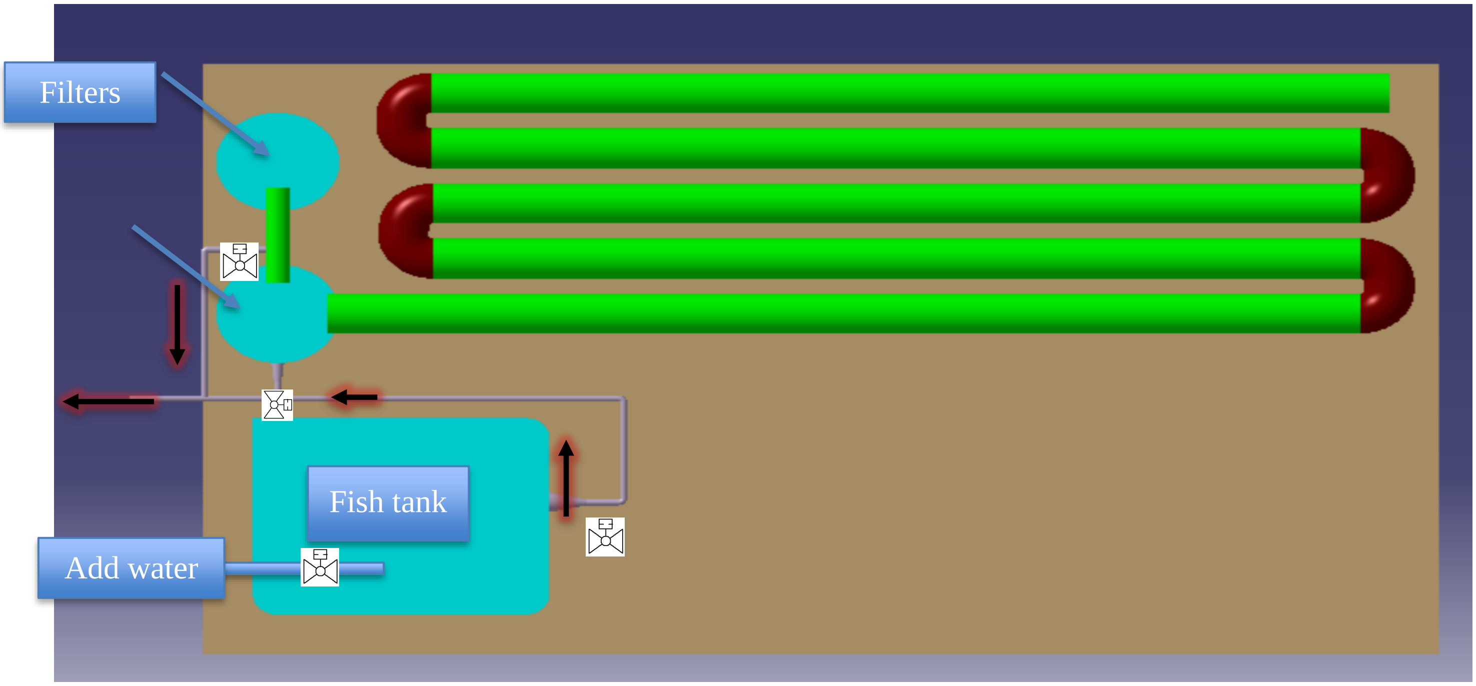


Figure 3.12 shows controlling valves position's part 1

Important notes about the last figure above; pH value is described before in chapter 3 and it's measured by the sensors in aquaculture part and biological part and hydroponic part, however every place its explained system action, so for the first part of aquaculture the value must be between 9 and 5, if the value is more 9 its need to open water inter the aquaculture part, and open water to leave the aquaculture part, however water flow rate added in aquaculture part is constant and its 193 l/h in our recommended project and for water leaves the tank to earth and waste is based of table above necessary for the depth water level and its max flow rate is 2200l/h its must close the waste valve when its water level is so low while it's no needed to exit all fish water if there is changing in pH level by adding water its mixed together and it decreases the high level while its increasing high level of pH to be equitation, moreover water flow rate the two filters is equal and its based of high water level as its pressure is acceleration of gravity multibed by water density and high and who is important to find the velocity based of pressure and finally find flow rate based of velocity have calculated.

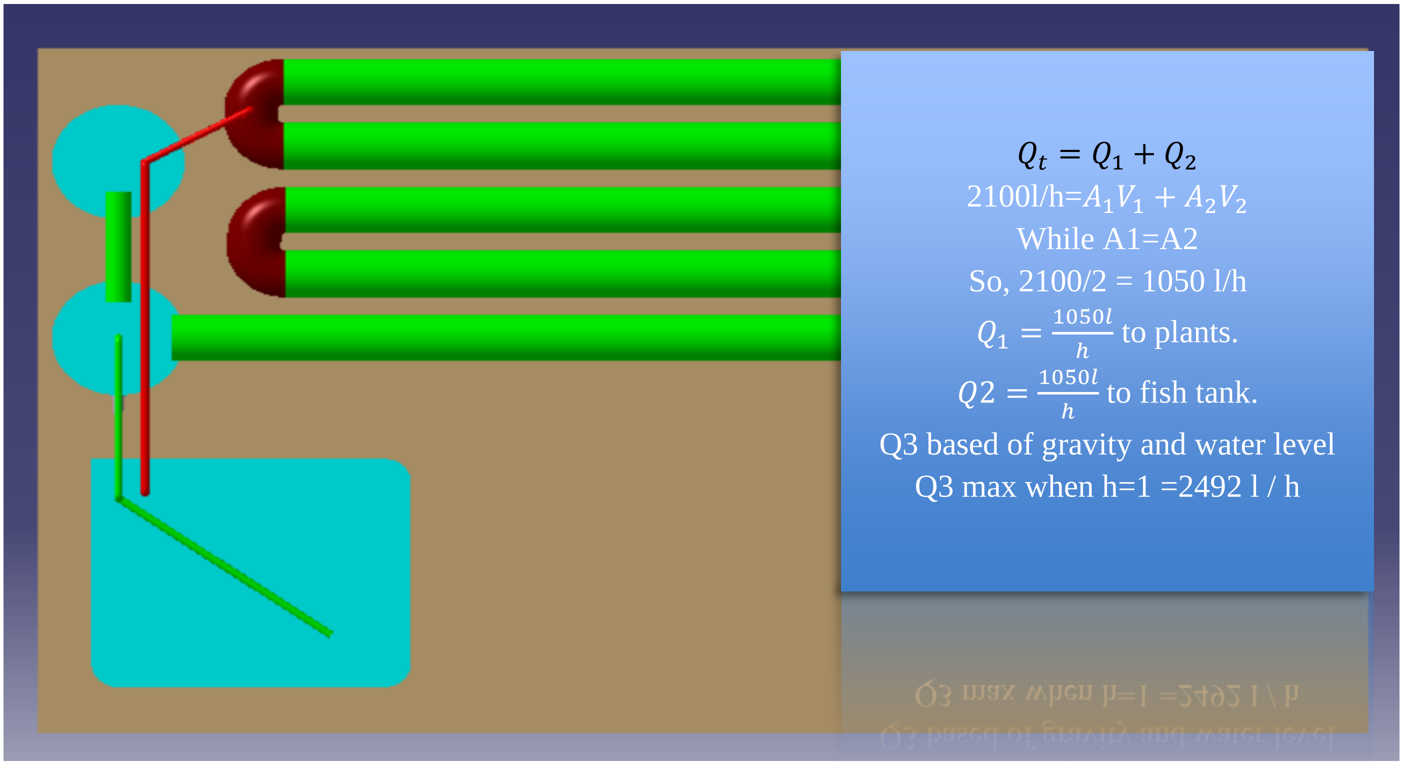


Figure 3.13 shows controlling valves position's part 2

Note, we assume the valve will fully open and that's mean flow rate enter = flow rate out for the singe valve open, for the double valve it should open and closed as needed for example when we don't need water more than PVC volume water size and we recommended to not waste water as much as possible to not west water for nothing without benefits so its better to close the water valve electronically as its connected with water flow meter and the recommended to enter water as needed to plants (hydroponic side), and its better to let water enter the fish tank if there is no needed to enter in hydroponic side.

About the loss in pipe its much calculation is based as following

Q1= 1050l/h= $2.916 * 10^{-4} \frac{m^3}{s}$

T1=20 C

$\gamma = 9.789\, {kN}/{m^3}$; specific weight

$\mu = 1.002 * 10^{-3}\, {Ns}/{m^2}$; dynamic viscosity

$v = 1.004 * 10^{-6}\, {m^2}/{s}$; kinematic viscosity

$h_l = F \frac{L}{D} \frac{V^2}{g}$; minor loss

$h_m = \sum k \frac{V^2}{2g}$; major loss

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 + h_p = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_l + h_m$$

Where:

F; is friction factor

L: pipe length

D: pipe diameter

V: velocity

G: gravity acceleration

K: loss coefficie

Renolds number = $Re = {}^{VD}/_{v} = 1.84 * 10^5$ mean turbulent flow

F=0.0152

Applying to Bernoulli equation we got:

$h_p = h_l + h_m$

$h_m = 0.065m$

$h_l = 0.66$

5. Nitrites plants solution addition of the hydroponic part

In this section is also recommended supporting the aquaculture nutrition comes from the fish, moreover, fish water completely has half plants nutritious but it can't growth all plants with all nutritious component that the plants needed and to let plants grow successfully by adding new plants nutrition as the hydroponic way by the plant's solutions, but it's so important method should not let plants water to fish try again, meaning if you use hydroponic solutions to support the plants that are not recommended to let water goes as cycle try again to fishes, meaning we have to close the cycle if you add any solution to the plants, there so toxic to fishes if you return the hydroponic solution to the fishes try again, however, a lot of fishes will get died because they live in water has a hydroponic solution and the hydroponic solution is so toxic to fishes, so we as project team recommended to use two method, the first method is supply the fish water to the plants at the beginning after one weak that's needed to add hydroponic solution to support the plant growth and completely get all agriculture parameters to support the solution to be safe and successful improving the plants and get all plants nutrients that needed for several kind of plants type, so figure below shows how you have to control the farm if you see that's fishes water solution is not enough to complete the plants growth, we recommended to add nnutrients support the plants agriculture parameters and at the next chapter we will show figures to support your thinking of hydrobromic solutions.

So as described of the definition before, its so important to know these solutions and to make this addition to the plants system, below figure explained how to control a system using both aquaponic and hydroponic together to achieve the best result of doing the plants and safety and successful growth of both fishes and plants without leak of any components and that's the most important case let us as team using this method.

Several important factors have to be considered when choosing fertilizers and preparing a hydroponic nutrient solution: according (smart-fertilizer web site, 2020).

1. Water quality – salinity, concentration of potential harmful elements
2. Required nutrients and their concentrations in the hydroponic nutrient solution in contact with aquaponic solution and achieve the save result for both plants and aquaculture to support nutrient balance and its so important point
3. pH value controlling by hydroponic solution and aquaponic solution.

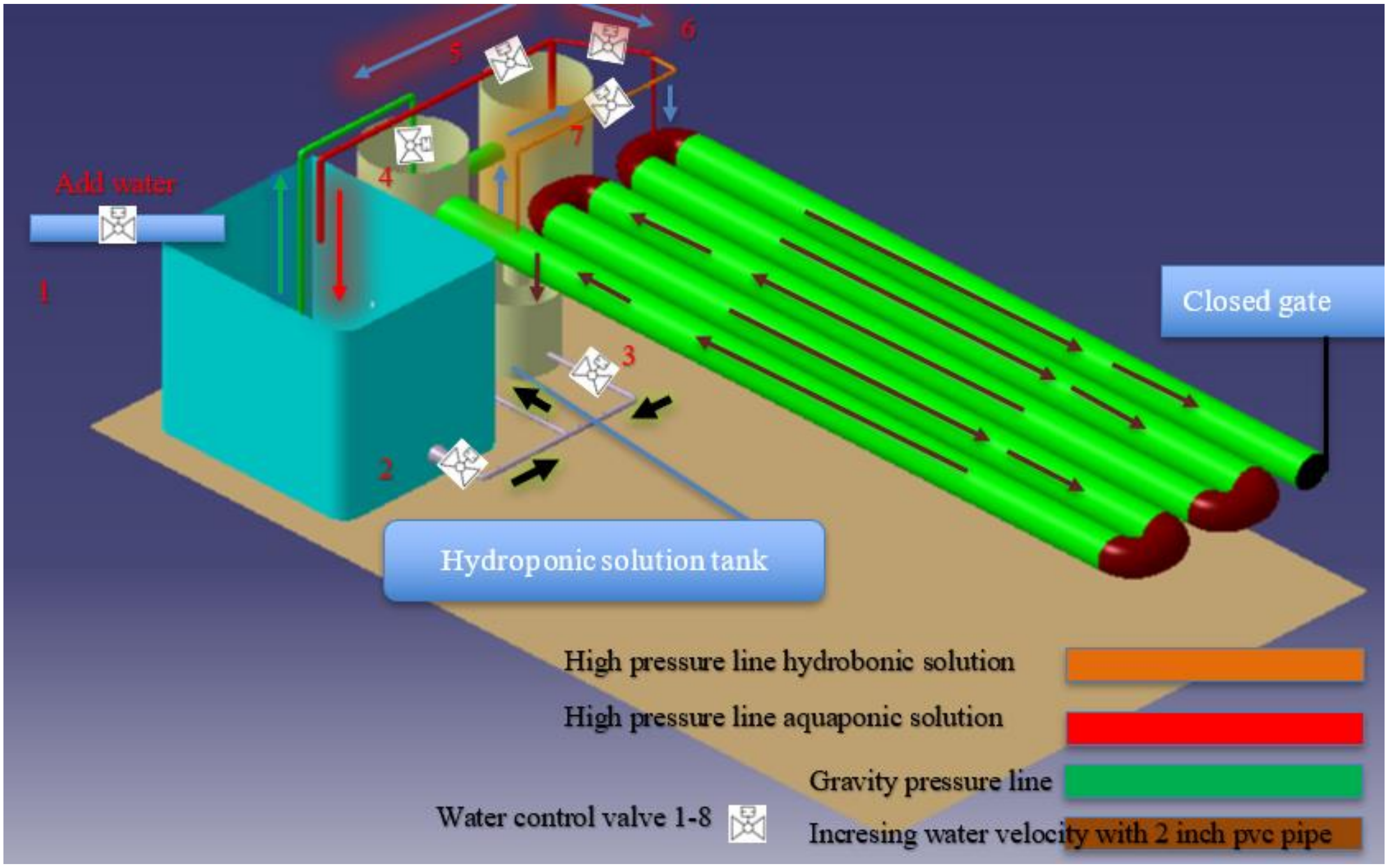


Figure 3.14 explained the hydroponic tank with all fluid motion directions with water controller's valves.

photos above discuss the liquid motion in comparison with two kinds of system, first system completely follows the fish water motion and the second system discusses the hydroponic liquid motion by its all aim is to integrate the benefits for both fishes and plants together in contrast with making any toxic level of water to both fishes and plants and to not be able to kill any of this we have to design the previous figure with the high sensitive controller of liquid motions and level while the hydroponic tank solution must not be less than 200 letters to accept all water liters in PVC pipe when using.

6. Motion study analysis

Motion analysis are the calculation of mechanical engineering definitions, and its identified as Motion analysis provides engineering simulation from a different angle. When the motion of a system is complicated (driving simulator), motion analysis can provide information on velocity, acceleration, reaction force of the moving components (TRIVISTA web site), so here is the components of the parts used to apply our project.

A) Valve assembly

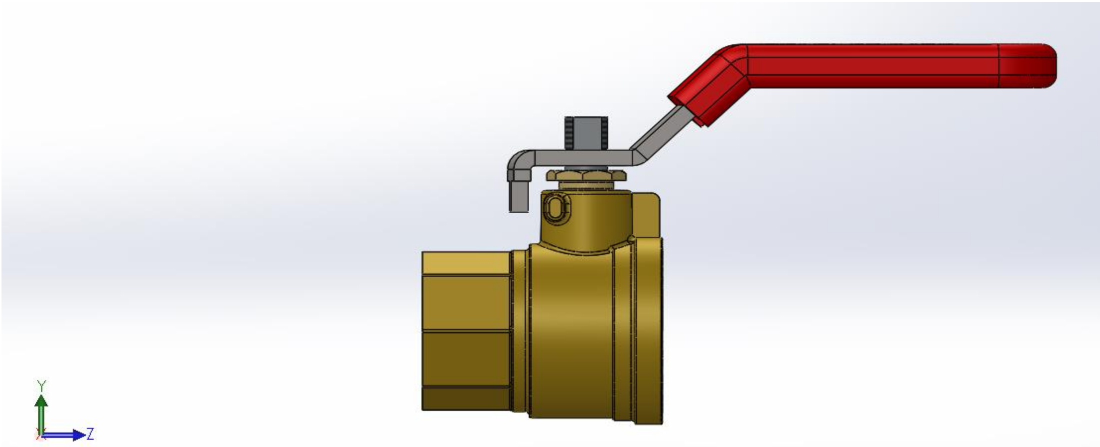


Figure: Valve assembly using SolidWorks program.

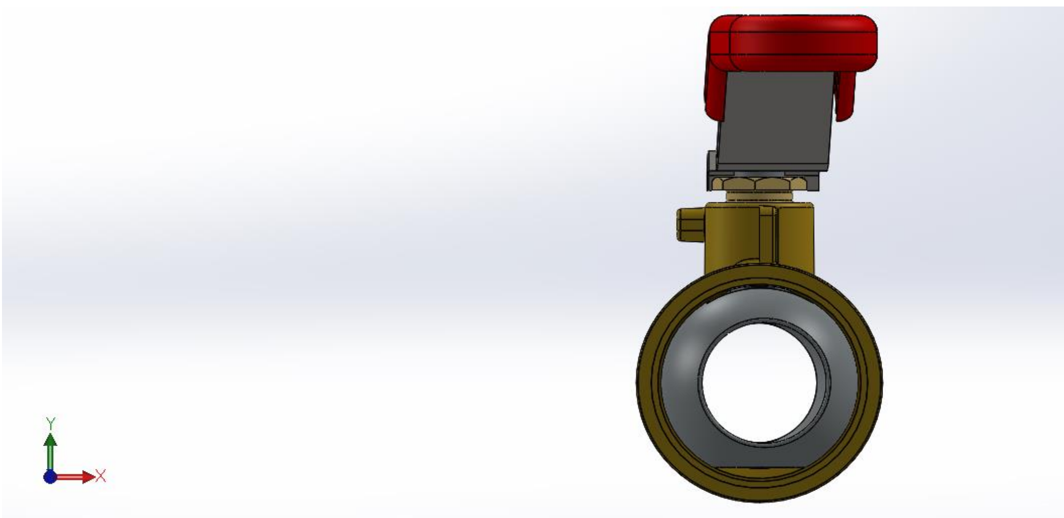


Figure: Valve assembly using SolidWorks program.

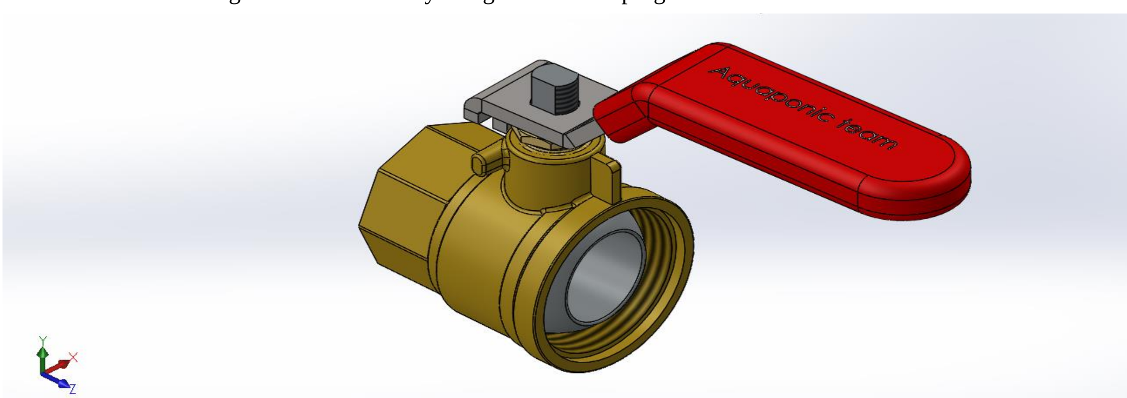


Figure: Valve assembly using SolidWorks program.

B) Valve motion analysis.

Explaining the basic calculation for valve assembly related to the Mechanical engineering, so at the beginning we will explain the torque required to open and close the valve, motor power and speed needed, and the displacements, velocity, and acceleration analysis for its motion, angular displacement, velocity and acceleration, related to their equations.

B.1) Displacement, velocity and acceleration calculation:

$V(velocity) = \frac{dR}{dt} \rightarrow \Delta R = \int vdt$ (area under curve v)---1

$a(acceleration) = \frac{dv}{dt} \rightarrow \Delta v = \int adt$ (area under curve a)--2

Total displacement = ΔR

Acceleration time = Deceleration time: $\Delta t = t_a + t_d$

Let us apply Equations (1) and (2) to triangular motion profile shown below

Equation (2): $v_{peak} = a * t_a$--(a)

Equation (1): $\Delta R = \frac{1}{2}(t_a + t_d) * v_{peak}$--(b)

From the definition of the triangular profile, the acceleration time is equal to the deceleration time

$$t_a = t_b = \frac{\Delta t}{2}$$

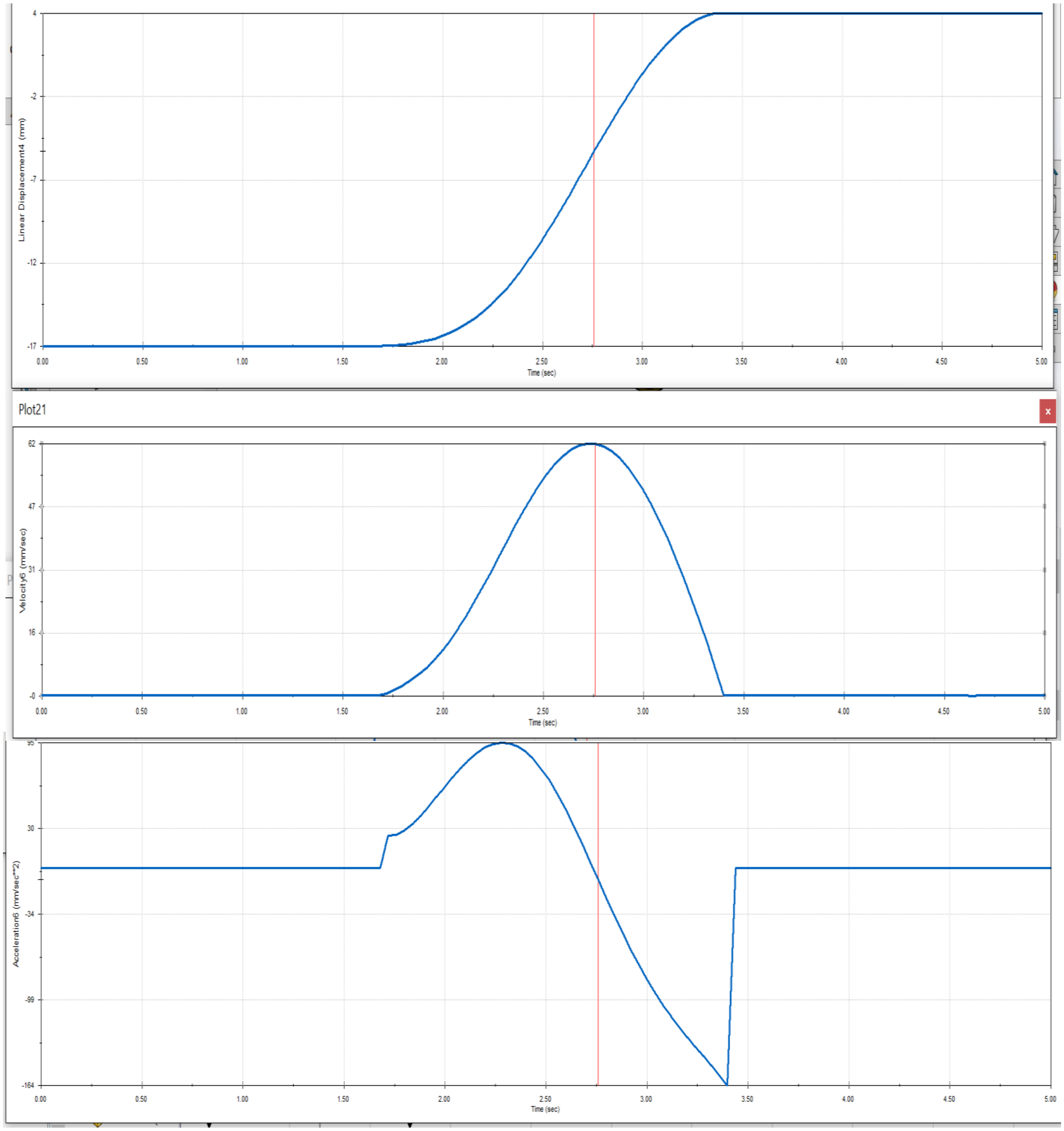
Now, Equations (a and b) can be rewritten as

Equation (a): $v_{peak} = a\frac{\Delta t}{2} \rightarrow a = 2\frac{v_{peak}}{\Delta t}$--(a1)

Equation(b): $\Delta R = \frac{1}{2}(\Delta t)v_{peak} \rightarrow v_{peak} = 2\frac{\Delta R}{(\Delta t)^2}$---(b1)

next will see the profiles for displacement, velocity, acceleration.

Tables Displacement, Velocity, and acceleration explanation curves, shows the Water valve motion.



Calculation above based of torque required to open and close the valve and motor speed and motor power required to do the job.

The force applied to a valve from a fish tank, when the water depth is 1 meter in our fish tank as menthid before is 9.78 kpa, when we use the diameter of the valve as shown below, we see that area of the water valve is 0.283mm^2

Maximum Pressure = 9.78 kpa

Force = pressure(kpa) * area (mm^2)

Force = 9.78 pa * 0.283 m^2 = 2.771 N

Torque required to open the valve is

$$T_r = \frac{Fd_m}{2}\frac{(l + \pi f d_m)}{(\pi d_m - fl)}$$

T_r: *is the torque reqired to open the valve.*

F: *the force applied on the valve*

d_m: *mean diameter of the screw teeth.*

l: lead distance =P*m= 0.7 mm when m=1

f: *fraction cofficient.*

P: $pith = 1/N$ N: number of teeth

our used project screw is $= M4 * 0.7$

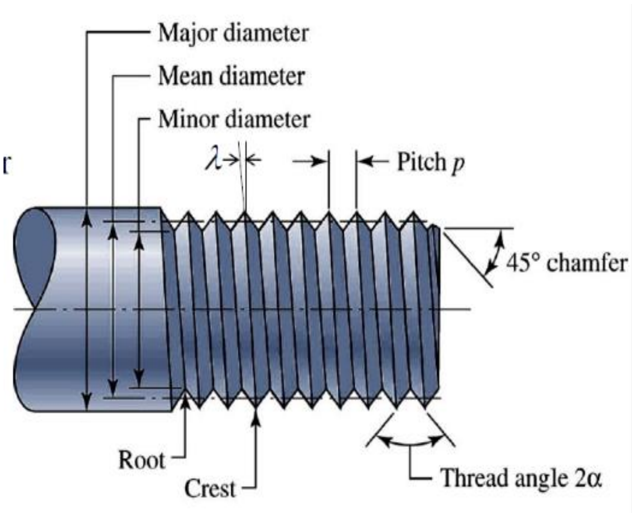


Figure: screw explanation.

Pitch= P =0.7 mm

Major diameter = d = 4mm

Thread depth = P/2 = 0.7/2 = 0.35 mm

$$d_m = d - {}^{p}/_{2} = 4mm - 0.35mm = 3.75mm$$

Now, torque required to close the valve is

$$T_r = \frac{Fd_m}{2}\frac{(l + \pi f d_m)}{(\pi d_m - fl)}$$

$$T_r = \frac{2.771N * 3.57mm}{2}\frac{(0.7mm + \pi 0.16 * 3.75mm)}{(\pi 3.75mm - 0.16 * 0.7mm)} = 1.15\ N.mm$$

The torque required to open the valve is

$$T_l = \frac{Fd_m}{2}\frac{(\pi f d_m - l)}{(\pi d_m + fl)}$$

$$T_l = \frac{2.771N * 3.75\ mm}{2}\frac{(\pi * 0.13 * 3.75mm - 0.7)}{(\pi * 3.75mm + 0.13 * 0.7mm)} = 0.517\ N.mm$$

Motor speed recommended to select is 20 rpm

Power (KW)=$torque\ (N.M) * speed\ (RPM)/9.5488$

Power (w) = $\frac{1.15*20}{9.5488} = 22\ watt$

B.2) Angular velocity and angular acceleration calculation:

Angular velocity(rad/s) is the rate of velocity at which an object or a particle is rotating around a center or a specific point in a given time period according to (toppr web site, www.toppr.com)

$$w = \frac{\Delta\theta}{\Delta t}$$

For an object rotating about an axis every point on the object has the same angular velocity,

$$w = \frac{v}{r}$$

Angular Acceleration(rad/s^2): When an object follows a rotational path, it is said to move in an angular motion or the commonly known rotational motion. In the course of such motion, the velocity of the object is always changing. Velocity being a vector involves a movement of an object with the speed that has direction. Now, since in a rotational motion, the particles tend to follow a circular path their direction at every point changes constantly. This change results in a change in velocity. This change in velocity with time gives us the acceleration of that object. according to (toppr webite,www.toppr.com)

$$\alpha = \frac{\Delta\theta}{\Delta t}$$

While the displacement is:

$$s = v_i t + \frac{1}{2}at^2$$

The angular displacement is:

$$\theta = w_i t + \frac{1}{2}\alpha t^2$$

Next page you will see the relationship of angular velocity and acceleration for the open and close water valve, so they explained as the completing of motion analysis for the aquaponic project, which is needed to setup the control, moreover close and open on real time.

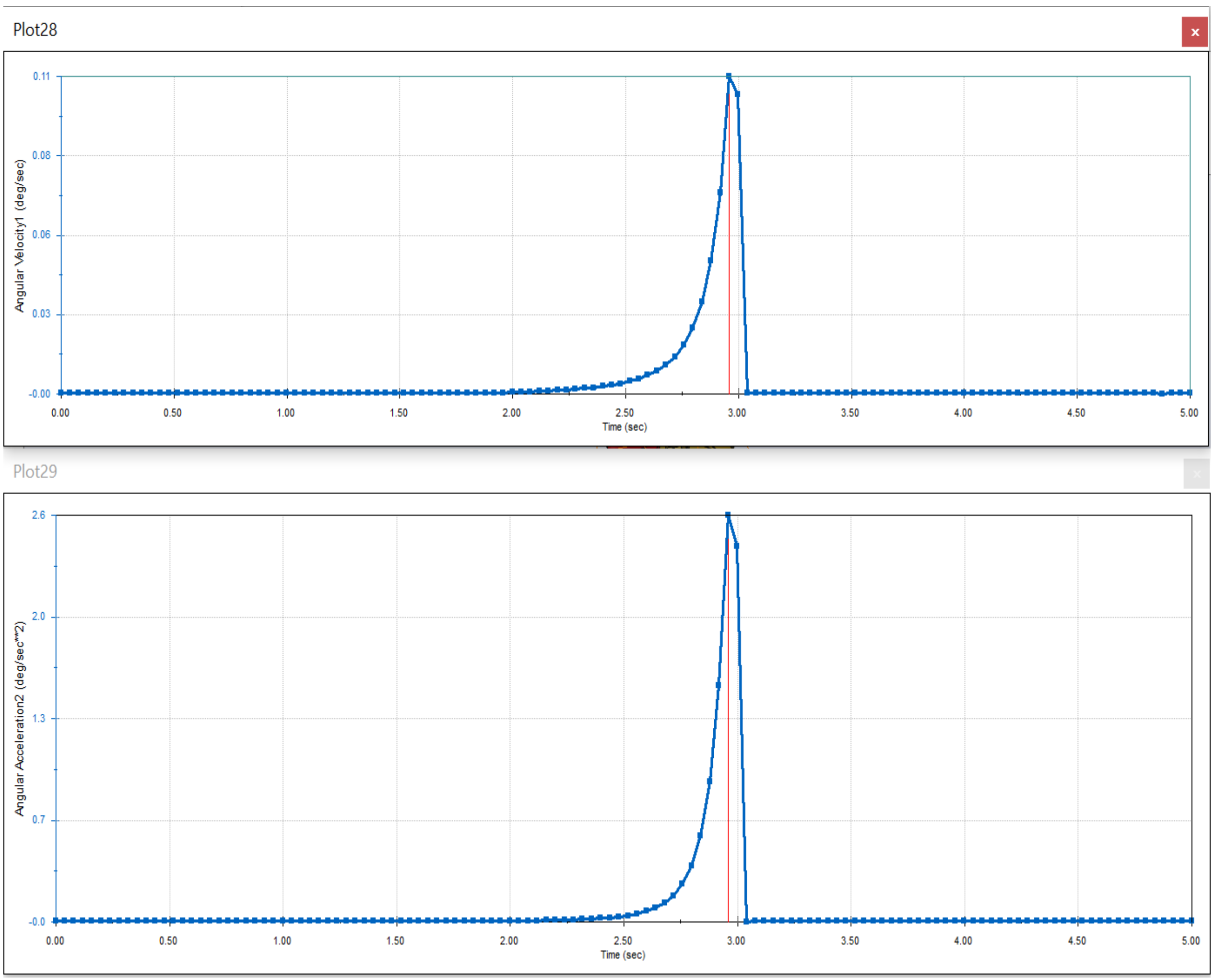


Figure: Explained the relationship between the angular velocity, acceleration during the motion period

B.3) Angular momentum calculation:

Angular momentum is a vector quantity, requiring the specification of both a magnitude and a direction for its complete description. The magnitude of the angular momentum of an orbiting object is equal to its linear momentum (product of its mass m and linear velocity v) times the perpendicular distance r from the center of rotation to a line drawn in the direction of its instantaneous motion and passing through the object's center of gravity, or simply m*r.

Angular Momentum = momentum of inertia * Angular velocity

$$L = I * \omega$$

Linar Momentum = Mass * Velocity

$$p = m * v$$

$$F\Delta t = m\Delta v = \Delta p = impulse$$

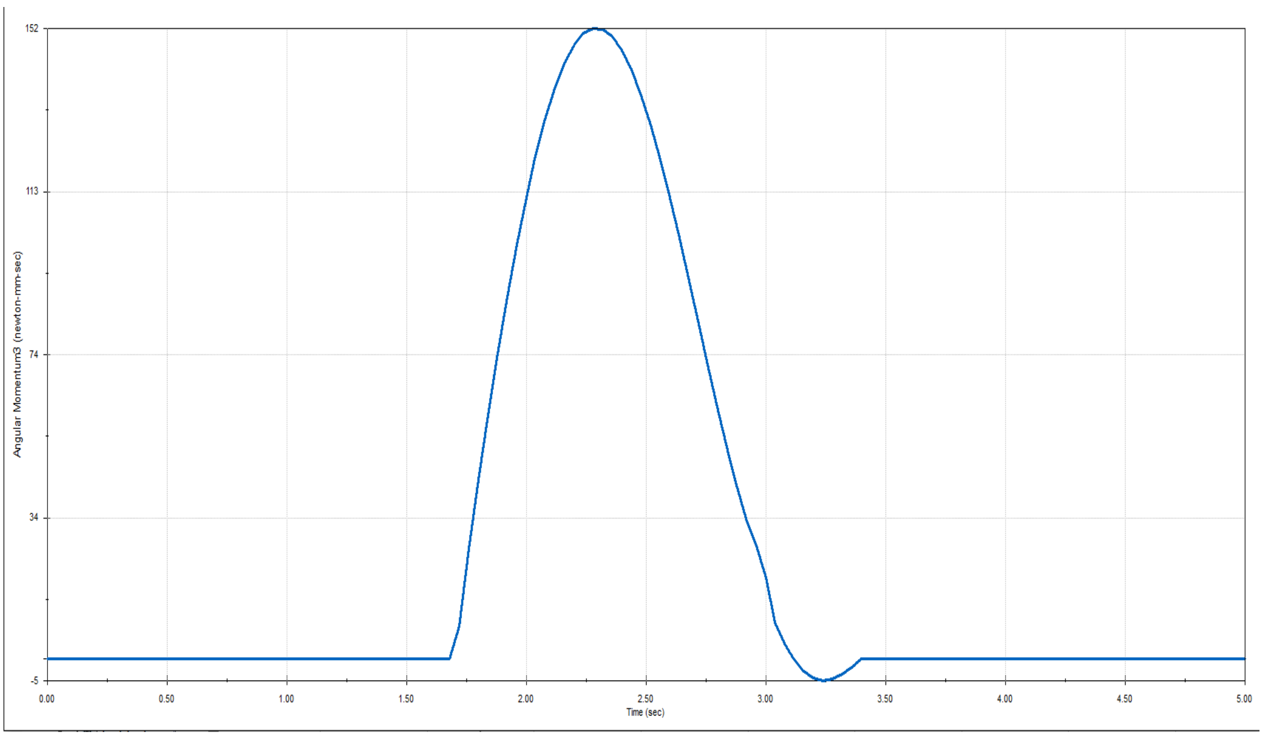


Figure: explaining the angular momentum of the water valve motion.

B.4) Pump water calculation:

A pump Is a mechanical basic tool, but its important device that supplies the force to move the fluid at a specific flow rate.

To show this equation below to calculate the water pump horse power according to the Bernoulli equation as mentioned before

$$\boldsymbol{\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 + h_p = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_l + h_m} \; ($$

Water horsepower = minimum power required to run water pump

TDH = Total Dynamic Head = Vertical distance liquid travels (in feet) + friction loss from pipe

Q = flow rate of liquid in gallons per minute

SG = specific gravity of liquid (this equals 1 if you are pumping water).

Water horsepower = $\frac{TDH*Q*SG}{3960}$. (wikiHow web site)

Actual power required = (water horsepower) / (pump efficiency).

We used a pump with parameters are Q max output = 3500L/h, and power input = 15 W and H max head = 2.5 m. according to models of pumps parameters catalog. (www.playitkoi.com)

2. System Cycle design with IoT Technique Solution

- **In this section we will explain how to use internet of things technique as a solution to facilitate the process of monitoring aquaponic system parameters that is most important to achieve a best production from the plants in hydroponic part and to preserving the life of fish in aquaculture part**

  In this section we will explain and provide an overview about general design of the system cycle and distribution of the main components and parameters and its sensors. We want to point out that this design is standard, and are modifiable according to many variables in the general framework of the project.

  The following figure shows the system main components and how the system cycle will be done in a suitable path, to achieve the greatest benefit from this design.

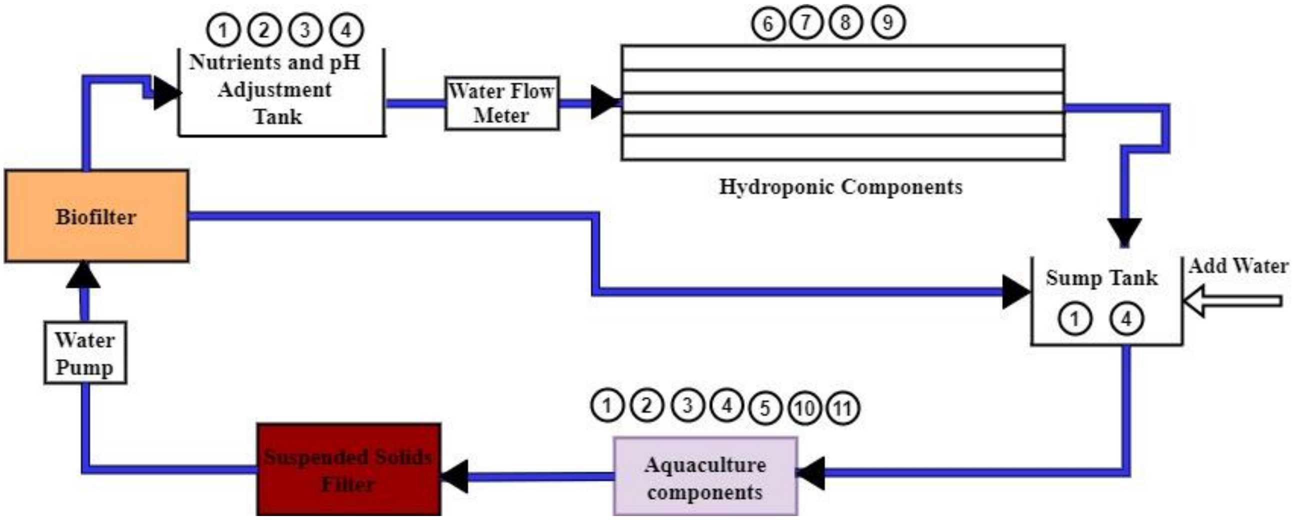


Figure 3.15: System Water Cycle and Component

Note: All Circled number on previous figure show recommended distribution of sensors in each part of the system to get the best control and monitoring.

In this design, we adopted a decoupled aquaponic system, explained in chapter two, which involves two water cycles, to get more control and monitor of each system part, and adjustment each part with each appropriate parameters to get equilibrium in the system.

Where the circled numbers in the figure (Figure 28), shows the distribution of system parameters and sensor's locations, where**:**

1. **pH sensor.**
2. **Water Temperature Sensor**
3. **Dissolved Oxygen Sensor.**
4. **Total Dissolved Solids Sensors (TDS).**
5. **Water Level Sensor in The Fish Tank.**
6. **Air Temperature Sensor.**
7. **Humidity Sensor.**
8. **Plant Height Sensor.**
9. **Camera (Monitoring Growth health of Plants).**
10. **Feed Control Device.**
11. **Water buoy. (Controlled by an Ultrasonic Sensor).**

3. System Setup Requirements

In this Section we will determine all requirements and to set up the system and types of sensors that will be used, and their functions and specification. These requirements can be classified into the following**:**

❖ Aquaculture and hydroponic requirements

- Fish aquarium.
- Suspended solids filter.
- Biological filter.
- Nutrient and pH adjustment tank
- Sump Tank.
- PVC Pipes.
- Agricultural greenhouse to build hydroponic part inside it.
- A suitable place to build a project.

❖ Computer based requirements:-

A. Hardware Requirements

1. Arduino and Raspberry Pi Controllers
2. Atlas Scientific EZO-DO Dissolved Oxygen Sensor.
3. Atlas Scientific EZO-EC Embedded Conductivity

   This sensor includes the following parameters**:**

   - **Electrical Conductivity (EC).**
   - **Salinity (SL).**
   - **Total Dissolved Solids (TDS).**

4. **DS18B20 Temperature Sensor:** To measure the water temperature.
5. **DIGITEN Water Flow Control Meter:** To control the flow of water in the hydroponic system.
6. **Atlas Scientific EZO-pH Embedded pH Circuit .001-14:** Read pH concentration in the water.
7. **Atlas Scientific EZO-pH Embedded pH Circuit .001-14:** Read pH concentration in the water.

B. Software Requirements

1. **Cayenne Internet of things Platform:** Include Online control and monitoring dashboard, and with android application connected to the system, we will show how this part works in the next section.
2. **Programming libraries for each sensor.**
3. **Internet connection:** For remote monitoring.
4. **Wireless IP Camera:** To monitor health of plants or fish.

4. System HW Components Design

After building aquaponic system main components that include aquaculture, hydroponic, and filtration components, we need to implement electrical components that connect all monitoring sensors and actuators of the system with each other.

The following figure shows a block diagram of the electronic components design, that form a basis of the autonomous and smart system setup.

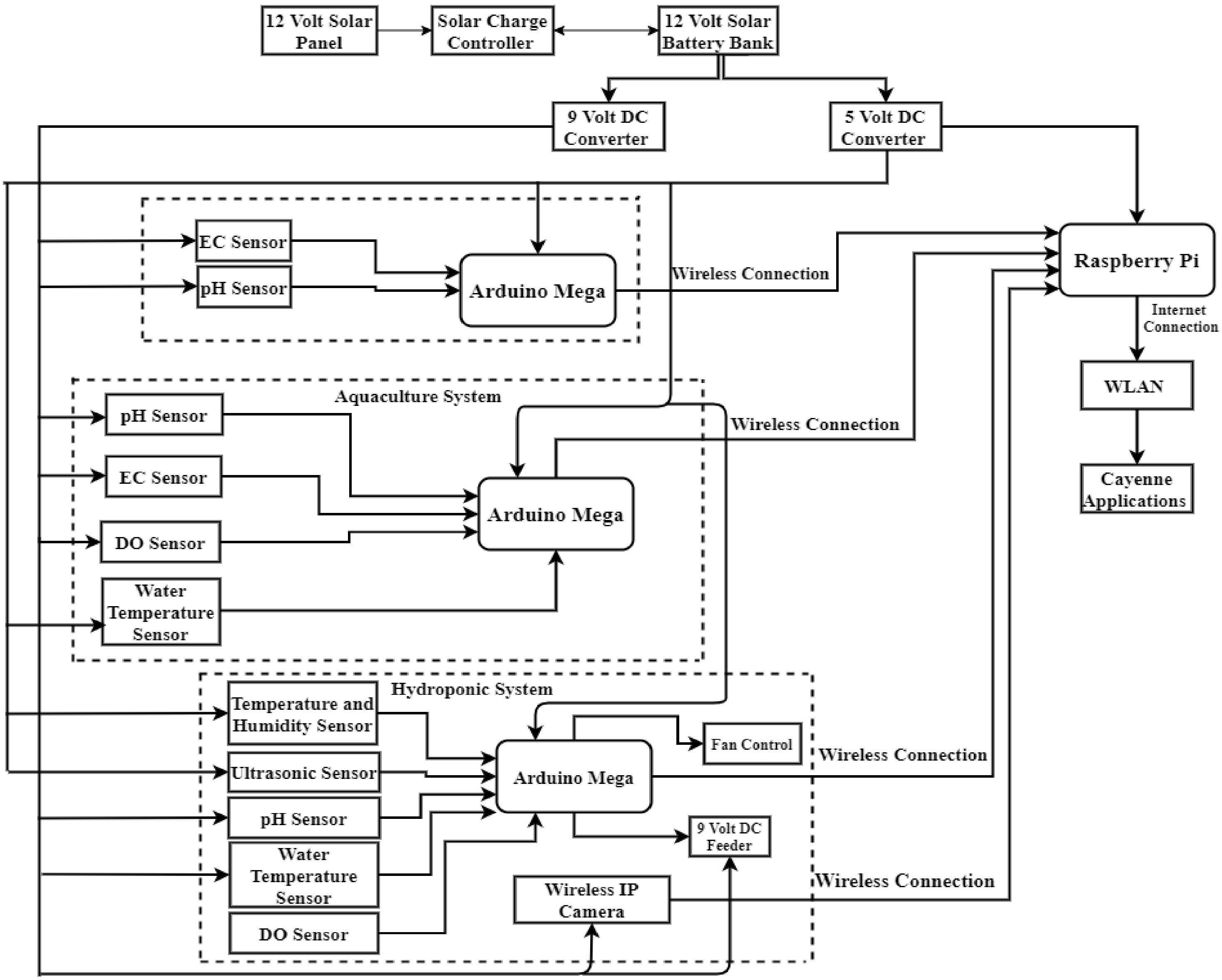


Figure 3.16: Block Diagram of IoT Technique

5. Internet of Things Techniques Implementation

In chapter two we talked about the internet of things techniques and its application. One of the main goals in our project is exploiting internet of things technology to build a remote smart autonomous aquaponic system that makes monitors, controls and performs all actions needed in real time, without a user intervention.

In this section we will talking about how to implement the internet of things technique in our project. And what is the internet of things application we will use in our project.

5.1 Blynk IoT Platform

Cayenne is an online IoT dashboard that takes most of the complication out of creating hardware-oriented programming. Originally it worked with just the Raspberry Pi. Now it is
available for the Arduino as well**.**

Blynk is a drag-and-drop programming system for the IoT that really does make it much easier. It not only makes it possible to build programs using drag-and-drop, it standardizes the connection of devices such as sensors and motors and makes sure that drivers are in place. In this sense it makes the programming and the hardware much easier**.**

All you have to do is install the Blynk agent using the web site. The Arduino needs to have an Internet connection - after all this is the Internet of Things - and this means either an Ethernet or Wi-Fi shield. You also need the Arduino IDE setup on a PC or Mac connected to the Arduino by USB, but this is fairly standard. All of the standard Arduino models are supported, including the more recent ones**.**

- **MQTT-Broker**
  The broker is primarily responsible for receiving all messages, filtering the messages, deciding who is interested in them and then publishing the message to all subscribed clients**.**

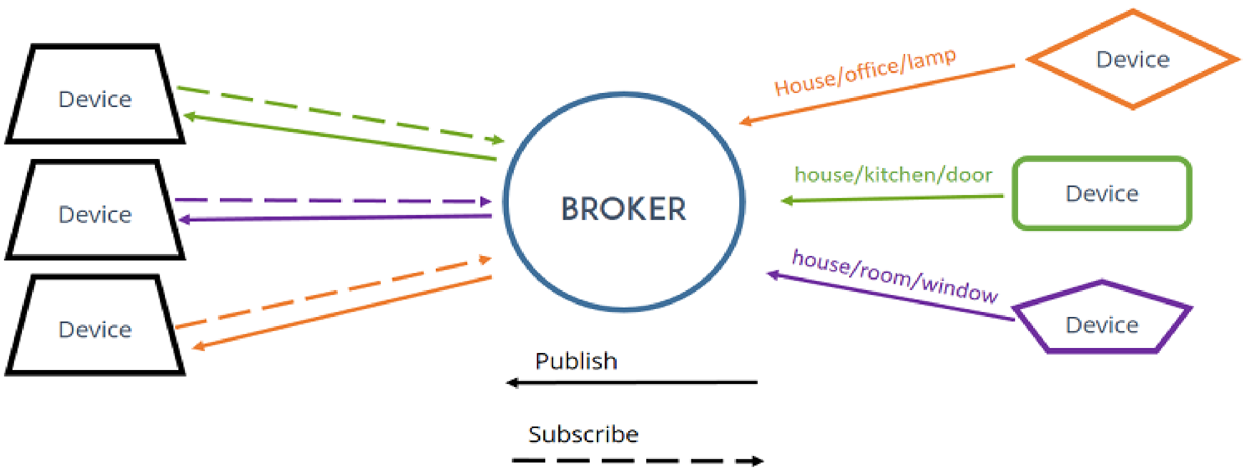


Figure 3.17: MQTT-Broker Overview (randomnerdtutorials.com)

Once the Blynk agent is installed you can interact with it via the mobile app or the website. Using the dashboard you can monitor and configure the device, but more importantly you can install sensors.

Arduino or raspberry pi program that handles the communication between the sensor and the dashboard. In most cases this is just a matter of selecting one of the example scripts, but there is nothing stopping you from going further and writing or customizing your own.

- **How cayenne Works**

Cayenne is the world's first drag and drop IoT project builder that empowers developers, designers and engineers to quickly prototype and share their connected device projects. Cayenne was designed to help users create Internet of Things prototypes and then bring them to production. The major component in the platform**:**

Cayenne Online Dashboard – Use customizable widgets to visualize data, set up rules, schedule events and more.

- **What do we need to use this technique?**

- **Hardware:** A Raspberry Pi or Arduino device connected to the Internet, or a LoRa device connected to a public or private gateway. The list of hardware that works with Cayenne will keep growing**.**

- **Sensors:** Cayenne works with temperature, luminosity, pressure/distance, motion and generic sensors connected to your Raspberry Pi devices**.**

- **Actuators:** Cayenne works with light, motor, valve, relay and generic actuators that are connected to your Raspberry Pi devices**.**

We will using these techniques and tools to remote monitoring and controlling in real a time, which all parameters' values will display on the Cayenne dashboard, and ability to control via the same dashboard.

5.2 Wireless Mesh IoT.

A wireless mesh network is made up of two or more wireless radios working together to share routing protocols in order to create an interconnected RF pathway. A wireless mesh network, no matter how many radios it includes, creates only a single name identifier, or Single Set Identifier (SSID) and could also create a single IP address for the entire mesh, clearly distinguishing the mesh from another wireless or mesh network.

We want to use this technology to connect controllers with each other wirelessly in the system, so that each controller can send and receive data and information with other controllers on the same network, and this is in the event that we want to obtain information from more than one place in the system at the same time**.**

And the most important benefit of this technology is the ability to set up a standalone controller, in case of any failure in system components**.**

- ### Mesh Network Architecture

The primary benefit of a wireless mesh network is the extended bandwidth and redundancy. A wireless mesh radio can communicate only with another wireless mesh radios using similar protocols, such as SSID, end-to-end encryption, wireless encryption, etc., but mesh radios, although they may use Wi-Fi chipsets, do not function as wireless

APs and communicate only with other wireless mesh radios in that SSID and mesh ID network. It provides added security at the physical layer, more so than even a wireless camera or AP, which allows any client machine (smartphone, laptop, tablet, etc.) to connect. The following figure shows an overview of mesh networks.

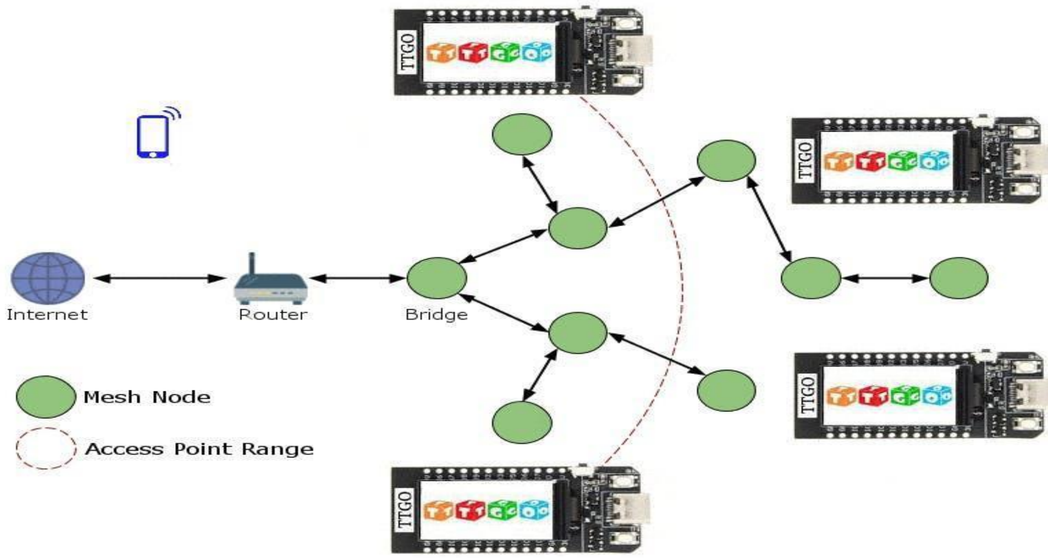


Figure 3.18: Mech Architecture (Hackster.io).

With this technique the nodes don't need to connect to a central node. Nodes are responsible for relaying each other's transmissions. This allows multiple devices to spread over a large physical area. The Nodes can self-organize and dynamically talk to each other to ensure that the packet reaches its final node destination. If any node is removed from the network, it is able to self-organize to make sure that the packets reach their destination.

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Ch 4

Project Implementation

1. Introduction

In this chapter we will implement, review and explain all system parts implementation stages, includes IoT hardware, software, and aquaponic components.

We need to mentioned that when we began the preparation process, we noticed that there are some components are not available in the Palestine market, and some other components are very expensive, so in this chapter, maybe there is some components not used from the block diagram in Ch 3.

2. IoT Hardware & Software Components Used

While we begin the preparation process, we notice that there are some components are not available in the Palestine market, and some other components are very expensive, so in this chapter

Before anything, we have prepared and purchased the required sensors and microcontrollers to build the internet of things architecture, that includes:

1) **Two Analog pH sensors**
2) **Two Digital TDS Sensors:** Measure Total Dissolved Solids in The Water
3) **Digital Water Temperature Sensor (DS18B20)**
4) **DHT22 Environment Sensor**
5) **Ultrasonic Sensor HC-SR04**
6) **Arduino Mega2560**
7) **ESP8266 Wi-Fi Module**
8) **DC Relay:** Control the Water Pump
9) **Raspberry Pi 4 With Camera for Remote Monitoring**

3. IoT Hardware Implementation

I. pH Sensor Calibration

To calibrate this sensor, you will need a wire to short the external part and the center of the probe connector. This causes a 2.5 volts tension on the Po analog output pin. I started off by connecting the external part of the BNC connector with the center of the BNC probe connector.

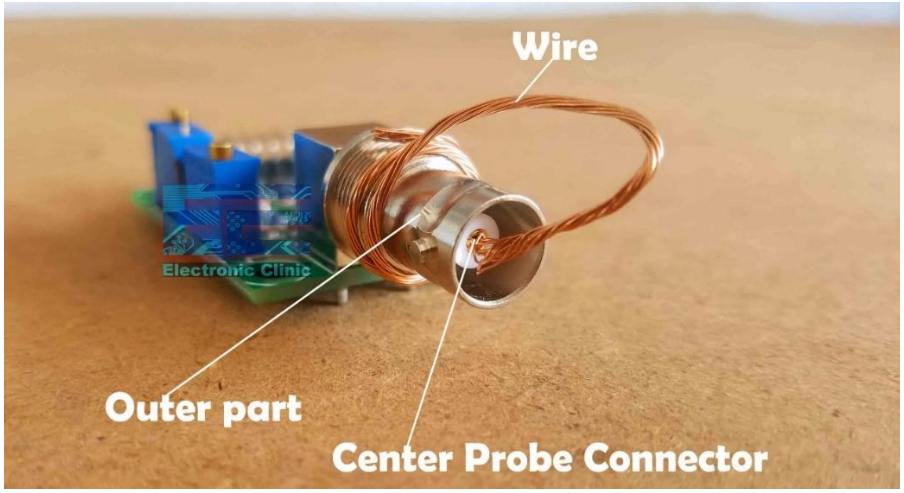


Figure 4.1: pH Sensor calibration

pH Sensor has 4 pins: (1)- Ground pins **(2)-** VCC-5V pin **(3)-** Input Analog pin connect to Arduino

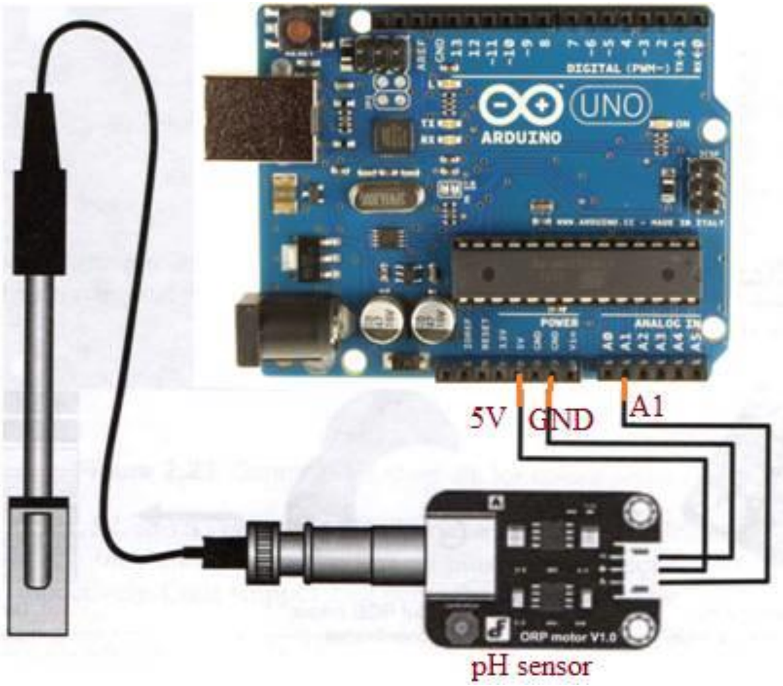


Figure 4.2: pH Sensor Connection

As above picture i connect the V+ pin with the Arduino's 5v. Connect the ground pin of the interface circuit with the ground pin of the Arduino, and finally connect the analog output pin Po with the A0 pin of the Arduino, and connect Arduino with the laptop to calibrate the pH sensor using the following Arduino code.

```
int pH_Value;
float Voltage;

void setup()
{
  Serial.begin(9600);
  pinMode(pH_Value, INPUT);
}
void loop()
{
  pH_Value = analogRead(A0);
  Voltage = pH_Value * (5.0 / 1023.0);
  Serial.println(Voltage);
  delay(500);
}
```

This is a very basic program that we are going to use for calibrating the pH sensor interface circuit. The purpose of this program is to the read the analog output pin Po and display the voltage on the serial monitor.

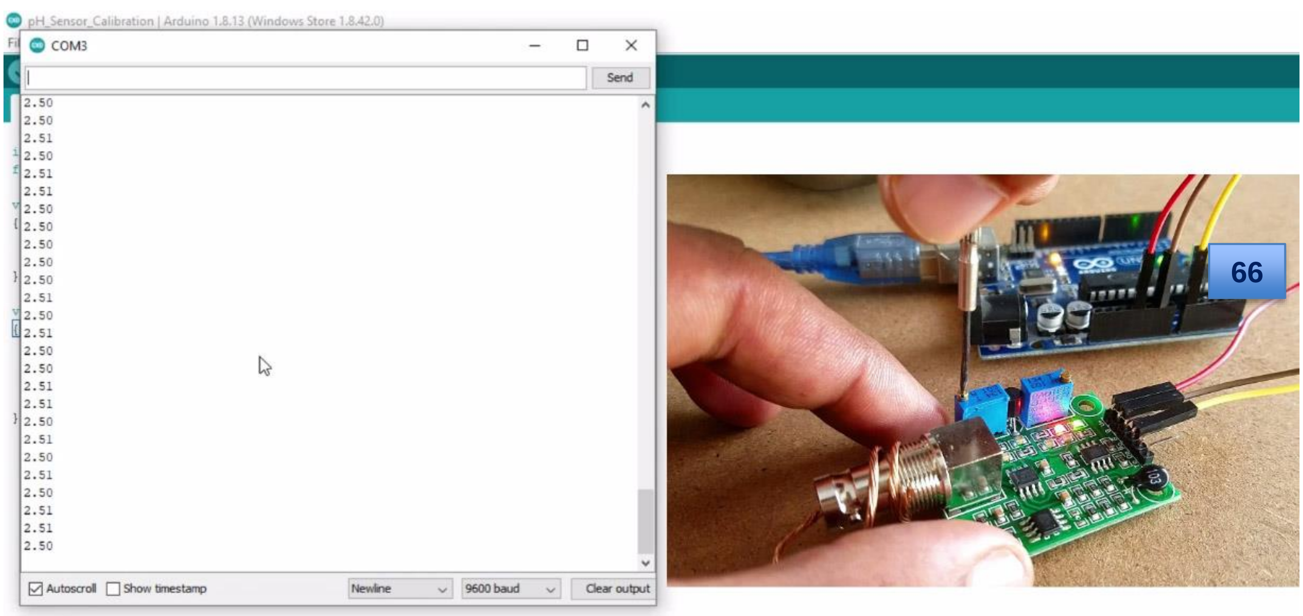


Figure 4.3: pH Sensor Calibration

If you see a value other than 2.50 then I will use the trimmer to adjust this value. I know that the pH value is from 0 to 14. A pH of 7 means 2.5 Volts. So, we are going to set it to 2.5 volts using the trimmer. Now, you can see the value is set to 2.5Volts. The pH Sensor is now calibrated.

Then I disconnect the Arduino board and also remove the wire. Now, it's time to connect the pH sensor with the interface board.

II. Block Diagram of The Hardware Implementation

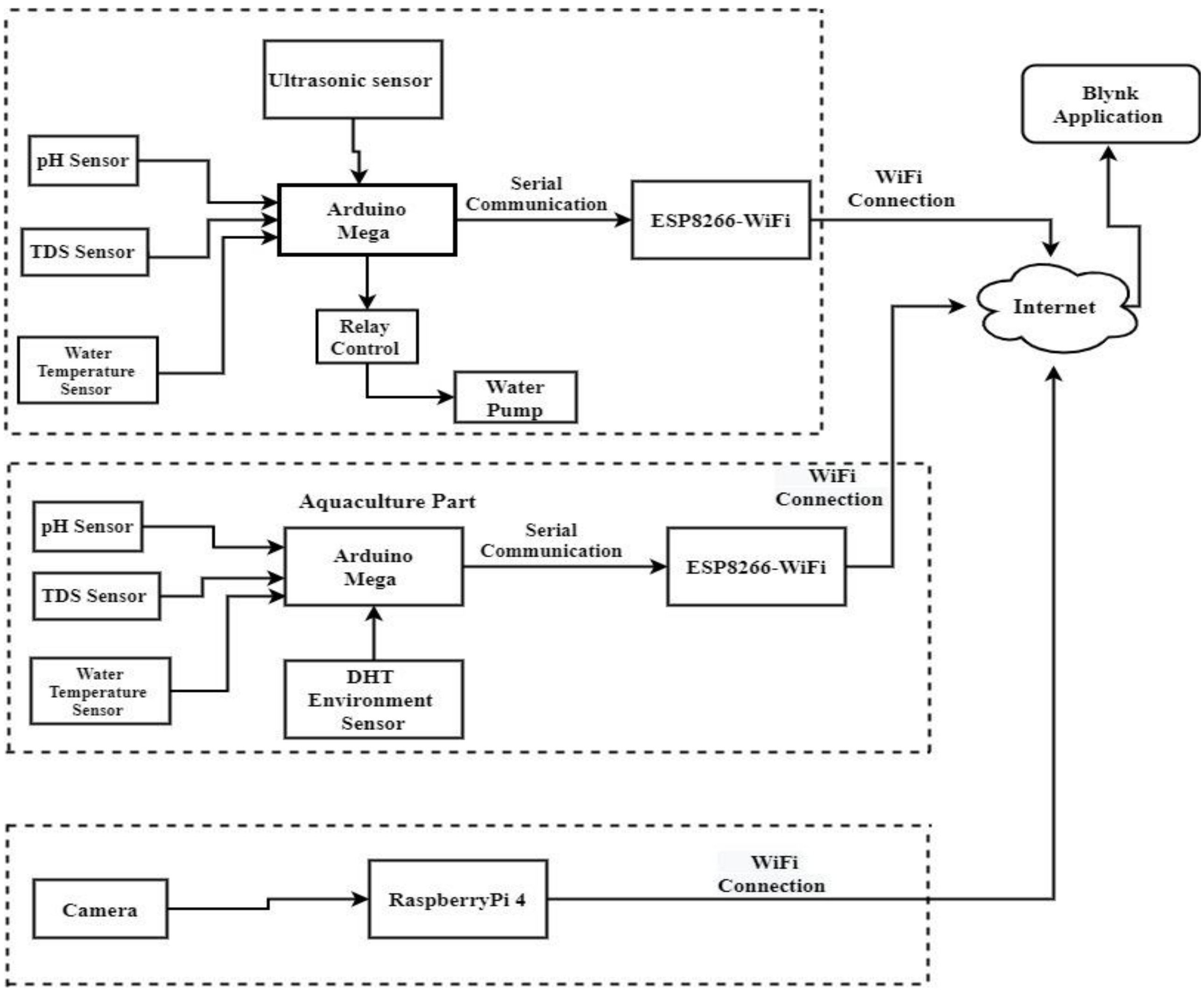


Figure 4.4: IoT System Block Diagram

III. The following picture shows the sensors and microcontroller connections implementation:-

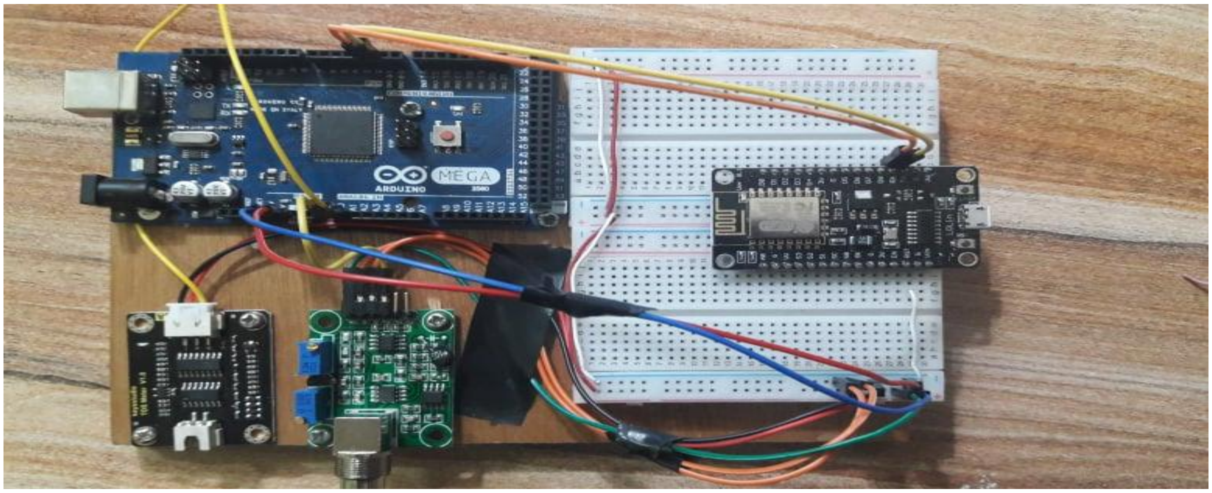
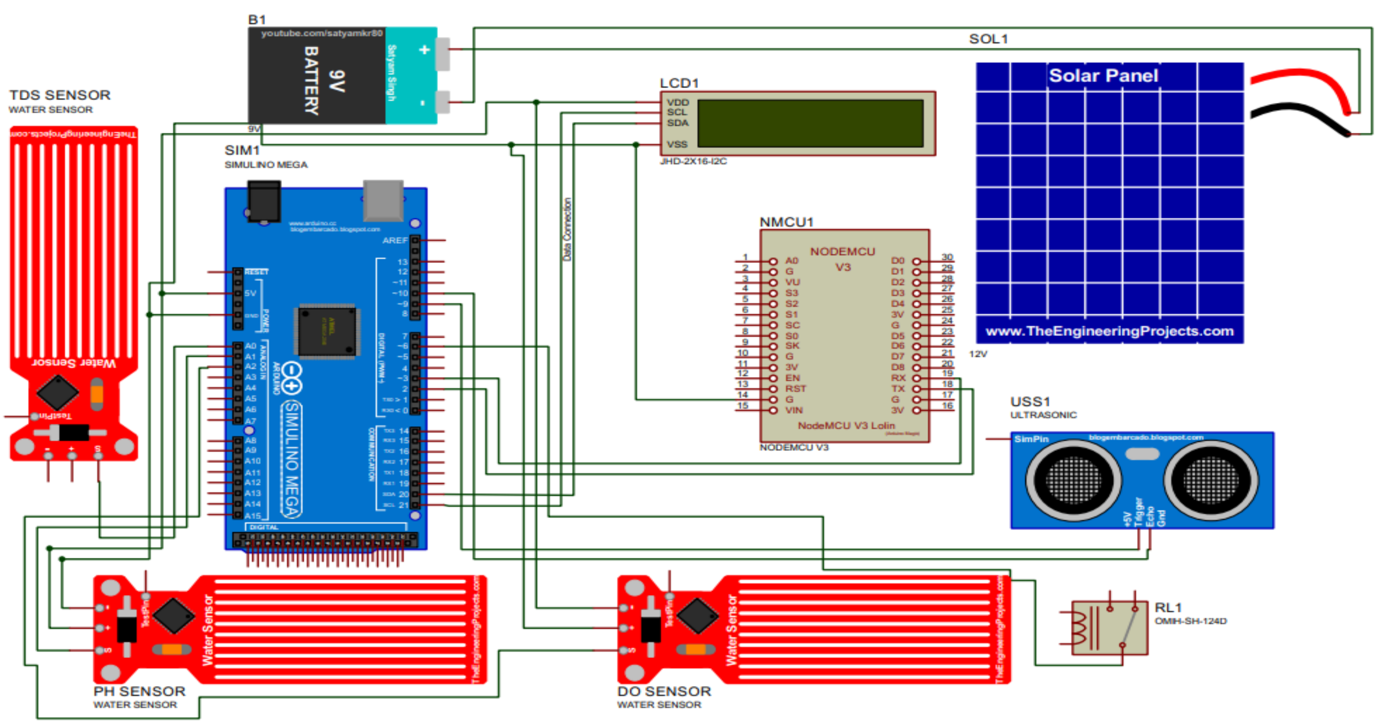
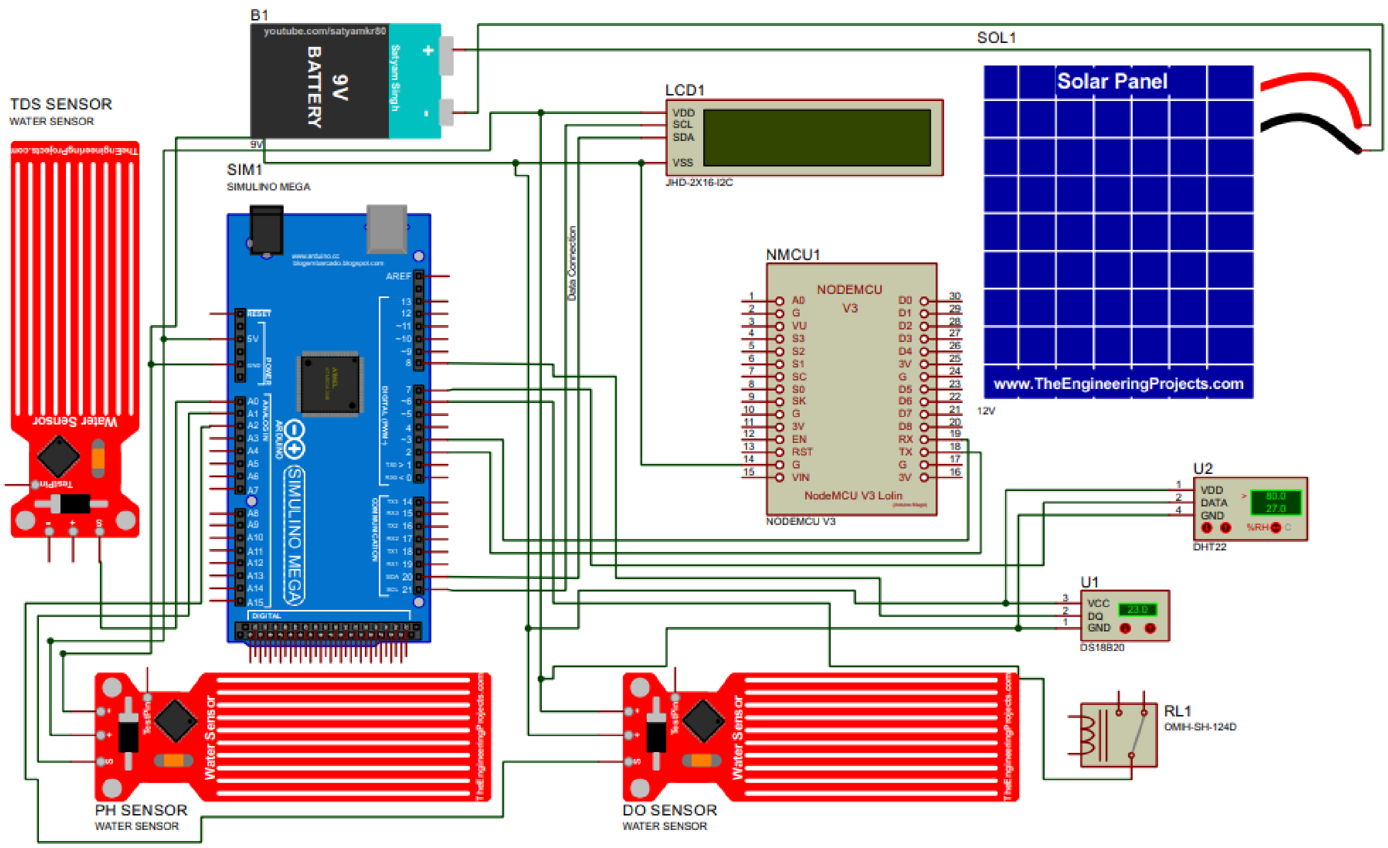


Figure 4.5: HW Implementation

IV. Schematic Diagram for Electronic Components Used in the Biological Filter: -



I. Schematic Diagram for Electronic Components Used in the Aquaculture Part.



4. IoT Software Implementation:

Step 1: In this step we programming all sensors with Arduino controller and ESP8266-Wi-Fi Module.

Step 2: In this step we installing and configuring Blynk Application to monitoring all system parameters as pH value and TDS value etc.

Step 3: Connect Blynk Application with ESP8266 Wi-Fi Module.

The following picture explain Architecture of “Blynk Application” and how it works:

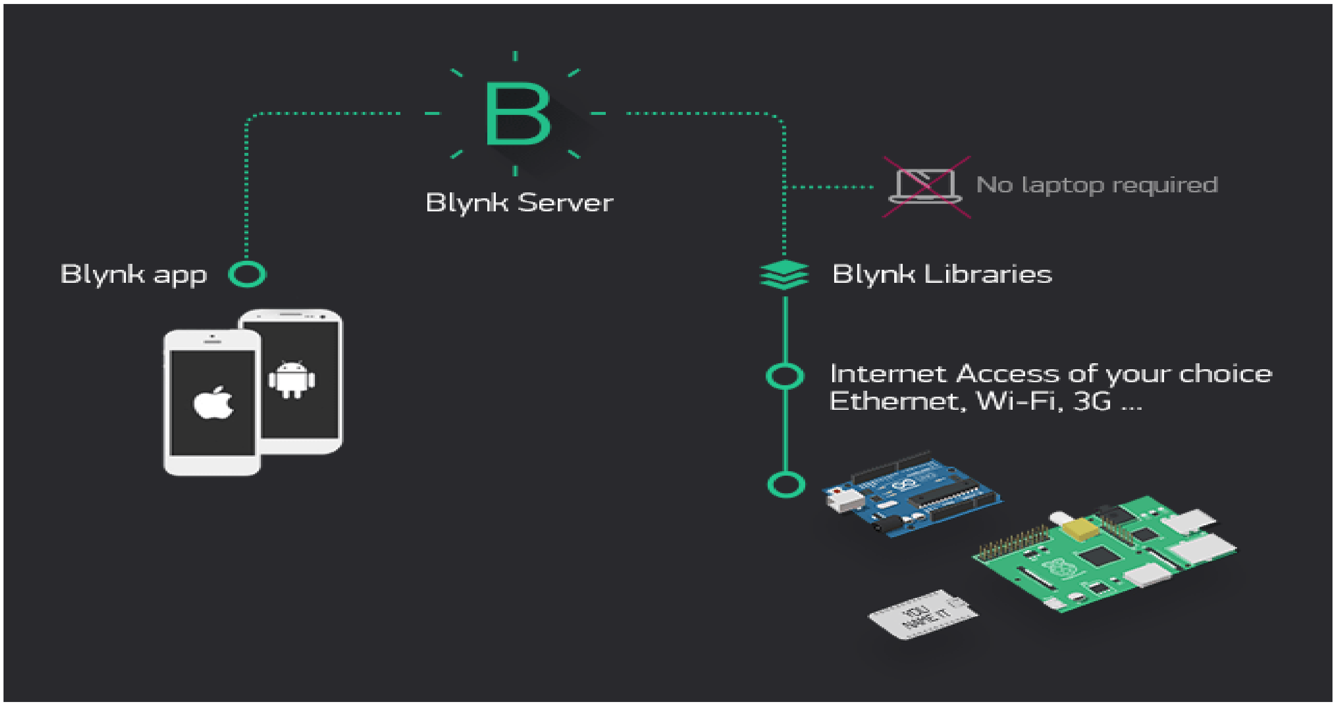


Figure 4.6: Blynk App Operation   http://docs.blynk.cc/images/architecture.png

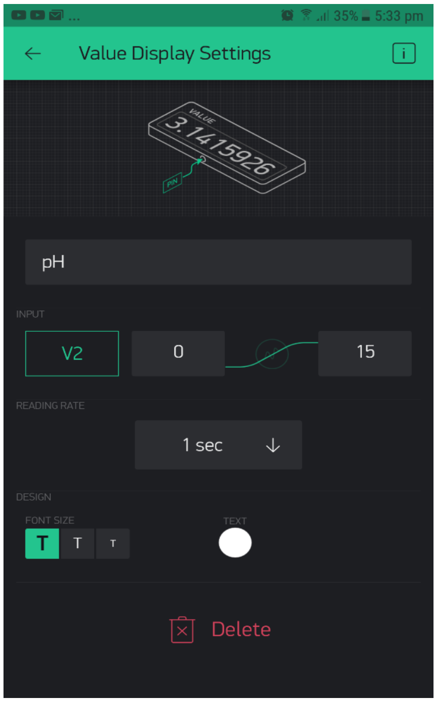
- **How the IoT system hardware connections will work?**

1) **Arduino microcontroller read digital and analog sensors.**
2) **Making decision by Arduino controller based on these values as needed.**
3) **On the Arduino controller Convert these values from “Float” or “Integers” to “String” values to be prepared to transmitted by serial connection to ESP Wi-Fi Module.**
4) **Then the Arduino microcontroller send these values as “string” to ESP8266 Wi-Fi Module by serial connection between Arduino and The Wi-Fi Module.**
5) **On the ESP8266 Wi-Fi Module receive these values and again converted to Integers or Float values.**
6) **ESP8266 send Values to Blynk app by connection to the internet network by SSID and Password of the Lan network predefined on the ESP8266.**

• Blynk App Connection with ESP8266 Wi-Fi Module

After connect all system parts, we will setup, connect and testing the Blynk app on some system sensors values, getting the following values on the app:

Each sensor value has a specific channel on the Blynk app, and this channel is connected directly to the Arduino code via internet.
The following figure explain how to connect each sensor value on the App with its channel to connect with ESP866 Module:



And the following code section explain how to connect App channel with ESP Module to display each sensor values:

```
void sensorvalue2()
 {
     float sdata = secondVal;
   // You can send any value at any time.
   // not send more than 10 values per second.
     Blynk.virtualWrite(V3, sdata);

 }
```

- ## Raspberry pi Setup: -

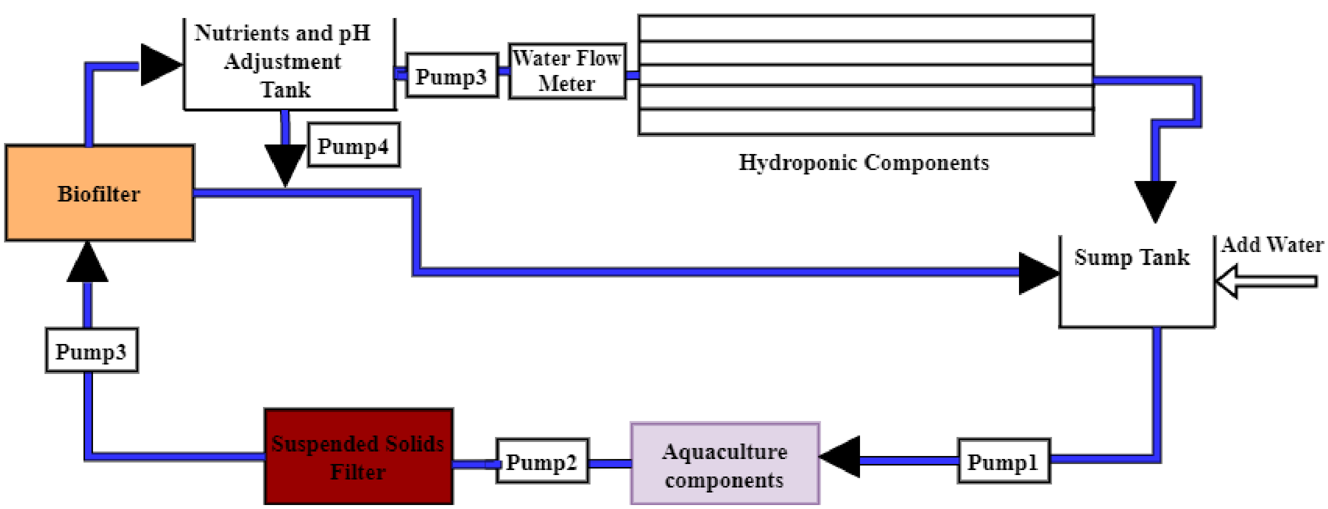
We will be using raspberry pi 4 in out design to monitoring in real time for the plant's status and healthy, and we can use take photo capture for each plant and make analysis for plants nutrients requirements based on the color of the leaf.
But now we will concentrate on remote monitoring of the plants from anywhere via internet, and in the following steps, we will explain how to configure raspberry pi camera for remote monitoring.

1) Connect The Camera Module with raspberry pi via flat cable.
2) Control the Camera Module via Command Line.
3) Download Camera Library
4) Open Camera by IP 192.168.1.200:5000

- ## Control System Flowchart

One of the most important water quality variables in aquaponics systems is pH and TDS. So, control system will be applied based on these parameters.
In our project we use Tilapia fish, so, Tilapia for example, require pH to be in the range of 6.0 to 9.0. Plants, on the other hand, grow best when pH levels are below 6.5.

This Flowchart is based on the figure 3.15



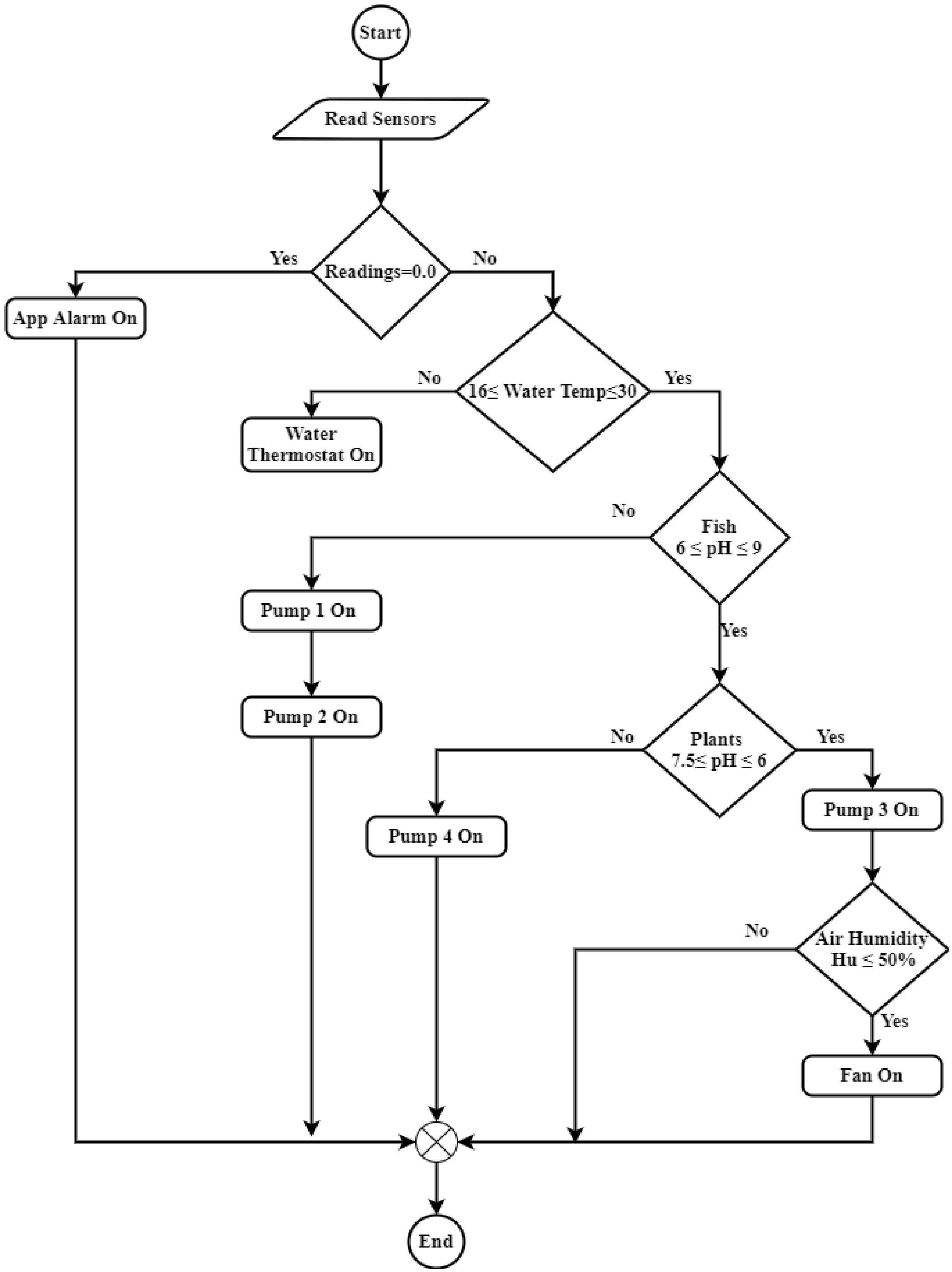


Figure 4.7: Control System Flowchart

- ## Adjusting pH Parameter: -

It is important to measure pH every day because it normally declines daily in response to nitrification processes. If pH levels get too low, nitrification will slow down or stop and ammonia will accumulate to levels that are toxic to the fish. When pH drops below 6.4, a base in the form of calcium hydroxide or potassium hydroxide should be added to the system to bring it back up to 7.0. Additions of the two bases should be alternated.

because both calcium (Ca) and potassium (K) are essential nutrients that must be supplemented in aquaponics systems. Here is the Southwest, water is alkaline and high in calcium content, so adding extra water rather than calcium hydroxide is often sufficient to raise the pH. Failing to measure pH for several days can lead to drops in pH to levels as low as 4.5. At pH 4.5, nitrification has stopped and TAN concentrations can climb to over 30 ppm. When this happens, it is crucial to add base very slowly over several days. Adding a large amount of base all at once will shift the majority of the TAN into the toxic un-ionized form (NH3), and this could kill all the fish.

Occasionally a problem can develop in which the pH does not decline over time but instead remains stable or starts rising. This can be due to something in your system causing pH to rise, such as hard water or other sources of minerals, such as net bags of crushed oyster shells that are sometimes added to systems to stabilize pH and add calcium. Rising or stable pH can also be indicative of anaerobic (oxygen-free) zones in your aquaponics system where denitrification is occurring. Denitrification produces alkalinity and stabilizes pH. To remediate this situation, filter tanks should be cleaned twice a week, and all deposits of organic matter accumulated in the hydroponic section should be removed.

- ## Water Temperature Adjustment

Water temperature in aquaponics systems will influence not only what type of fish can be reared but also plant growth and the performance of the biofilter. Fish species are temperature-dependent. Warmwater species such as goldfish, bass, catfish, and tilapia prefer temperatures ranging from 65 to 85°F, while cold-water species such as trout thrive at temperatures in the range of 12°C to 18°C. Tilapia prefer temperatures of 27–29°C for maximum growth. When water temperature drops below 70°F, growth slows dramatically, reproduction stops, and the incidence of disease increases. Tilapia will die when temperatures drop below 50°F. Vegetables grow best at temperatures ranging from 21°C to 75°F, and biofilters (nitrifying bacteria) perform optimally at temperatures ranging from 25°C to 30°C. As with other water quality parameters, the key is to find a temperature that falls within the acceptable range for all three components of the aquaponics system.

5. Aquaponic Part Implementation

plumbing parts:

1. Record elbow 90-degree d1=50 mm, d2=50mm.
2. PVC pipe 4-inch diameter
3. PVC pipe 2-inch diameter
4. Way record
5. Austin minus PVC
6. PVC connection part (Mofi)
7. Objection PVC
8. Flexible PVC extensions
9. Plastic faucet 20 mm
10. T pipe connection in and 2 out flow rate
11. Pump and air flow supply with air hose and air rock distributor air

here is the hydroponic solution recommended from our project team to use in comparison of aquaculture nutrition plants product and plus the hydroponic solution must add in contact with solutions and product resulted. So here is the table explained the content should using to achieve best plants result. According to (smart-fertilizer web site, 2020).

Table 4.1 Common nutrient ranges in hydroponic nutrient solutions

Nitrogen	Nitrate ($NO3^{-}$), Ammonium ($NH4^{+}$)	100-250 ppm elemental N
Phosphorus	Dihydrogen phosphate ($H2PO4^{-}$) Phosphate ($PO4^{3-}$) Monohydrogen phosphate ($HPO4^{2-}$)	30-50 ppm elemental P
Potassium	Potassium (K^{+})	100-300 ppm
Calcium	Calcium (Ca^{2+})	80-140 ppm
Magnesium	Magnesium (Mg^{2+})	30-70 ppm
Sulfur	Sulfate ($SO4^{2-}$)	50-120 ppm elemental S
Iron	Ferrous ion (Fe^{2+}) Ferric ion ($Fe3^{+}$)	1-5 ppm
Copper	Copper (Cu^{2+})	0.04-0.2 ppm
Manganese	Manganese (Mn^{2+})	0.5-1.0 ppm

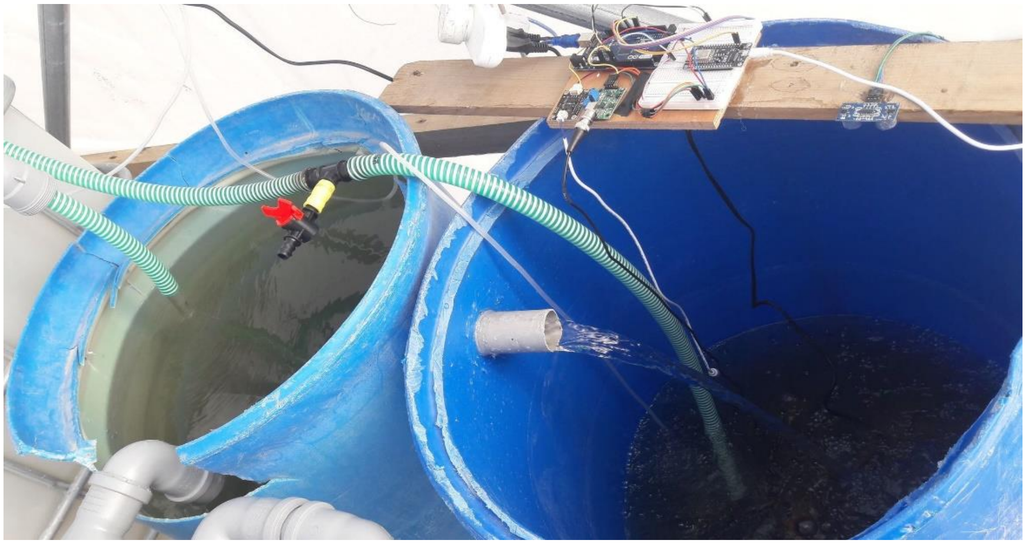
Zinc	Zinc (Zn^{2+})	0.3-0.6 ppm
Molybdenum	Molybdate ($MoO4^{2-}$)	0.04-0.08 ppm
Boron	Boric acid (H3BO3) Borate ($H2BO3^{-}$)	0.2-0.5 ppm elemental B
Chloride	Chloride (Cl^{-})	<75 ppm
Sodium	Sodium (Na^{+})	<50 ppm TOXIC to plants

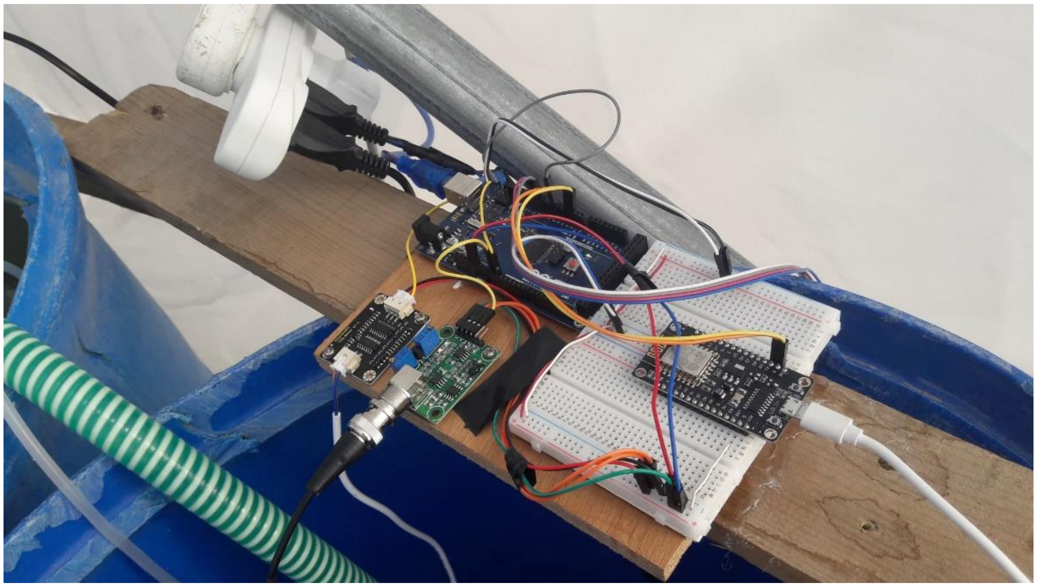
And which suggested nutrient solutions for various crops according to (smart-fertilizer web site, 2020).

Table 1.2 nutrient solutions for various crops

Crop	N	P	K	Ca	Mg
Concentration in mg/l (ppm)					
Tomato	190	40	310	150	45
Cucumber	200	40	280	140	40
Pepper	190	45	285	130	40
Strawberry	50	25	150	65	20
Roses	170	45	285	120	40

❖ The following pictures is taken to show the implementation of biological and mechanical filter with internet of things parts that includes controllers and sensors:





Chapter 5
Results and Conclusion

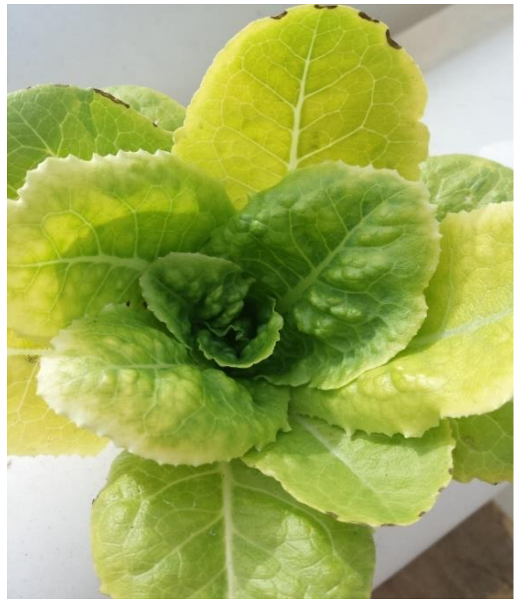
In this chapter we will discuss the results we obtained in the project, compare our project objectives and expected results that we mentioned in chapter one with these results, and the conclusion of all results we obtained**.**

In this chapter we will see the production results for the plants and fish's growth under greenhouse closed system condition, with sensors reading for monitoring the parameters of agriculture in comparison with mechanical and computer engineering, however results show for the reader the leak for agriculture parameters and its solution to avoid happens try again in future of the project.

5.1 Results of Plants Production: -

Pictures below show the results for first week of plants after build our aquaponic design, and explained the start of cultivation as plants root should be fully depth of water in PVC pipes without any soil, but it should have water solution for 24 h it's may be aquaponic solution or hydroponic solution as we explained before in chapter 4 with the water cycle loop of two method as we described before.

But during second week we noticed that there is yellow leaves of plants, and the following picture show this problem we encountered:

And the following pictures show plants after two weeks and half of using nutrient solution to solve plants yellow leaves problems, which appears because of leak of some nutrients:



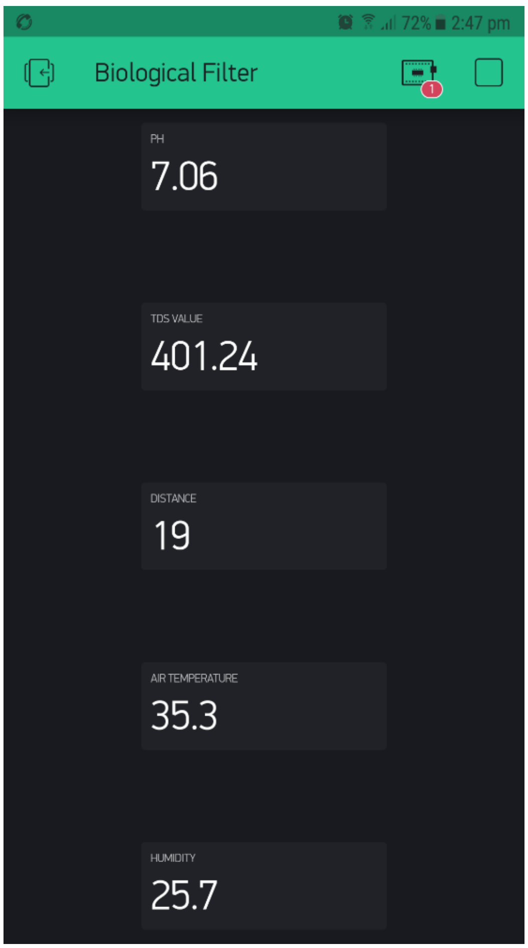
Eventually after 6 weeks, we obtain this result of planting in aquaponic system:

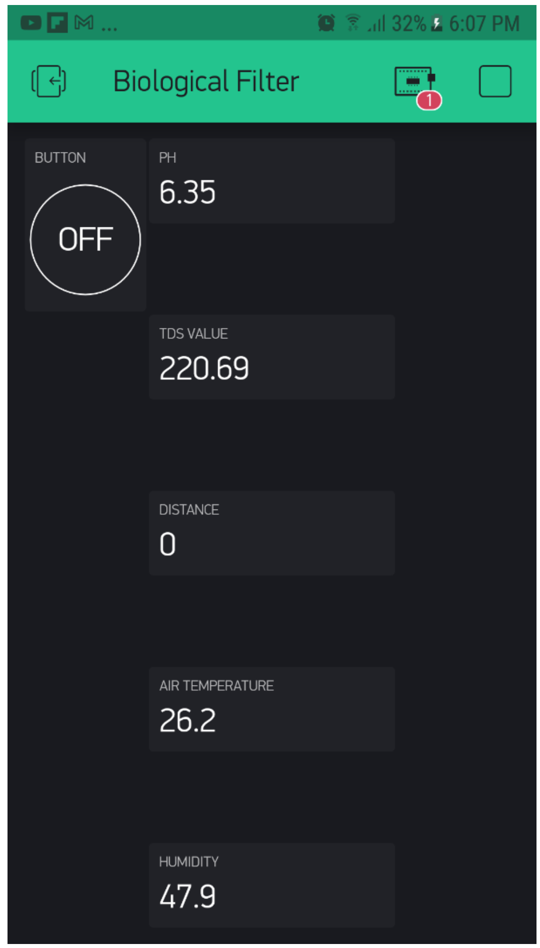



5.2 IoT Results Using Blynk App: -

All results we mentioned previously in this chapter was obtained after monitoring and adjustment of most important aquaponic parameter which include pH value, TDS (Total Dissolved Solids), Dissolved oxygen, and air moisture and temperature, this done by Blynk IoT app and hardware.

The following screenshot picture taken for Blynk app during real time monitoring remotely via internet:





5.3 Comparison of Project Result with Project Objectives: -

In chapter one we mentioned the main objectives in our project and expected results that may be achieved, so we can conclude our results and comparison as the following:

1- The first objective was designing an independent real time smart aquaponic monitoring prototype that combines between hydroponics system and aquaculture system**,** and this goal it is partially achieved because our prototype system sometimes we need to intervention by user, for example we need intervention to add nutrients for plants in hydroponic part based on plants leaves status, so we cannot say this system is completely independent**.**On other hand, this prototype combine between plants cultivation that represented in hydroponic part, and exploit fish breeding as a nutrient water for hydroponic part.

But this system is smart, real-time monitoring and controlling via internet of things, is smart when he is sensing some parameters and made decision based on that, and there is ability to manual controlling by the user via internet of things hardware and software.

2- Second goal was exploiting the internet of things technology as tools to achieve a remote monitoring of the system and make the aquaponic system more efficient and smarter**,** this goal has been achieved by using Blynk IoT application for monitoring and controlling remotely by build IoT hardware component in this system. So, this prototype is smart, real-time monitoring and controlling via internet of things, is smart when he is sensing some parameters and made decision based on that, and there is ability to manual controlling by the user via internet of things hardware and software.

3- In traditional aquaponic system that not using any technology for monitoring or controlling, in this case we need permanent presence in aquaponic system location to ensure that all part operates in properly manner. So, we conclude that the using internet of things in this design is save time and effort.

4- High quality of plants production was achieved by add some nutrients in water tank of hydroponic part, in first two week, we noticed that there is problem in plants leaves then solved by monitoring and adding nutrients solution.

5- The ability of deal with system failure was done by using Blynk application, such that when any sensor not read values the application send alarm via internet, and when the Arduino controller electrically disconnected is also send notification or real time alarm for the user.

5.4 Comparison of Project Result with Project Expected Result: -

1- The availability of the IoT monitoring system is achieved by implementation of system failure alarm or notification, and on the other hand the electrical availability was designed in system Block diagram and in schematic diagram by supporting electrical current for the system by solar panel, but this design not achieved because of costs limitations.

2- For getting accurate sensors reading we need high expensive sensor to achieve this result, so actually we using cheap sensors that not give us accurate reading, and also this because cost limitation.

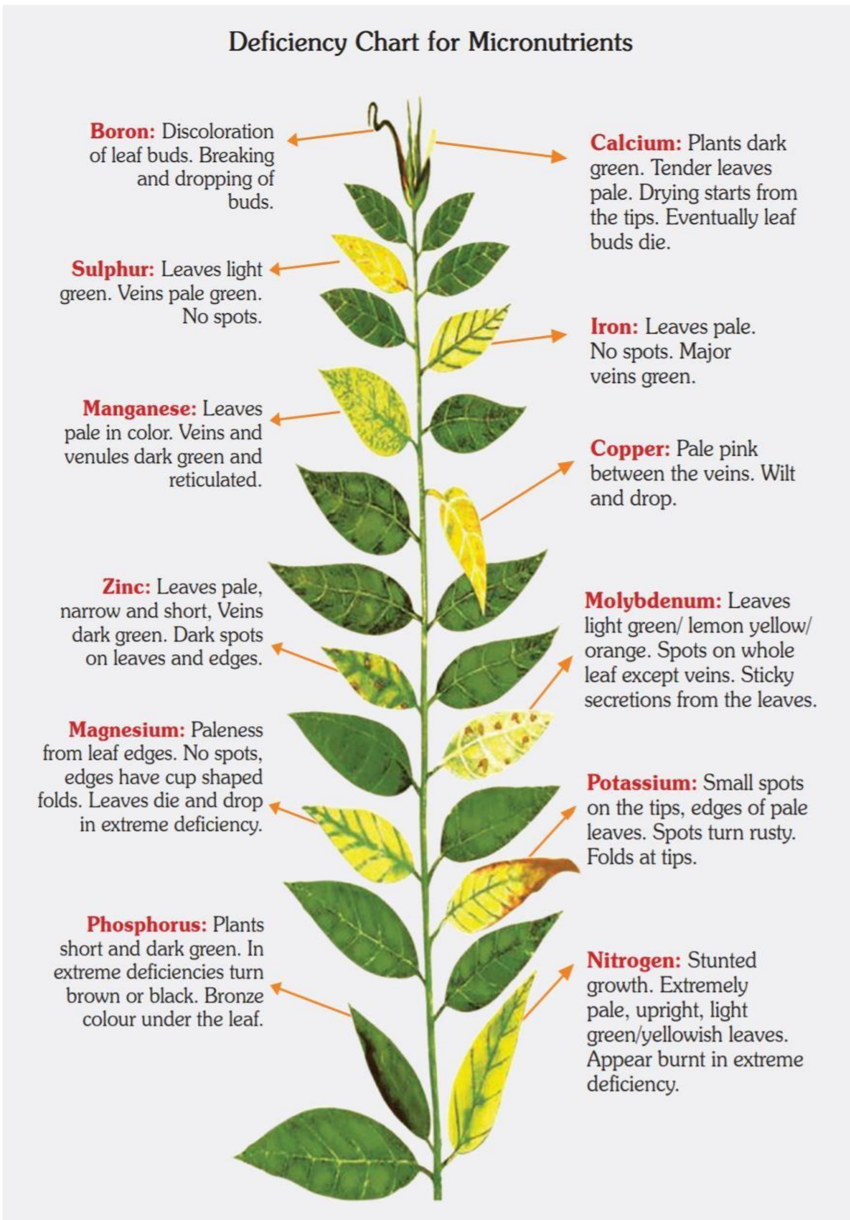
3- This system have ability to extensible, both in terms of plants cultivation or increasing the amount of fish, such that does not need wide area to extend this aquaponic system, but any variation of size of the system need new calculation of the amount of nutrients needed by the plants and fish.

5.5 Future Work: -

One of important ideas that can be added to aquaponic system is the artificial intelligence, that represented in the image processing of the plants leaves in the hydroponic part, by this feature we can monitor plants leaves by smart camera and determine what is problem or plants diseases may affect plants, and we can determine the mineral deficiency in the plants and adding nutrients solution to the water according this images processing for getting the high quality of plants production.

Essential elements needed for the crop growth are broadly classified relative Quantity that are normally plants should have and those classified into macro nutrients and they are K, N, P, O, H, C, and secondary nutrients Ca, Mg, S, and micro nutrients are Na, Fe, Se, Co, Mn, Zn, Cu, Mo, B, Cl. **Notes: N, P, K is highly mobile.**

The following picture explain how this monitoring and image processing of plants leaves can determine what is minerals needed for plants:



ELEMENT	SYMBOL
Boron	B
Calcium	Ca
Carbon	C
Chlorine	Cl
Cobalt	Co
Copper	Cu
Hydrogen	H
Iron	Fe
Magnesium	Mg
Manganese	Mn
Molybdenum	Mo
Nitrogen	N
Oxygen	O
Phosphorus	P
Potassium	K
Sodium	Na
Sulphur	S
Zinc	Zn