Aquaponics

Practicum

Aquaponics Systems: Designing and Building



Developed For Training Purpose

By Dr, Allan Bachan

Partners in ***Empowering Communities with Opportunities and Education Solutions***

In Trinidad and Tobago communities have expressed a growing interest in aquaponic farming as a sustainable method to provide a source of healthy, fresh, and cost-effective protein and vegetables, while providing job and educational opportunities for our young entrepreneurs. Increased interest in aquaponic farming can be attributed, in part, to the ability to utilize brownfields and other underutilized properties and buildings in or near towns and populated areas for aquaponics operations. This positioning is crucial to overcoming food insecurity and in providing new work opportunities for underserved communities, particularly among food insecure areas.

In conducting community training in aquaponics most participants indicate that the lack of a practical resource guide that they can refer to when setting up their system is a major limitation to this kind of training.

This step-by-step guide is developed to address this need and describes how to build the Media Bed, Nutrient Film Technique (NFT) and Deep-Water Culture (DWC) systems for the small-scale aquaponic units. The actual design theory for the three systems is explained in Lesson 6. This training component focuses solely on how to construct them using cheap materials that are widely available. In addition, it provides brief explanatory comments and calculations for some of the most complicated components of each system.

This User Guide has been prepared for informational purposes only.

The trainer would like to acknowledge BHP for supporting this programme and the development of the material in this information product. I would like to acknowledge my team Mr. Kevin Muhammad and Miquel Garcia, who provide support and assist in the practical component of the training.

Contents

Aquaponic System Design Topics

Things to Consider Before Starting an Aquaponics System

Personal Considerations

1. Choose an aquaponics system that you want to implement. You can choose between a media-based system, a raft system, and NFT system, or a combination of these systems.
2. What are the goals and purpose of your aquaponics system? Why do you want to have an aquaponics system? What plants or fish are you planning to grow and raise? Are you going to eat your fish? These questions should be given thought to plan your system correctly and know what system will meet your goals and purposes.
3. Are you a do-it-yourself (DIY) person? Are you a do-it-yourself person, or do you prefer to purchase a well-proven free-made design?

Design Goal:

We promote the creation of a durable, low maintenance, highly efficient, low energy/resource usage, and adaptable aquaponics system that can demonstrate outdoor and commercial potential

So, the key factors considered for the design of each unit are:

i. material cost.

ii. material availability; and

iii. production capacity.

Thus, the materials for each design shown in the diagrams have all been selected because they are all widely accessible, affordable and most importantly waste material that we recycle.

Designing an aquaponic unit

Summary

Aquaponics is the integration of recirculating aquaculture and hydroponics in one production system. In aquaponics, the aquaculture effluent is diverted through plant beds and not released to the environment, while at the same time the nutrients for the plants are supplied from a sustainable, cost-effective and nonchemical source. This integration removes some of the unsustainable factors of running aquaculture and hydroponic systems independently. The technology presented in this document provides a description of the concept of aquaponics and an overview of the three most common methods of aquaponics being utilized at present. In addition, the factors to consider when selecting a site for an aquaponic unit and the components essential for any method of aquaponics are described in detail in this document.

Consideration while designing an aquaponic unit

- Site selection.
- Water quality in aquaponics.
- Essential components of an aquaponic unit.

You may wish to review in Lesson 6 of your Training Booklet.

Tools And Materials

Every system requires a selection of PVC pipe, PVC connections and fittings, hoses and tubes. These provide the channels for water to flow into each component. Make sure that the pipes and plumbing used in the system have never previously been used to hold toxic substances. It is also important to use pipes that are non-transparent to light, which will stop algae from growing.

Bulkhead valves, uniseals, silicone sealant and Teflon tape are also needed.

In addition, some general tools are needed such as hammers, drills, hand saws, electric saws, measuring tapes, pliers, channel-locking pliers, screwdrivers, levels, etc. One special tool is a hole-saw and/or spade bit, which is used in an electric drill to make holes, necessary for inserting the pipes into the fish tanks and filters, as well as for making holes in the grow beds in NFT and DWC systems.

Work gloves, Safety goggles Marker Pipe wrench Hammer Pipe cutter/ Haxsaw Spirit level Measuring Tape Screw driver	Angle Grinder Electric drill Circular drill bit (hole saw) Jig Saw

EXERCISE 1

Conduct Exercise

<u>MAKING THE FISH TANK</u>

(1) DRILLING THE HOLE FOR THE FISH TANK EXIT PIPE

	a) On one side of the IBC tank, mark a point 5” from the top and 8” from the side of the tank

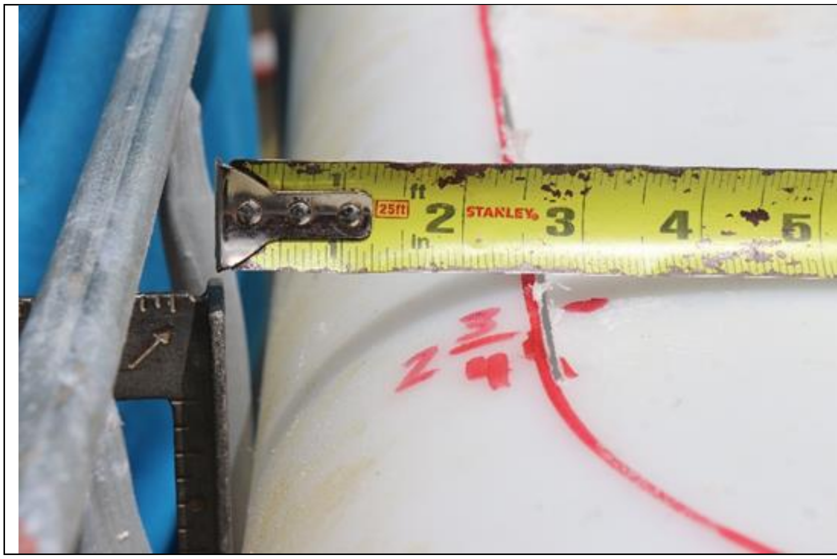
	b) Drill a hole at that point using the 3” holesaw. Note: the holesaw size should be 3” and not 2” for a 2” uniseal

Trainer: Dr. Allan Bachan

 	c) Insert a 2” uniseal inside this hole.

(2) PREPARING THE FISH TANK COVER

	a) Remove the two horizontal steel lengths attached to the top surface of the IBC tank holding the inner plastic container in place. If you cannot unscrew, cut the screws with an angle grinder

	b) Draw a rough square shape on the top surface of the tank 2.75" from the four sides of the tank.

	c) Then, using the jig saw or an angle grinder, cut along the square shape and remove the cut piece from the top.

	d) Once removed, wash the inside of the container thoroughly with soap and leave to dry for 24 hours. The cut piece removed will be used as the fish tank cover which can be hinged on.

(3) INSTALLING THE FISH TANK EXIT PIPE

Here we would look at two options:

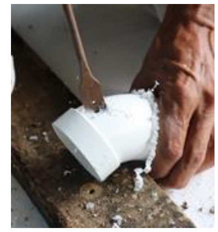
OPTION 1

The fish tank exit pipe is made of 2 lengths of PVC pipe (2”) combined using 2 PVC elbow (2”), 1 PVC Endcap (2”) and 2 PVC coupler (2”).

 	a) Slot a short length of 2” PVC through the uniseal (2”) and attach to a 2” PVC elbow on the inside end.
	b) Attach a 2’ coupling after the top elbow. This allows for cleaning of the pipe without having to empty the tank. c) Attach the other (vertical) pipe length to the elbow that is now connected to the uniseal (2”).

 	d) The length of 2″ PVC along the bottom surface of the tank is cut with horizontal slits by using the angle grinder to allow solid waste to enter the pipe but to prevent fish from doing so.

	e) The pipe with the slits is connected to the elbow on the bottom of the tank The open end of the PVC length along the bottom surface of the fish tank is sealed with a 2″ PVC endcap.

f) Finally, drill a ¾” diameter hole into the PVC elbow attached to the uniseal. This small hole prevents any air seal forming inside the pipe, which would drain all the water out of the fish tank in the event of power cut or if the pump stopped working. **This step is not optional**.	  

	g) Take another 2”PVC elbow and connect it to the pipe slotted through the uniseal on the outside of the tank.
	h) Add a connector to connect to the **Mechanical Filter or Directly to the grow bed.**

OPTION 2

The fish tank exit pipe is made of 1 length of PVC pipe (2”), 2 PVC elbow (2”), 2 PVC Endcap (2”) and 2 PVC coupler (2”)’ 1 PVC Tee (2”), and 2 PVC PVC 45º Elbow (2”).

a) Measure and cut 2 pieces of 2” pipe to a length of 10”.	b) Take one piece of 10” PVC Pipe and attach an elbow to one end	c) Attach a Tee to the other end.	d) Take the other piece of 10” PVC Pipe and attach to the other end of the Tee.	e) On the other end attach another 2” Elbow.

f) Measure and cut 3 pieces of 2” pipe to a length of 24”.

g) Cut horizontal slits by using the angle grinder. This will allow solid waste to enter the pipe but to prevent fish from doing so.

	h) The pipe with the slits is connected to each of the two elbows on either side and the Tee in the center i) The open end of the PVC length along the bottom surface of the fish tank is sealed with a 2" PVC endcap. **Place on the bottom of the tank**

	j) Measure 4″ from the base of the IBC tank. Drill a hole to take a 2″ uniseal. k) Insert the uniseal. L) Slot a 12″ length of 2″ PVC through the uniseal (2″).

	m) Attach two 2″ PVC 45°elbow on the inside end. n) Cut a piece of 2″ pipe to a length of 6″. o) Insert one end into the 2″ PVC 45°elbow and on the other end attach a 2′ coupling.

p) Finally attach the Exit pipes to the other end of the 2' coupling. This allows for cleaning of the pipe without having to empty the tank.	

	q) On the outer 2" pipe add a 2" ball valve to control the and a 2" connector to connect to the **Mechanical Filter or Directly to the grow bed.**

(4) INSTALLING THE FISH TANK FILLING PIPE

	
Connect your inlet water line coming from your sump. a) on the upflow line 1" PVC add a shut off valve that will be used to regulate the water flow back to the fish tank. b) Install a 1" elbow.	c) cut a piece of 1" PVC to span the length of the Tank. Drill 1/4 " holes along the pipe. Attach the spray pipe to the elbow.

(5) INSTALLING THE CLEANOUT/ DRAIN LINE:

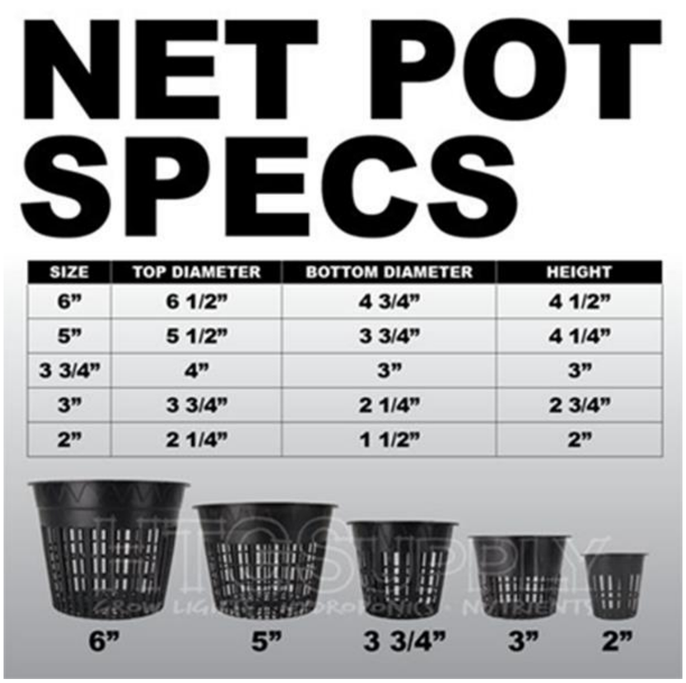
 	For the removal of the solid waste, drill a hole using a 3" holesaw at the lowest point of the IBC. Inset a uniseal (2"). Insert a PVC pipe, and you can connect a valve to it in order to regulate the draining.
	Don't Forget to Cover if you have too much sunlight

EXERCISE 2

Conduct Exercise

PLANTING THE PLANT

Make sure the plant pot has enough holes to allow the root system to grow out into the pipe but also to prevent the growing medium from falling out. Using Netpot is recommended.



NET POT SPECS

SIZE	TOP DIAMETER	BOTTOM DIAMETER	HEIGHT
6"	6 1/2"	4 3/4"	4 1/2"
5"	5 1/2"	3 3/4"	4 1/4"
3 3/4"	4"	3"	3"
3"	3 3/4"	2 1/4"	2 3/4"
2"	2 1/4"	1 1/2"	2"

For planting, follow the steps below:

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<tr><td></td><td></td><td></td></tr>
<tr><td></td><td>a) take some hydroton & put it into the netpot. about 1/4 to 1/3 full (i like 1/3 full)</td><td>b) Place the plant in the netpot</td></tr>
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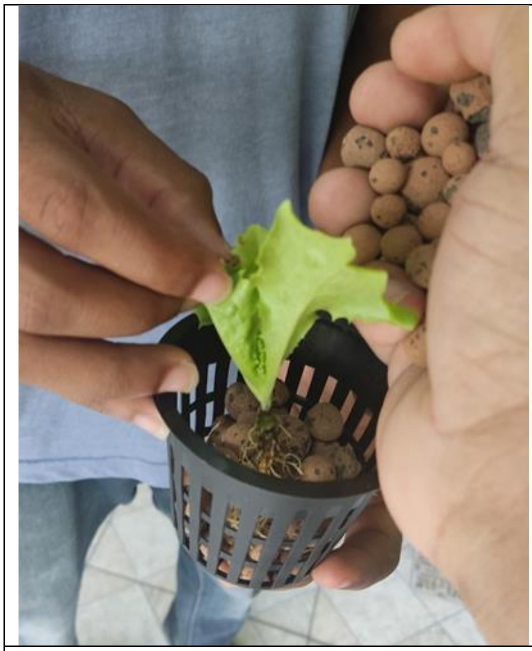
<tr><td></td><td></td></tr>
<tr><td>c) Scoop some hydroton in a cup or use you hand & fill netpot to the top</td><td>Easy peasy</td></tr>
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EXERCISE 3

Conduct Exercise

MAKING THE MECHANICAL SEPARATOR

Take two blue barrels (200 litre) and wash both barrels with soap thoroughly and leave to dry in the sun for 24 hours.

Mechanical filtration

Before we get started, you need to recall that there are different kinds of solids. These are:

1. Settable solids
2. Suspended solids
3. Floating solids

The water needs to be free from the suspended particles formed by floating debris, food particles and fish waste before it returns to the fish tank. If you want your operation to run smoothly, you will need some type of solids waste removal.

Furthermore, this method of filtration prevents the plant roots from getting clogged in an NFT aquaponics system, hence facilitating oxygen absorption and the intake of dissolved nutrients. We will get rid of the settable solids by using a solids separator or Mechanical Filter. There are two types that we will build out: **Swirl Filter and Radial flow separator.**

<u>Swirl Filter</u>

Build your own swirl filter by following the simple instructions below:

Take a big drum with a volume of 55 gallons (200 L). a) Mark two holes on adjacent sides, The bottom inlet hole should be halfway from the bottom and the top outlet hole should be 10” from the top of the barrel.	 
b) Drill these two holes to each take a uniseal (2”) with the lower one as the inlet and the higher one as the outlet that will be connected to the grow bed or biofilter.	

c) Cut two 18” pieces of 2” PVC pipe. Insert the cut 2” PVC pipe with 8” into the tank.	

Construct the Swirl. d) On the lower inlet pipe attach a PVC T to the end.	
e) Cut two 6” pieces of 2” PVC pipe. Insert the cut 2” PVC pipe on either end of the PVC T.	

f) To the end of each attach a 45^0 elbow (2”) with the outlet opposite to each other.	
g) The upper pipe is the outlet to the biological filter. Insert an elbow with the open end facing upward.	

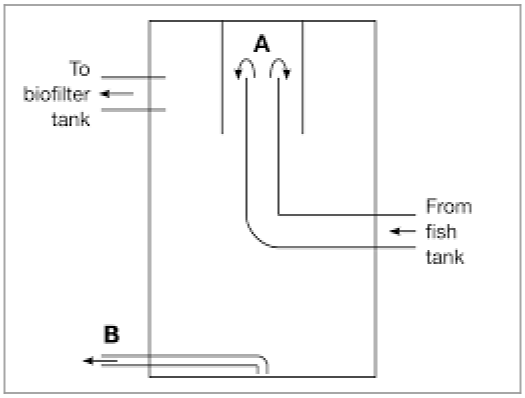
 	**Construct the baffle:** h) Take a plastic sheeting and cut to the circumference of the container. i) Cut two holes so that the baffle fit over the 2” outlet elbow

	j) Drill small holes so that sediments are restricted from entering but allowing the water to flow.

	**Install a cleanout:** k) For the removal of the solid waste, drill a hole at the lowest point of the barrel. Inset a uniseal (3/4”). Insert a PVC pipe, and you can connect a valve to it in order to regulate the flow. That is all!
	l) Attach 2” coupling on the both the inlet and outlet lines to connect to the biofilter and the fish tank

Radial flow separator

The radial flow separator, also called the radial flow filter or radial flow settler, is the most used filter in aquaponics. It’s more efficient than using a vortex or clarifier but is a little bit more complicated.



Take a big drum with a volume of 55 gallons (200 L). a) Mark two holes on adjacent sides, The bottom inlet hole should be halfway 18” from the bottom and the top outlet hole should be 10” from the top of the barrel.	 

b) Drill these two holes to each take a uniseal (2”) with the lower one as the inlet and the higher one as the outlet that will be connected to the grow bed or biofilter.	
c) Cut two 12” pieces of 2” PVC pipe. Insert the cut 2” PVC pipe with 4” into the tank	

Inlet pipe from the fish tank. d) Attach a PVC elbow (2”) to the bottom inlet and top exit pipe facing upward.	

e) Cut an 12” pieces of 2” PVC pipe. Insert the cut 2” PVC inlet pipe on the bottom elbow.	
f) Construct the inlet Sleeve: Take a piece of 4” PVC Pipe and cut so the bottom rests on the inlet (bottom) elbow and extends 6” over the barrel cover.	 
g) Drill a hole at the top surface of the barrel cover to take a uniseal (4”) and slide in the inlet sleeve pipe. Cover the sleeve with a 4” endcap. This allows you to view and clear any restrictions without taking the system offline	

Outlet pipe to the Biofilter. h) Attach a PVC elbow (2”) to the top exit pipe facing upward.	

 	**Construct the baffle:** i) Take a plastic sheeting and cut to the circumference of the container. j) Cut two holes so that the baffle fits over the 2” outlet elbow and the 4” inlet pipe sleeve. Drill small holes so that sediments are restricted from entering but allowing the water to flow.

Construct the baffle:

k) Fit the baffle over the 2” outlet elbow and the 4” inlet pipe sleeve.

Install a cleanout:

l) For the removal of the solid waste, drill a hole at the lowest point of the barrel. Inset a uniseal (3/4”). Insert a PVC pipe, and you can connect a valve to it in order to regulate the flow.

	m) Attach 2” coupling on the both the inlet and outlet lines to connect to the biofilter and the fish tank

EXERCISE 4

Conduct Exercise

MAKING THE BIOFILTER

Biological filtration

The biofilter is installed between the mechanical filter and the hydroponic containers. The minimum volume of this biofilter container should be one-sixth that of the fish tank.

Build your own biofilter by following the simple instructions below:

Take a big drum with a volume of 55 gallons (200 L). a) Mark two holes on adjacent sides, The bottom inlet hole should be 18″ from the bottom and the top outlet hole should be 10″ from the top of the barrel.	 
b) Drill these two holes to each take a uniseal (2″) with the lower one as the inlet and the higher one as the outlet that will be connected to the grow bed.	

	**Install a drain out / cleanout:** c) For the removal of the solid waste, drill a hole at the lowest point of the barrel. Inset a uniseal (3/4”). Insert a PVC pipe, and you can connect a valve to it in order to regulate the flow.
	d) Attach 2” coupling on the both the inlet and outlet lines to connect to the biofilter and the fish tank

e) Cut two 18” pieces of 2” PVC pipe. Insert the cut 2” PVC pipe into the uniseal with 12” into the tank.	

Construct the outlet pipe. f) The upper pipe is the outlet to the plant beds. Insert an elbow with the open end facing upward.	

Construct the inlet pipe. g) Attach to the inlet a PVC 90^0 elbow (2”) facing downward.	

h) Cut a 12 " piece of PVC and attach to the elbow Attach another PVC 90^0 elbow (2") to the bottom inlet. The baffle will rest on this elbow.	

	**Construct the baffle:** i) Take a plastic sheeting and cut to the circumference of the container. j) Cut a hole so that the baffle fit over the elbow on the bottom of the inlet pipe

	k) Drill small holes so that sediments is restricted to the bottom but allowing the water to flow upward through the biofilter medium.

	l) Place the baffle on the end so it rests on the bottom elbow (2”). This will keep the biofilter medium from blocking the drainout.

m) Fill the Biofilter tank with the biofilter medium 4" below the outlet pipe. One commonly used biofilter medium is Bioballs available from fish and aquaculture supply stores but can be costly. These are designed to be an ideal biofilter material, because they are small, specially shaped plastic items that have a very large surface area for their volume (500–700m^2/m^3). Other cheeper media can be used, including plastic bottle caps, discarded netting, and nylon scrub pads.	

Starting the Nitrification Process

Fish cycle

- Run the fish tank with chlorine and chloramine-free water for a few days
- Make sure all components are functioning properly
- Add fish at 20% of stocking density (Aquarium stocking density is commonly 1” per gallon)
- Keep fish food to a minimum for the first 10 days
- Monitor water quality and fish behaviour.
- Add 20% more fish every 4-6 weeks for best outcome

Fishless cycle

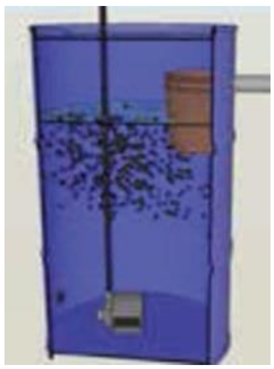
- Use commercial ammonia tablets and bacterial supplement
- Use worm tea made from worm castings
- Use pond or river water (with caution)
- Use the filter pad or water from someone’s system
- Use urine – yes I realize its weird, but its sterile

EXERCISE 5

Conduct Exercise

MAKING A SUMP TANK

The sump tank can be made using the whole open top barrel or cutting a closed top barrel in half.

For the latter take a closed top Blue barrel and mark the half way mark. Take the angle grinder or circular saw and cut the plastic container into two.

ELECTRIC BOX + AIR PUMP

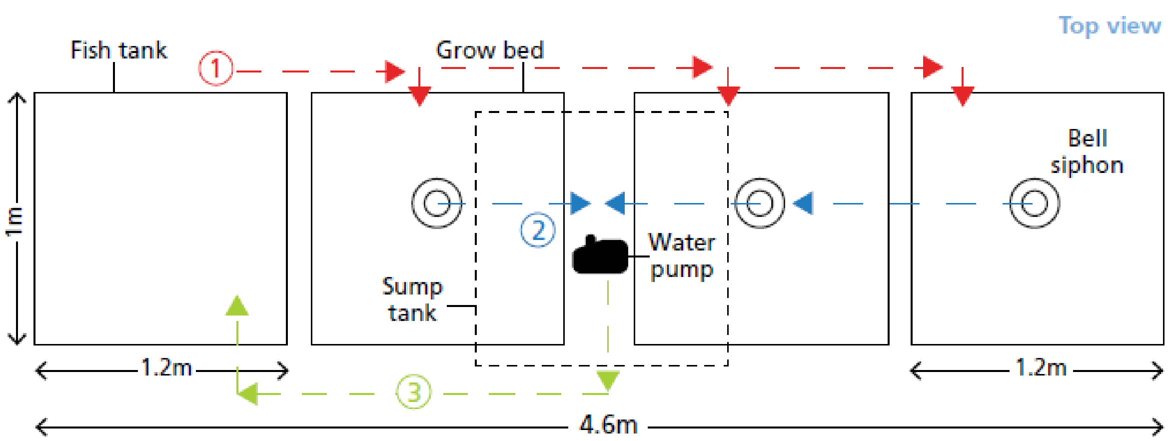
Place the electric box in a safe place higher than the water level and shaded from direct sunlight. Make sure it is still water proof after plugging in the water and air pump plugs, and put the air stones inside the fish tank.

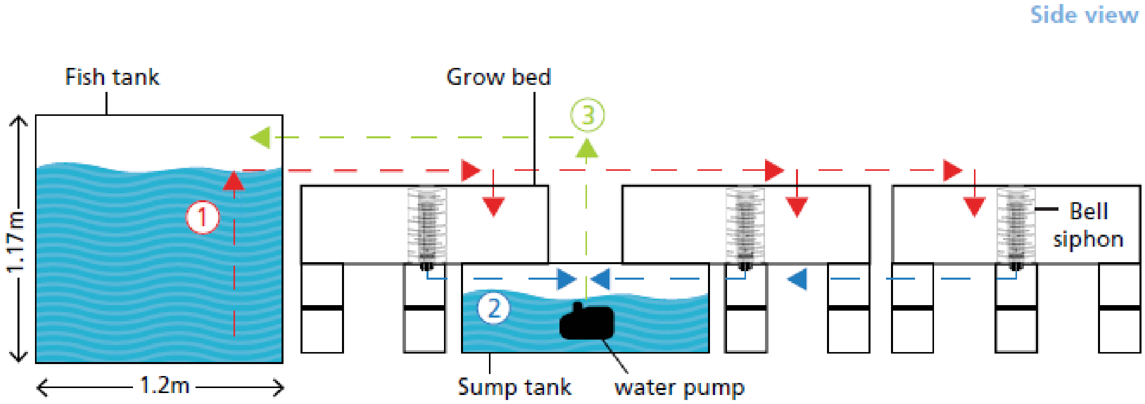
EXERCISE 6

Conduct Exercise

THE MEDIA BED UNIT

Source: Food and Agriculture Organization of the United Nations (FAO)





Water flow diagram

1. Water flows by gravitation from the fish tank to the media beds.

2. Water flows from the media bed into the sump tank.

3. Water flows back to the fish tank from the sump by using the water pump.

MAKING TWO MEDIA BEDS FROM ONE IBC

Take the IBC tank or the closed top blue barrel and mark a line bisecting the tank into two. Take the angle grinder and cut the plastic container along the mark.

Now, take each media bed and mark a centre point on the base or close to away from the IBC's red caps. Drill a hole (1" in diameter) at each centre point and insert the tank connector (see Bell Syphone installation).

EXERCISE 7

Conduct Exercise

<u>MAKING AUTOSIPHONS: *BELL SIPHON*</u>

The bell siphon is a type of autosiphon that exploits a few physical laws of hydrodynamics and allows the media bed to flood and drain automatically, periodically, without a timer.

The following materials are needed to make one siphon:

Media Guard

1 - 3"or 4” PVC pipe (approximately 12" long)

Bell Dome

1 - 2" PVC pipe (approximately 10" long)

1 - 2" PVC cap

Bell Siphon

1 - 3/4" PVC pipe (approximately 6" long)

1 - 3/4" to 1 1/2" flared reducer

Grow Bed Connections

1 - 3/4" Male adapter (thread to slip)

1 - 3/4" Female adapter (thread to slip)

2 - #18 o-rings

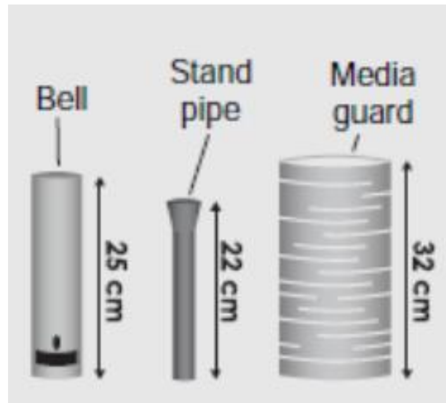
Or 1 – 3/4" bulkhead

Drain Pipe

- 2 - 3/4" PVC pipe 4" long
- 2 - 3/4" 90^{o}elbow

Tools:

- Drill and Drill bit (1/8")



1. CREATE THE BELL DOME.

	a) Take a 10” section of PVC (2”) and cut out 2 pieces using the angle grinder. This will set the height for the wet zone.

	b) Then, drill a hole (0.4” or 10mm in diameter) using a drill bit about 1.5cm from the two cut pieces.

	c) Finally, cap the other end of the bell using the PVC endcap/stopper (2”).

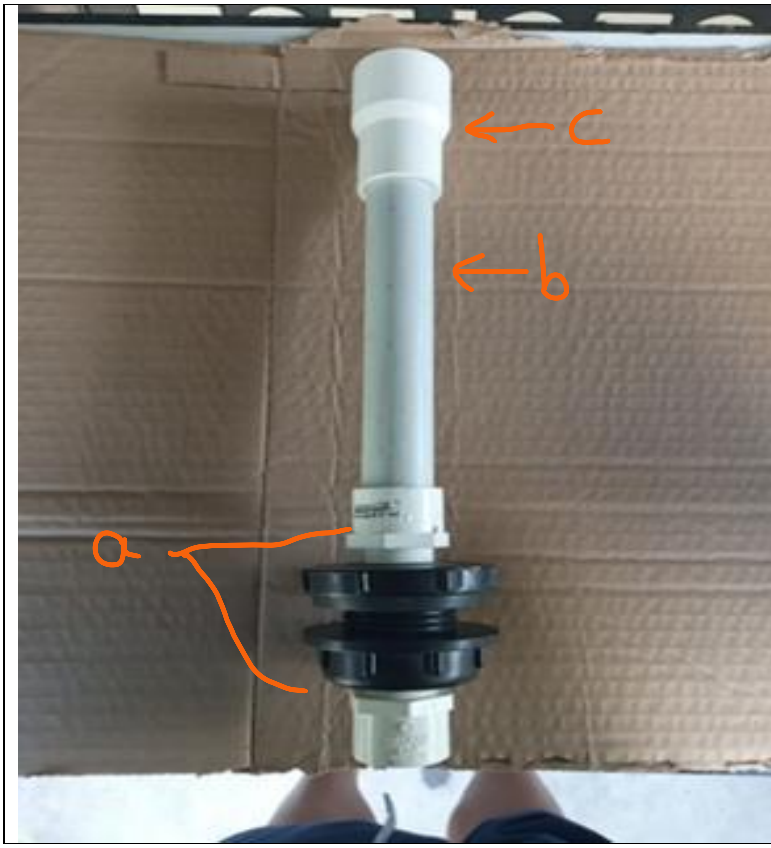
2. MAKE THE MEDIA GUARD

 	**Next, make the media guards**. Take the 13″ length of PVC pipe (3″ or 4″) and cut slots along their entire length using the angle grinder. This will allow water to enter the bell Siphon but keep the media from entering and clogging the system.

3. INSTALL THE BULKHEAD

		
a) Mark the centre point in the media bed. Drill a hole (3/4″ in diameter) at the centre point.	b) Insert the male of the bulkhead (3/4″) with the rubber washer placed inside the media bed.	c) Tighten a female adapter onto the male on the other side using a wrench

4. CREATE THE STANDPIPE



a) Screw two 3/4” male adapter one on the inside and one on the outside of the bulkhead.

b) Slot the standpipe into the PVC adaptor (3/4”).

c) Attach the flared reducer (3/4" to 1 1/2") to the top of the standpipe. The purpose of this adapter is to allow a larger volume of water to initially flow down the standpipe when the water has reached the top. This helps the siphon mechanism to begin draining the water out into the sump tank.

5. PUTTING IT TOGETHER

a) Install the Standpipe

b) Place the bell siphon over the standpipe

c) Place the media guard over the bell siphon and standpipe

	d) Finally, connect the ¾" PVC drain pipe to the other end of the male adapter underneath the media bed, which allows the water to flow out of the media bed. This then drains into the 2" mainflow channel which connects all the media beds' drain pipes.

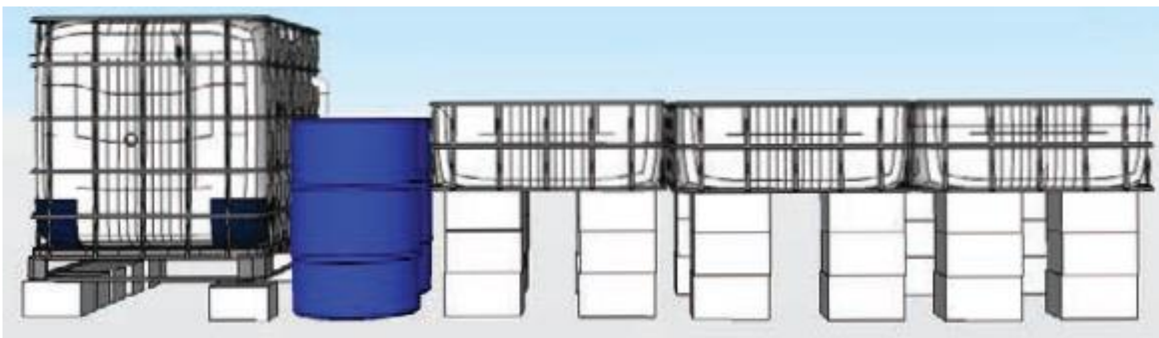
6. PLUMBING THE UNIT: MEDIA BEDS TO THE SUMP TANK (DRAIN PIPE)

For media bed, attach a drain pipe using an appropriate length of 2" PVC pipe to the elbow connection underneath the media bed, which exits from the bottom of the bell siphon standpipe. Next, slot an appropriate length of 2" pipe into a drilled hole on the side of the sump tank allowing the water to flow directly into the sump.

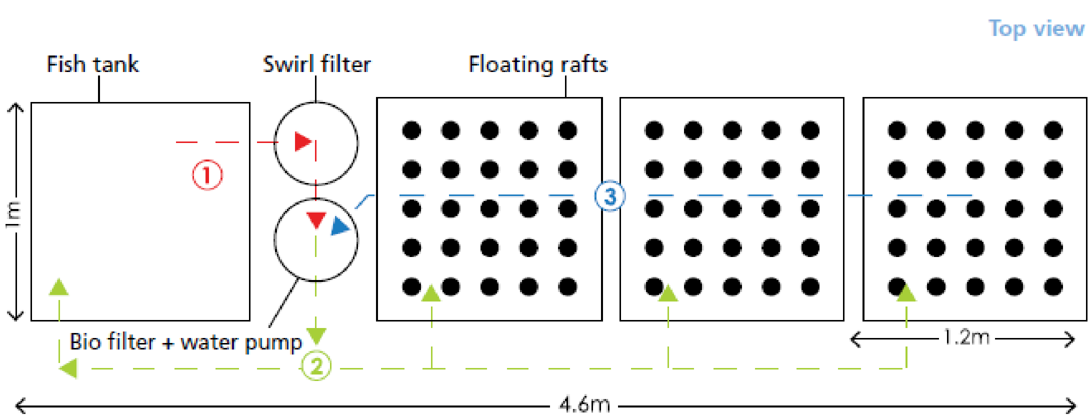
EXERCISE 8

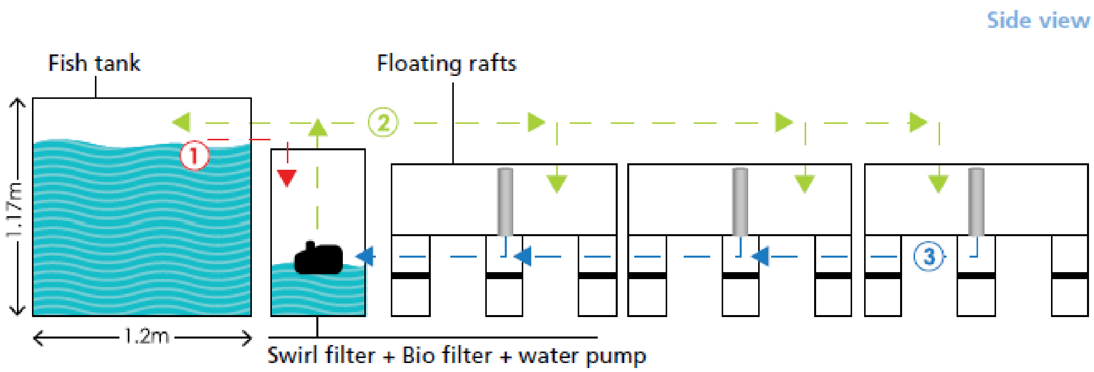
Conduct Exercise

THE DEEP WATER CULTURE (DWC) UNIT



Source: Food and Agriculture Organization of the United Nations (FAO)





Water flow diagram

1. Water flows by gravitation from the fish tank to the swirl filter and biofilter.

2. Water is pumped, using the submersible pump, from the biofilter to the fish tank (80% of the flow) and the DWC canals (20% of the flow).

3. Water flows back from the canals to the biofilter.

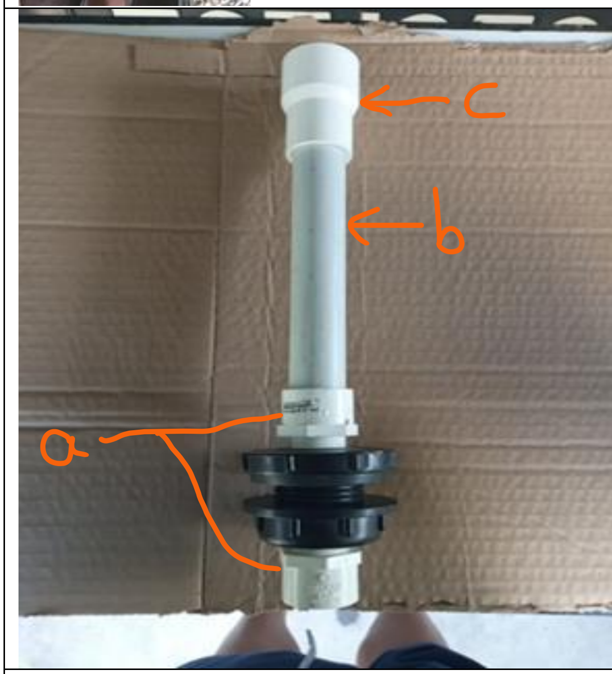
1. ASSEMBLING THE DWC CANALS

Place the concrete blocks 12" apart. The fish tank should be raised up about 6" from the ground; do so by using concrete blocks. Then, place the grow beds (including the metal support frames) on top of the blocks. (Make sure the grow beds are secure on top of the blocks. If not, slightly adjust the layout of the blocks underneath).

2. INSTALL THE BULKHEAD

		
a) Take each DWC canal and mark their centre points in the bottom of the container. Drill a hole (1" in diameter) at the centre point.	b) Insert the male of the bulkhead (1") with the rubber washer placed inside the media bed.	c) Tighten both sides of the connector using a wrench.

3. CREATE THE STANDPIPE

	a) Screw two 1” male adapter one on the inside and one on the outside of the bulkhead under the tanks
	b) Slot the standpipe into the PVC adaptor (1”). c) Attach the flared reducer (1" to 2") to the top of the standpipe. The purpose of this adapter is to allow a larger volume of water to initially flow down the standpipe when the water has reached the top.

4. PREPARING THE DRAINAGE PIPES INTO THE SUMP

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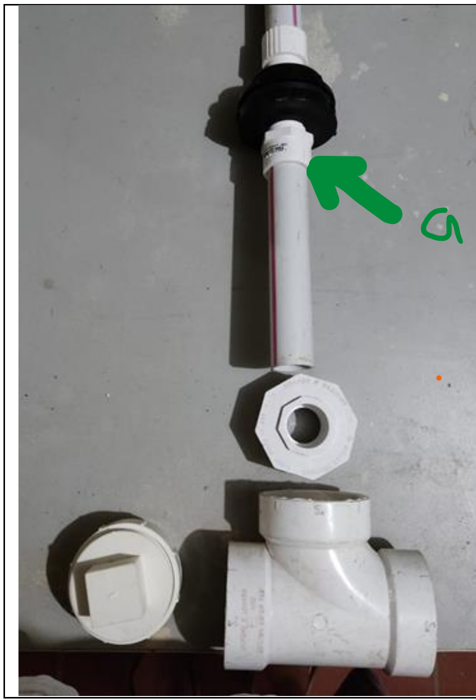
<td></td>
<td>Install DWC DRAIN PIPE

a) Connect a 1” PVC drain pipe to the other end of the male adapter underneath the media bed.

This allows the water to flow out of the media bed into the 2” mainflow channel which connects all the media beds’ drain pipes.</td>
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<td>b) Insert a 2” to 1” reducer at the top of each PVC T connectors.</td>
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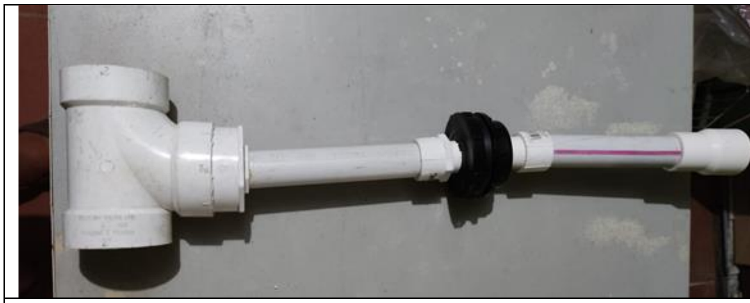
	c) Fix PVC T connectors underneath all the DWC canals.

	d) Install a PVC screwcap at the DWC canal T connector that is farthest from the fish tank. e) Take three pieces of 2” PVC pipe and connect the T-connectors underneath the canals.

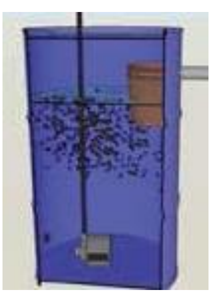
	f) Finally, connect the ¾” PVC drain pipe to the other end of the male adapter underneath the canals, which allows the water to flow out of the canals. This then drains into the 2” mainflow channel which connects all the canal drain pipes.

5. CONNECTING THE DRAINAGE PIPES INTO THE SUMP

Finally, drill a hole into the side of the sump barrel to take a 2″ uniseal using the Holesaw bit. This hole should be lower than the drain lines below the canals.

Then insert a 4″ piece of 2″ pipe into the uniseal and connect a PVC coupling on the outside. Then take one more piece of 2″ PVC pipe and connect the PVC coupling to the final T-connector underneath the tank.

6. ADDING THE SUBMERSIBLE PUMP TO THE SUMP



For this unit, the submersible pump is placed at the bottom of the sump barrel.

Water is pumped from there into two locations: the 3 DWC canals and the fish tank. 80 percent of the water flows to the fish tank while 20 percent flows into the plant canals. The taps are used to control the water flow at each location.

8. MAKING THE RAFTS

Key principles and rules of thumb for making the polystyrene rafts:

- All water in the canals should be fully covered (no exposure to light).
- Choose polystyrene sheets or PVC sheets that are thick enough to hold the weight of the vegetables.
- The sheets must not release any toxins to the water (make sure it is safe for food production or food-grade quality).
- Plant hole sizes and spacing are dependent on the type of vegetables to be planted. The planting hole size can range 2" to 3". This depends on the size of net cups available

	a) Place the polystyrene sheets or PVC sheets on top of the DWC canals and mark the edge lines. b) With a knife or a jig saw, cut the outline of the canal.

	c) Drill the plant holes using a circular drill bit. Along with planting holes, make sure to cut one hole for the standpipe of each canal

9. INSTALLING THE AIR PUMP AND STONES

For this unit, the air pump is used to integrate air into the DWC canals. The air pump should be placed into a protected box at the highest point in the system.

10. FINAL CHECKS

Once all parts of the system are in place, fill the fish tank, both filters and DWC canals with water and run the pump to check for any leaks in the system. If leaks appear, fix them immediately where they arise by: Tightening the plumbing connections. Checking all uniseals and taps for both filters. Reapplying Teflon to threaded connections. Making sure all valves are in their ideal position.

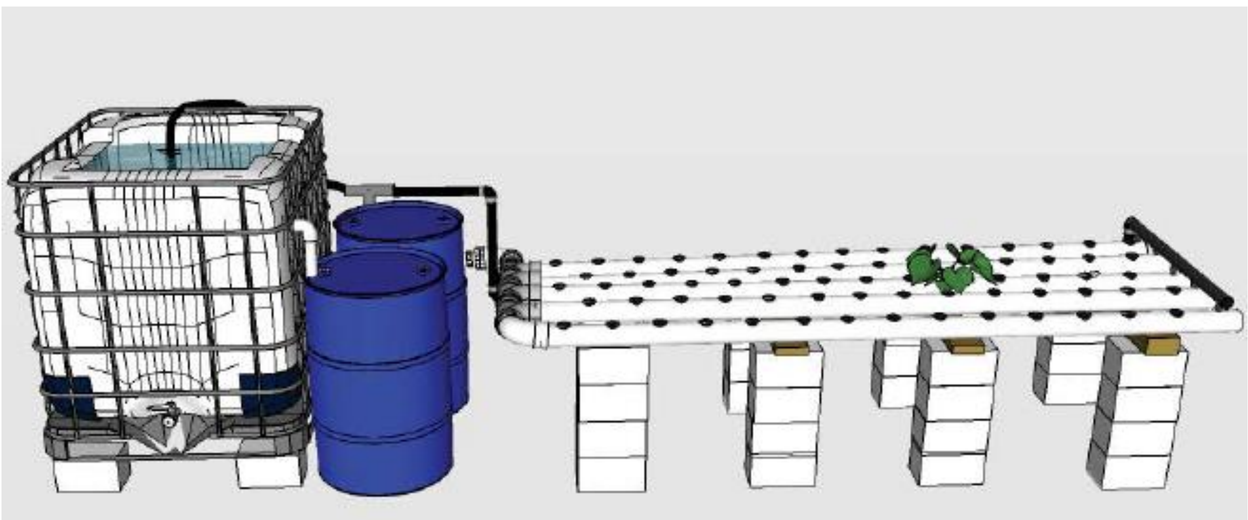
Finally, check the flow rates of the water flowing into each DWC canal. Knowing that the volume of each canal is about 300 litres, the ideal flow rate for each canal should be 75–300 litres per hour according to the 1–4 hour residency time.

Note: Water inflow can be measured by using a stopwatch and an empty 1 litre plastic bottle. At 75 litres/hour the 1 litre bottle should fill up in 48 seconds, at 300 litres/hour in 12 seconds.

EXERCISE 9

Conduct Exercise

THE NUTRIENT FILM TECHNIQUE (NFT) UNIT

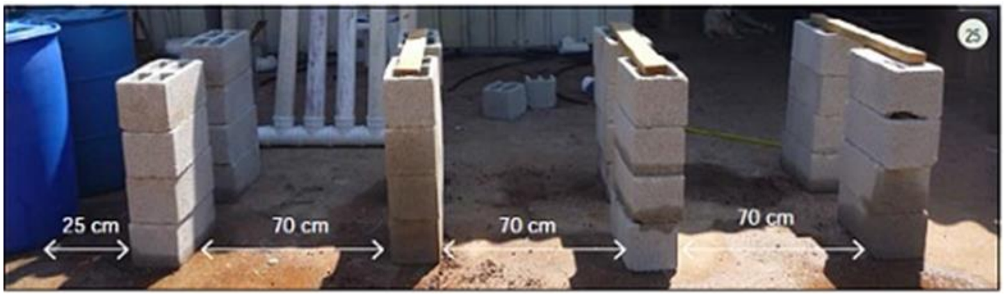


Source: Food and Agriculture Organization of the United Nations (FAO)

1. ASSEMBLING THE NFT PIPES

a) Measure the area you want to set up your system in.

b) Either purchase blocks or build a stand for housing the grow pipes.



Place the NFT pipes (4”) on top of the stand and attach to the base using a PVC Pipe Clamp

This arrangement will create a small slope allowing the water to easily flow through the pipes and return to the sump barrel.

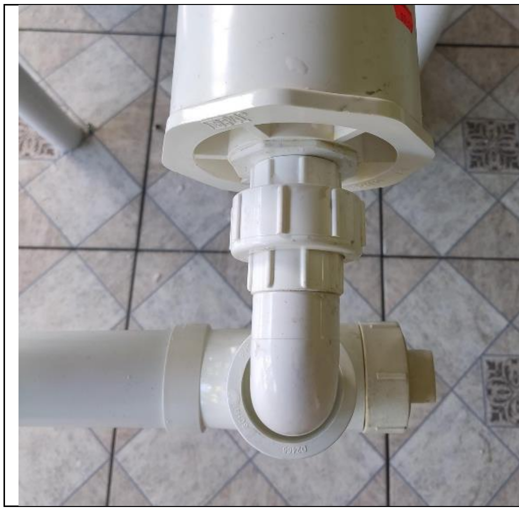
The recommended slope for a N.F.T. system is typically a **1:30 to 1:40 ratio**. That is for every 30 to 40 inches of horizontal length, one inch of drop (slope) is recommended.

2. MARKING THE PLANT HOLES

	a) Place the NFT pipes on top of the blocks and wood lengths. b) Stretch and secure a chalkline along the top of each pipe to mark uniform distances accurately.

	c) Mark a point every 10” along the pipe which will be the centre point for the holes.

	d) Drill the holes according to the size of the net pots. For optimal plant growing space, use a triangular pattern.

	e) Fit the end caps (4”) or Reducer (4” to 1”) to the ends of the pipe nearest and furthest from the fish tank.

	f) If an endcap is used, drill a hole 1” above the 4” PVC Pipe to insert the inflow and center for the outlet

3. CONSTRUCTING THE INLET DISTRIBUTION PIPING FOR EACH NFT PIPE

	a) Position his 2” PVC pipe 6” above the plant beds. The 2” line from the Biofilter is the water source to all the NFT Pipes. b) Split the main water source is split using PVC T (depending on the number of pipes in the system). c) Add a reducer (2” to 1”) to each PVC T.

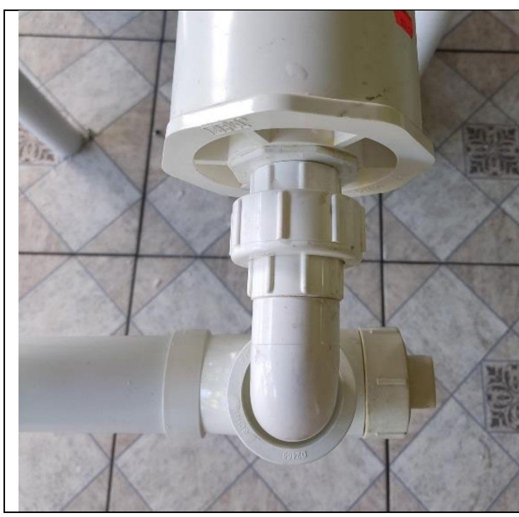
	d) Cut two 4” pieces of PVC pipe (1”). e) Insert one piece into the reduced PVC T. f) Add a 1” shut off valve and then insert the second piece of 1” pipe. The shut off valve controls the amount of water dispensed into the tubes, if the system is not completely level, you can adjust the tap to balance the water distribution in each tube.

	g) An elbow is then attached. h) Measure a 4″ piece of 1″ pipe and attach to the elbow. i) Attach another elbow and make a connection into the 4″ PVC Pipe Plant beds holding the plants using a 1″ coupling. **This is repeated for each NTF Pipe on the system.**

4. CONSTRUCTING THE OUTLET TO THE PIPES

The water from each bed is merged using PVC elbow (again depending on the number of pipes in the system.

This feeds into a main line that carries the outflow to the sump tank

	a) Fit the end caps (4″) or Reducer (4″ to 1″). b) Cut two pieces of 1″ pipe to a length of 6″ insert into the reducer. c) Add a 1″ union. This will allow foe easy dismantling and cleaning of the system. d) Insert the other 1″ pipe into the other end of the union and add a 1″ elbow. The water from each bed is merged using PVC elbow (again depending on the number of pipes in the system.

e) This main outflow line can be sized with a 2”- 4” pipe depending on the number of NFT pipes.

The greater the number the bigger the pipe that is used. Remember it is OK to oversize as it facilitates expansion.

This can be positioned 6” below the beds. This will allow for better drainage as the number of beds increase.

f) Cut a pieces of 1” pipe to a length of 6” insert into the elbow and a reduced 2” or 4” Tee

g) Install a PVC screwcap at the T connector that is farthest end to allow for cleaning.

h) The NFT pipes. Are connected together.

5. CONNECTING THE END OF THE GROW PIPES BACK TO THE SUMP

	**i) At the end of the main overflow line add a 2"- 4" PVC union.** **j) Then add 2"- 4" PVC elbow and insert PVC Pipe back to the sump.**

6. FINAL CHECKS

Once all parts of the system are in place, fill the fish tank, both filters and DWC canals with water and run the pump to check for any leaks in the system. If leaks appear, fix them immediately where they arise by: Tightening the plumbing connections. Checking all uniseals and taps for both filters. Reapplying Teflon to threaded connections. Making sure all valves are in their ideal position.

Finally, check the flow rate of the water flowing into each NFT pipe. The flow rate can be measured with a stopwatch and an empty 1 litre plastic bottle. A flow rate of 1–2 litres/minute, which is the standard in NFT pipes, should fill the bottle in 1 minute (1 litre/minute) or 30 seconds (2 litres/minute).

Clogging of the channels because of the roots

Roots dangling in the water are great for the nutrition and health of your plants. However, as they grow the plant's roots will also grow. Over time this can lead to the blockage of your channels, preventing water from getting to the rest of your plants and stopping your fish from getting the clean water they need.

In fact, a clogged channel can cause the death of your plants and fish! That's why only small plants are used in NFT channels like lettuce.

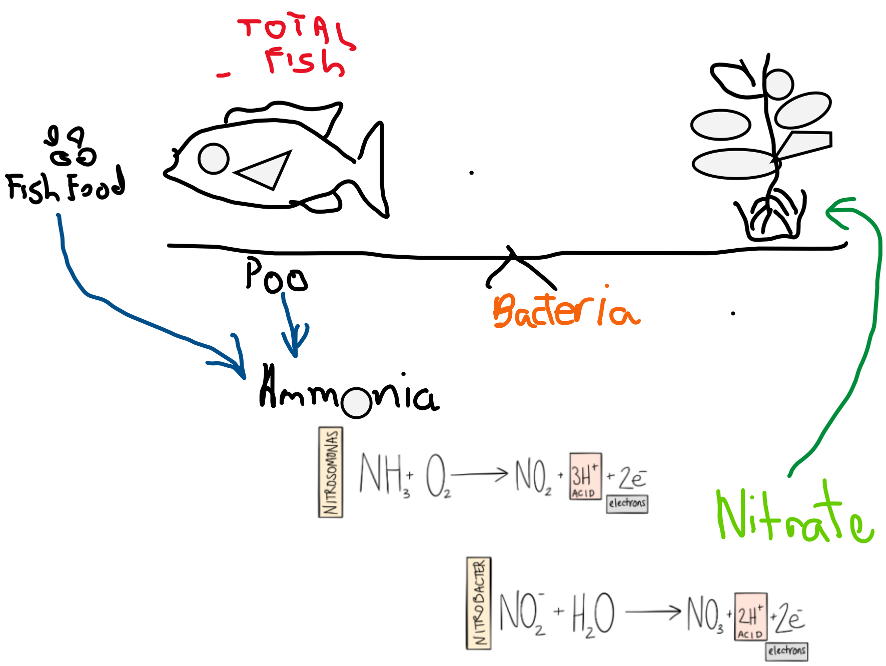
EXERCISE 10

Conduct Exercise

LET'S DO SOME KEY CALCULATIONS

BALANCING THE FISH AND PLANTS: COMPONENT CALCULATIONS

Recall that Aquaponic systems need to be balanced. The fish (and thus, fish feed) need to supply adequate nutrients to the plants; the number of plants should be adequate to use all the nutrients released, but not in excess to prevent any risk of deficiencies. The biofilter needs to be large enough to process all of the fish wastes, and enough water volume is needed to circulate this system.



This balance can be tricky to achieve in a new system, here we will provide sme helpful calculations to estimate the sizes of each of the components. The most successful way to balance an aquaponic system is to use the feed rate ratio. This ratio is the most important calculation for aquaponics so that the fish and plants can thrive symbiotically within the aquaponic ecosystem. The ratio estimates how much fish feed should be added each day to the system, and it is calculated based on the area available for plant growth. This ratio depends on the type of plant being grown; fruiting vegetables require about one-third more nutrients than leafy greens to support flowers and fruit development. The type of feed also influences the feed rate ratio, and all calculations provided here assume an industry standard fish feed with 32 percent protein. Lower-protein feeds can be fed at higher rates.

Although extremely helpful, this feed ratio is really only a guide, particularly for small-scale units. There are many variables involved with this ratio, including the size and type of fish, water temperature, protein content of the feed, and nutrient demands of the plants, which may change significantly over a growing season. These changes may require the farmer to adjust the feeding rate. Testing the water for nitrogen helps to determine if the system remains in balance. If nitrate levels are too low (less than 5 mg/litre), then slowly increase the feed rate per day without overfeeding the fish. If the nitrate levels are stable, then there may be deficiencies in other nutrients and supplementation may be required especially for calcium, potassium and iron. If nitrate levels are increasing, then occasional water exchanges will be necessary as nitrate rises above 150 mg/litre. Increasing nitrate levels suggest that the concentration of other essential nutrients is adequate.

QUESTION 1

How Many Fish To Balance Out The Number Of Plants In A Growing Space Of 240m^2?

In a correctly designed and balanced aquaponics system, the ratio between fish and plants is based on feeding rate ratio. The feed rate ratio is the amount of feed (g) fed to the fish daily per square metre of plant growing area.

In our system the Growing space available (m^2) is 240m^2

Assumptions

UVI Scientifically proven Feeding Rate = 60-100g/m^2/day.

Don't know what plants you will be using in the system so we will use a figure that is suitable for a broad range of plants: **Feeding Rate =75g/m^2/day.**

(1) Calculate DAILY INPUT

=Feeding Rate x Total amount of growing area

=75g/m^2/day x 240m^2 = 18kg/day

(2) Calculate YEARLY INPUT

=Daily Input x Days in year

= 18kg/day x365 = 6570 Kg/yr

(3) Calculate FEED CONVERSION RATIO

Feed conversion ratio will be based on the type of fish.

For Tilapia the Feed Conversion Ratio is 1.5-2 (depending on how good you are).

So reasonable Feed Conversion Ratio is 1.7

(4) Calculate Feed Conversion Efficiency

This is how efficient the fish is in converting its feed into biomass.

Tilapia Feed Conversion Efficiency Ratio = 0.59

So 59% of the feed input is going to be converted to fish biomass/ weight.

(5) From here we can determine the ANNUAL FISH WEIGHT GAINED by the amount of feed that we put in.

= YEARLY INPUT x FEED EFFECIENCY RATIO

= 6570 Kg/yr   x 0.59 = 3876 Kg of Annual Fish Weight Gain

(6) DETERMINE HARVEST WEIGHT

Desired Harvest Weight for Tilapia = 500g (1.1 lb)

(7) DETERMINE INITIAL STOCKING WEIGHT

From here we need to determine initial stocking weight ie what size are the fish going to be when you put them inside the Grow out tanks.

Normally the INITIAL STOCKING WEIGHT PER FISH = 50g

Note: If the fish is less than that at a small fry weight and we put them in to grow out its not going to consere space efficiently. So if less let them grow out in separate tanks to get to the initial stock weight.

(8) From Here Determine the AMOUNT OF WEIGHT THAT IS GOING TO BE GAINED from the initial stacking weight up to the desired harvest weight.

= Desired Harvest Weight for Tilapia – Weight at initial stocking

= 500 – 50 = 450 g (1lb)

(9) Determine the NUMBER OF FISH we can put into the system annually.

=Annual Fish Weight Gain / AMOUNT OF WEIGHT the fish needs to gain before harvest

=3876 Kg/ 0.450 KG = 8613 Fish Annually

(10) Determine the ANNUAL WEIGHT OF FISH

= Number of Fish Annually x Desired Weight

= 8613 x 0.5Kg =4306 KG Annual Fish Weight

(11) Determine Number of Harvest per Year

Assume Harvest Intervals for Talapia = 6 weeks

Number of Harvest per Year =52 weeks in a year/ 6 week harvest intervals = 8.7 harvests per year

(12) Determine the Weight of Fish per Harvest

= Annual Fish Weight / No of Harvest per Year

= 4306/ 8.7 = 495 KG of Fish per Harvest

(13) Determine the TANK VOLUME that is going to house that amount of fish

We choose 40 KG per m^3 as the Tilapia Stocking Density. You could go higher or lower, but this will pretty much maximize you fish and plant production.

Higher stocking densities require more sophisticated aeration techniques to keep the DO levels stable for fish as well as greater filtration.

TANK VOLUME = Fish Weight per Harvest/ Tilapia Stocking Density

= 495KG/ 40 KG per m^3 = 12 m^3 or 12000L

Reference Back to your design. If the Tank volume is less you will need to add and everything will be OK.

QUESTION 2

I want to produce 25 heads of lettuce per week in my aquaponic system. What is the growing area needed? What biomass of fish is required?

In order to produce 25 heads of lettuce per week, an aquaponic system should have 10–20kg of fish, fed 200grams of feed per day, and have a growing area of 4m^2. The calculations are as follows:

Lettuce requires 4 weeks to grow once the seedlings are transplanted into the system, and 25 heads per week are harvested, therefore:

25 heads/week x 4 weeks = 100 heads in system

Each 25 heads of lettuce require 1m2 of growing space, therefore:

100 heads x 1 m^2÷25 heads = 4 m^2

UVI Scientifically proven Feeding Rate Ratio = 60-100g/m^2/day. (Each square metre of growing space requires 60-100g of fish feed per day)

<u>Assumptions</u>

Don't know what plants you will be using in the system so we will use a figure that is suitable for a broad range of plants: Feeding Rate = 75g/m^2/day. therefore:

4 m^2 x 75 grams feed/day÷ $1m2$_ = 300 grams feed/day

The fish (biomass) in a system eats 1–2 percent of their body weight per day, therefore:

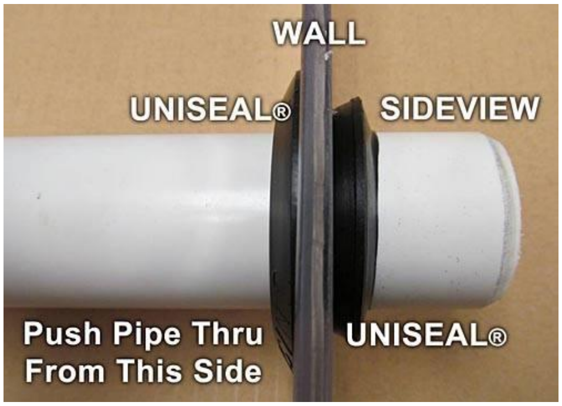
300 grams feed/day x 100 grams of fish ÷ 1-2 grams feed/day = 15-30 kg of fish biomass

ATTACHMENT 1

Uniseal and Hole saw sizing

Uniseal® Pipe and Holesaw Size Table

Uniseal® Size Sch 40 Pipe I.D.		Pipe O.D. Size *3		Holesaw Size Required			Available Metric Holesaws	Water Flow Per Minute
Imperial	Metric	Imp	Metric	Imp	Metric			
3/16"	4.75mm	0.250"	6mm	0.315"	8mm	*1	8mm drill bit	
1/4"	6.5mm	0.375"	9.5mm	0.5"	12.7mm	*2	13mm drill bit	
1/2"	12.7mm	0.84"	21mm	1.25"	31.7mm	*2	32mm holesaw	32 litres
3/4"	19.2mm	1.050"	27mm	1.25"	31.7mm	*2	32mm holesaw	50 litres
1"	25.4mm	1.315"	33mm	1.75"	44.4mm		44mm holesaw	73 litres
1 1/4"	32mm	1.66"	42mm	2"	50.8mm		51mm holesaw	115 litres
1 1/2"	38mm	1.9"	48mm	2.5"	63.5mm		64mm holesaw	160 litres
2"	51mm	2.375"	60mm	3"	76.2mm		76mm holesaw	250 litres
3"	76.2mm	3.5"	89mm	4"	101.6mm	*2	102mm holesaw	635 litres
4"	102mm	4.5"	114mm	5"	127mm	*2	127mm holesaw	1100 litres


WALL
UNISEAL®
SIDEVIEW
Push Pipe Thru
From This Side
UNISEAL®

ATTACHMENT 2

Tips for your aquaponics system

Use good construction materials

- Fiberglass is best but expensive
- The most popular tanks are made from plastic containers, modified IBCs or even old bathtubs
- Round fish rearing tanks are preferred over rectangular tanks as they are stronger and self-cleaning. IBC Totes are recommended.
- Hydroponic tanks can have concrete walls with HDPE liners, or half barrels or half IBC Totes. Remember to be cost effective and use what is available and recyclable.
- Remember it is important to wash the medium thoroughly These particles can clog the system and potentially harm the fishes' gills.
- Finally, it is important to work with material that is comfortable for you.

Apply sound Media bed construction praactice

Materials should be

- strong enough to hold water and growing media without breaking;
- able to withstand difficult weather conditions;
- made of food grade material that is safe for the fish, plants and bacteria;
- can be easily connected to other unit components through simple plumbing parts and
- can be placed in close proximity to the other unit components.

Shape: The standard shape for media beds is a square or rectangle, with a width of about 1m and a length of 1-3m. Larger beds can be used / manufactured, but they require additional support (i.e. concrete blocks) in order to hold their weight. The beds should not be so wide that you are unable to reach across, at least half-way.

***Depth**:* Media bed depth is important because it controls the amount of root space volume which determines the types of vegetables that can be grown. If growing large fruiting vegetables such as tomatoes, okra or cabbage, the media bed should have a depth of 12", without which the larger vegetables would not have sufficient root space, would experience root matting and nutrient deficiencies, and would probably topple over.

Small leafy green vegetables only require 6"–8" of media depth.

Choice of medium: All applicable growing media will have several common and essential criteria. These include:

- The medium needs to have adequate surface area while remaining permeable for water and air, thus allowing the bacteria to grow, the water to flow and the plants roots to breathe.
- The medium must be inert, not dusty, and non-toxic,
- it must have a neutral pH and inert (meaning the medium will not leach out any potentially toxic substances) so as not to affect the water quality.

- available and cost effective.
- easy to work with.
- lightweight, if possible.

Fish Stocking Density

40 KG per m^3 as the Tilapia Stocking Density

Use a feeding rate ratio for design calculations

- Keep feed input relatively constant by staggering stocking and harvest of each fish cohort.

Daily fish feed by plant type (Feeding Rate Ratio)

- Feeding rate ratio is the daily amount of feed per unit of plant growing area.
- The optimum Feeding Rate Ratio (UVI Aquaculture Programme): 2-3 $oz/yd^2/day$ or 60-100g of fish feed per square meter of plant per day

Fish feeding rate

- 1 to 2 percent of total body weight per day

Feed Conversion Ratio

- Feed conversion ratio (FCR) is the conventional measure of production efficiency: the weight of feed intake divided by weight gained by the animal. Lower FCR values indicate higher efficiency.
- **For Tilapia it is 1.5-2**

Feed Conversion Efficiency Ratio

- This is how efficient the fish is in converting its feed into biomass.
- Tilapia **FEED CONVERSION EFFICIENCY RATIO** = 0.59
- So, 59% of the feed input is going to be converted to fish biomass/ weight.

Remove solids

At least 25% of feed given to fish becomes solid waste, based a dry weight.

- The wet weight of sludge is much greater
- Remove solid waste before it enters the hydroponic component.
- Solids adhere to plant roots, create anaerobic zones and affect water and nutrient uptake and nitrifying bacteria.
- Decomposing solids consume oxygen and produce ammonia

Common Plant Densities

Here are some other common plant densities:

Lettuce – between 6 and 8 plants per square foot
Basil – between 3 and 12 plants per square foot
Cauliflower – between 3 and 5 plants per square foot
Cucumbers – between 1 and 2 plants per square foot
Eggplant – between 1 and 2 plants per square foot
Peppers – between 1 and 2 plants per square foot

Cabbage – between 3 and 4 plants per square foot

Supplement with calcium, potassium and iron

- Plants require 13 nutrients for growth. Fish feed supplies 10 nutrients in adequate quantities.
- Generally, supplement with Ca, K and Fe.
- Add Ca and K as bases – $Ca(OH)2$ and KOH
- Add Fe as a chelated compound or foliar spray

Ensure good aeration

- Fish, plants and bacteria require adequate dissolved oxygen (DO) levels for good health and growth.
- DO levels of 5 mg/L or higher should be maintained in the fish rearing tank and, in the water, surrounding plants roots.

Be careful with aggregates

- Aggregates such as pea gravel, sand and perlite are excellent media for growing plants. However, organic matter generated in aquaponic systems can clog aggregate media and channelize the flow. Clogged areas become anaerobic, killing plant roots.
- Dissolved organic matter and ammonia promote the growth of bacteria which can clog aggregates.

Oversize pipes

- Use oversized pipes to reduce the effects of biofouling. Growth of filamentous bacteria in pipes restricts the flow. Biofouling can even restrict water flow in 4-inch drain lines from fish tanks, causing water levels to rise.
- Pipes downstream from solids removal component are less likely to clog.

Use biological control

- Pesticides must not be used to control insects and plant diseases because they are not approved for fish culture.
- Therapeutants (chemical substances) for treating fish parasites and diseases should not be used because they may harm beneficial bacteria and vegetables may absorb and concentrate them.
- Biological control methods are the only option for controlling insects and diseases.
- Use hardy fish and best management practices to prevent fish disease and parasite problems.

Ensure adequate biofiltration

- In a raft aquaponic system adequate biofiltration occurs in the hydroponic component. When the optimum feeding rate ratio is maintained, there is excess waste treatment capacity.

- In aquaponic systems using Nutrient Film Technique (NFT) there is less surface area for nitrification, and a separate biofilter is needed.
- Separate biofilters are used when fish require excellent water quality.

Maintain adequate water exchange rates

- Rearing tank – 1 hour (UVI system – 1.37 hours)
- Clarifier – 20 minutes
- Deep flow hydroponics channels – unimportant as long as they are aerated
- Unaerated channels must have a faster exchange rate

Monitor and Maintain the Main Water Quality Parameters

There are five key water quality parameters for aquaponics: dissolved oxygen (DO), pH, water temperature, total nitrogen concentrations and hardness (KH). The range of parameters to maintain are:

- Dissolved oxygen (DO): 5–8 mg/litre
- pH. 6–7
- Ammonia 0 mg/litre
- Total Ammonia Nitrogen (TAN): <1 ppm
- Nitrite (NO_2): 0 mg/litre
- Carbon Dioxide: < 15 mg/L
- Nitrate (NO_3): 5–150 mg/litre
- Water Temperature: 18–30°C

Control pH in your system

- Nitrification is more efficient at pH 7.5 or higher and practically ceases at pH values less than 6.0.
- Nitrification is an acid producing process that continually decreases pH.
- pH must be measured daily, and base [$Ca(OH)_2$ and KOH] must be added to neutralize the acid.
- pH affects nutrient solubility.
- The optimum pH for nutrient solubility is 6.3-6.5.
- In aquaponic systems, pH 7.0 is recommended as a compromise.

Ensure power backup

- Have a smaller mobile generator that can run key aeration systems.
- Manually exercise the generator weekly and keep it fully fueled.