

Handbook for construction and operation of domestic scale aquaponic systems in the West Bank



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1. Introduction

Many communities in the occupied Palestinian territories (oPt) live at risk of food crisis. This is caused by a combination of economic factors preventing purchase of sufficient high quality food, and political and environmental factors preventing the proper development of the Palestinian agricultural sector. Bedouin communities, traditionally nomadic pastoralists who are increasingly finding themselves becoming settled, are amongst some of those people most at risk of food insecurity. Often these communities find themselves in areas with very poor soil quality, and severely limited access to water which prevents any form of community based subsistence agriculture of plant crops. Traditionally, these problems were mitigated by the nomadic lifestyle which allowed seasonal relocation to more fertile areas. However, with the loss of this lifestyle Bedouin communities find themselves in an increasingly vulnerable situation.

It is therefore important to promote strategies whereby marginalised communities may increase domestic food production, to both increase the variety of food consumed, and increase the quality of the diet. However, interventions to this end must be extremely resource efficient, and able to produce a worthwhile harvest without dramatically increasing the demand for water in unconnected communities.

2. What is aquaponics?

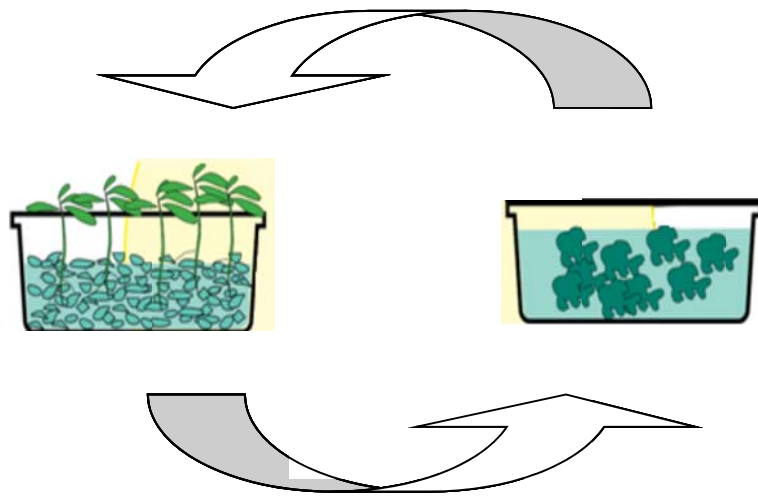
Aquaponics is a water efficient method for growing both fish and plants in a self-contained system. Aquaponics is a combination of two food production systems – recirculating aquaculture and hydroponics. The word aquaponics is made up from the words *aquaculture* and *hydroponics*.

Aquaculture = Fish farming

Hydroponics = Growing plants without soil, using a nutrient enriched water supply

Aquaponics = Growing fish and plants together in one closed system

	Intensive Aquaculture	Hydroponics	Aquaponics
Fish production	High densities, quick growth	No	High densities, quick growth
Plant production	No	High densities, quick growth	High densities, quick growth
Water efficiency	High	High	Very high
Wastes generated	Nutrient rich effluent water, possibly containing hormones and antibiotics	Pesticides and fertilisers in effluent water	Wastes processed in the system
Inputs used	Clean water, fish food, antibiotics, electricity	Clean water, chemical nutrient solutions, pesticides	Clean water, fish food, electricity



Aquaponic systems combine the benefits of recirculating aquaculture with those of hydroponic plant growth, while mitigating the disadvantages of both. Fish are fed, and produce nitrogen-rich wastes, which are carried in the water to the plant growing beds. The growing plants, and the medium in which they are grown, act as a bio-filter for the water in which the fish wastes are converted to soluble nutrients and then absorbed by the plants. The result is vigorous plant growth, and clean water ready to return to the fish tank. Thus, the waste of one biological system becomes the nutrient source for another.

2.1. Types of aquaponic system

There are three main types of aquaponic system, differentiated by the type of hydroponic plant-growing component used.

2.1.1 Floating Raft, or Deep Water Culture

Plants are grown in sheets of Styrofoam, which float on the surface of water-filled growbeds. Water from the fish tank is continually pumped into the growbeds, and continually overflows back into the fish tank. The growbeds need to be aerated at all times to prevent root rot. In addition, water must pass through a separate mechanical and biological filter prior to reaching the growbeds, to remove any particulate matter that could otherwise clog the plant roots.



2.1.2. Flood and drain

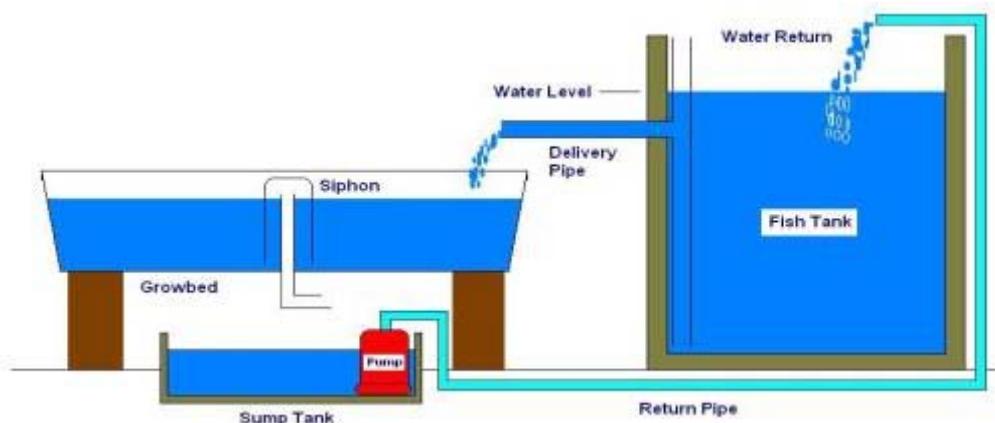
Plants are grown in a medium filled growbed. The substrate media serves two purposes – as the biological and mechanical filter, and as a support for the plants, which can root in it much like in soil.

The growbed is filled with water from the fish tank, and then drained. During the flood, water and nutrients are brought into the plant root zone. During the drain, air is drawn into the plant root zone, and the water returns to the fish tank.

The flood/drain cycle can either be controlled by running the pump on a timer, or by building an automatic draining device, called an *autosiphon* into the growbed.



A variation on the simple flood and drain setup is the CHOP (Constant Height One Pump) system. In a constant height system, the fish tank water level is higher than the growbeds, and water overflows from the fish tank into the growbeds. The growbeds then drain into a separate sump tank (the lowest part of the system) from which water is continually pumped back into the fish tank. Constant height systems offer several advantages over simple flood and drain systems: The water level in the fish tank stays constant at all times; the sump tank receives only filtered water draining from the growbed, and so the pump is much less likely to clog up with solids; there is a greater overall water volume, lending increased system stability.



2.1.3. Nutrient film (NFT)

Plants are grown in pipes through which a small amount of water is continually flowing. Water is pumped continually from the fish tank to a separate mechanical and biological filter (to remove any particulate matter that could otherwise clog the plant roots), and then on to the growing tubes, which continually drain back into the fish tank.



2.1.4. Characteristics of different types of aquaponic system

	Floating raft	Flood and drain	Nutrient film
Filtration	Additional filter needed	Provided by growbed	Additional filter needed
Plant support	Tall plants need wires/sticks	Provided by growbed	Tall plants need wires/sticks
Evaporation	Very low	Medium	Very low
Electrical failure	Eventual plant death from lack of oxygen	Plants have water and air around roots – can survive for a reasonably long time	Plant death from lack of water
Maintenance	Medium	Low	Medium
Biological and thermal stability	Higher overall water volume per unit growbed area gives greatest biological and thermal stability	Good	Pipes with thin film of flowing water can cause significant fluctuations in water temperature
Growbed options	Growbeds cannot be stacked	Growbeds cannot be stacked	Allows for very flexible configuration, including stacking pipes vertically

2.2 Aquaponic system components

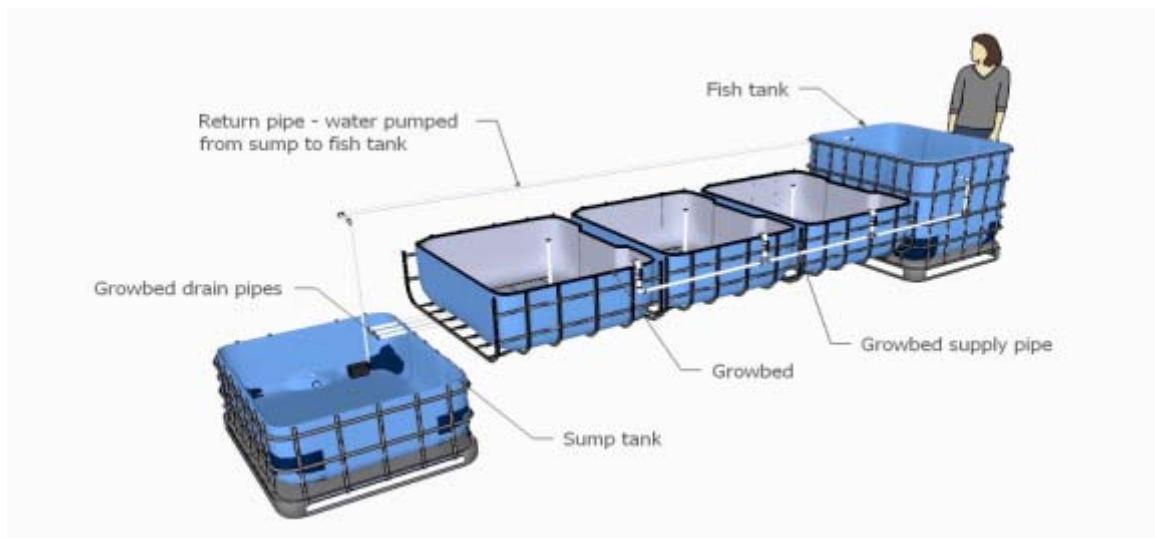


Figure 6: Aquaponic system components

Aquaponic systems all have several components in common:

- A fish tank – to house the fish.
- Growbeds – the hydroponic constituent in which the plants are grown.
- Pump – to move the water from the lowest part of the system to the highest.
- Plumbing through which the water moves.

Some aquaponic systems may also have:

- A sump tank – the lowest part of the system, in which water collects and the pump is located.
- Air pump – to ensure adequate oxygenation of the water.
- Growing medium – provides mechanical and biological filtration and plant root support in flood and drain growbeds.
- A solids separating filter – to remove solids before the water reaches the hydroponic growbed.

Aquaponic system components such as fish tanks, growbeds and sump tanks may be constructed from a variety of materials, from custom made, injection moulded parts to lined earthen pits. In the oPt, custom made parts would be prohibitively expensive, and thus render the system un-replicable by communities without external financial support. Pond liner is also very hard to locate in the oPt, and so despite the fact that lined wooden frames can make very economical options for growbeds, the difficulty of locating pond liner would also render this method un-replicable by communities. Intermediate Bulk Containers (IBCs) are cubic, palletized plastic containers, generally of 1m³ volume that are ubiquitously used to transport industrial quantities of liquid. As such they are readily available second-hand in the oPt, and often used by farmers for water storage. Their shape, strength, cost and availability make them ideal for use in aquaponic system construction - they can be cut to create growbeds, fish tanks and sump tanks. One point to note with re-used materials is to ensure that the previous contents were non-toxic (IBCs always display health and safety information for the original contents), and that they are cleaned very thoroughly prior to use.

2.3. Low cost, domestic scale aquaponic system design

The three different hydroponic methods that can be used in aquaponics each have advantages and disadvantages, which make them more or less appropriate for use in different situations. For the purposes of enhancing food security in marginalised Bedouin communities, the primary concerns are:

- Ease of operation and maintenance
- Affordability and replicability
- Water efficiency
- Thermal stability in fluctuating seasonal climates
- Ability to withstand power outages

Flood and drain aquaponic systems, particularly CHOP systems, have the lowest maintenance requirement, and also enable the production of a far wider variety of crops than the other two systems. However, they have the lowest water efficiency, and are prone to fluctuations in water temperature owing to the lower volume of water than an equivalently sized floating raft system. In the oPt the appropriate growing medium to fill the growbeds is the most expensive component of such a system. Floating raft systems offer higher water efficiency, and increase the overall thermal stability of the system; however, their requirement for an additional filtration system prior to the growbeds can introduce a more complicated system design and maintenance requirement. NFT systems can be incredibly space efficient, but expose plants to a high risk of desiccation in the event of a power failure.

As a CHOP flood and drain system requires a sump tank to collect the water in prior to returning it to the fish tank, the system lends itself to combination with a floating raft component: The sump tank becomes a dual purpose sump and raft tank; the flood and drain growbeds provide the mechanical filtration required prior to the water reaching the floating raft growbeds. By combining both growing techniques in one system it is possible to reduce the overall cost by reducing the requirement for growing medium, and increase the thermal stability of the system by increasing the water volume.

A system with 6m² growing area, and an approximately 800L fish tank has been shown to be an ideal size for domestic production in previous studies by the implementing contractor, enabling production of a significant quantity of vegetables and a standing crop of up to 24kg fish.

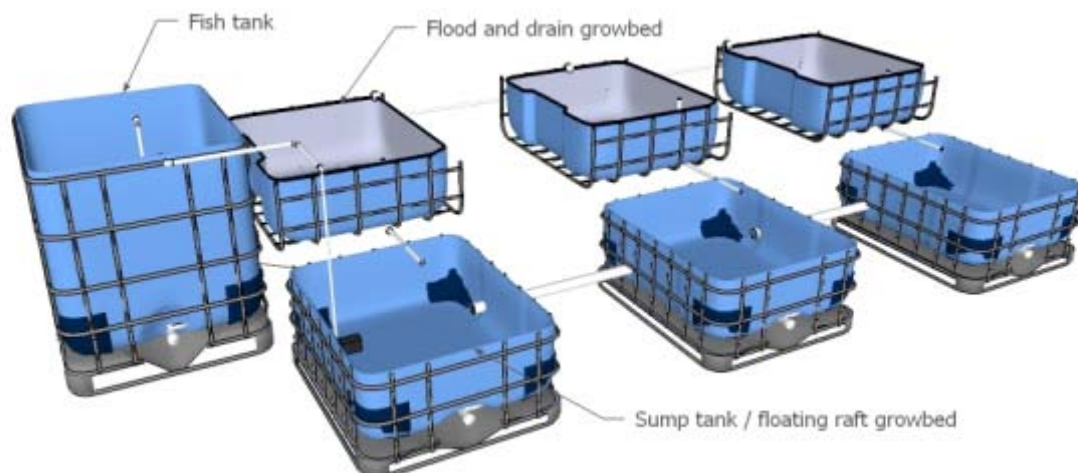


Figure 7: Diagram of the combined flood and drain/floating raft aquaponic system design used in this project

3. Construction of the aquaponic system

3.1: Site and household selection

Aquaponic systems are very appropriate technology for use in the oPt, and there is no “ideal” site – the system design can be modified to suit almost any environment, from rooftops to the desert. However, there are a few factors to take into consideration when identifying potential beneficiaries and locations:

- Availability of water, and water storage
- Availability of electricity
- Accessibility of the location to the beneficiary (i.e. if on a rooftop, are there permanent stairs?)
- Time and Interest level of the potential beneficiary – operation of an aquaponic system requires some investment on the part of the beneficiary in terms of factual learning and a commitment to daily maintenance/operation activities.

3.2: Prepare site

It is important that the aquaponic system components are positioned relative to the same “ground level”. The easiest way to achieve this is (if not building on an already level concrete surface such as a rooftop) is to first completely level the site. Levelling individual components with each other on an uneven floor is also possible, but far more time consuming in the long run.

3.3: Gather and prepare materials

If all the materials are prepared in advance, their assembly to construct the aquaponic system is fast and straightforward. Please refer to appendix 1 for a complete materials list for construction of the aquaponic system design presented in Figure 7.



Figure 8: Plumbing components required for construction of the domestic scale aquaponic system

3.3.1: Preparation of the IBCs

If the IBCs to be used are second hand, verify that the previous contents were non-toxic, and inspect them for any signs of damage, both to the plastic tank and to the metal frame and pallet – reject if they do not meet expectations.

Select one IBC for the fish tank. Using an angle grinder cut out and remove the top of the plastic liner, ensuring to leave the sides intact. Leave the plastic liner inside the metal frame.



Figure 9: Cutting IBCs

The remaining three IBCs will be cut as follows to make the flood and drain growbeds and floating raft/sump tanks:

- Remove the plastic liner from the metal frame
- Measure and mark a line all the way around the circumference of the plastic liner 50cm from the bottom (standing upright, the tap is at the bottom of the plastic liner), and draw a second, parallel line 15cm further towards the top (65 cm from the bottom)
- Cut the plastic liner carefully along these two lines. This produces two sections – a 50cm tray (the floating raft/sump tank) and a 35cm tray (the flood and drain growbed)
- The metal frame must now be cut; the “bottom” of the frame, including the pallet, will become the base and support of the flood and drain growbed, and so the frame should be cut so that the sides extend approximately 35cm above the pallet – the exact height will be determined by the geometry of the particular frame.
- The remaining “top” part of the frame should be cut to approximately 50cm; it will be placed around the floating raft/sump tank to provide lateral support.
- Thoroughly wash the insides of all the tanks; ensure that the taps seal, and seal the lids in place with strong flexible sealant such as silicone or Sikaflex™.

3.3.2: Laying out the components

Using 2 breeze blocks to support each corner, lift one of the IBC pallets, and associated plastic liner, to a height of 45cm above the ground level (distance from the floor to the bottom of the plastic liner). This is the first flood and drain growbed. Place one of the floating raft/sump tanks, inside its associated frame, immediately in front of this growbed.

Repeat to position the remaining two flood and drain growbed/sump tank pairs, leaving a space of approximately 80cm between pairs to provide adequate access. Make sure that the flood and drain growbeds are aligned with each other, and that the bottom of the plastic liners are levelled with each other, and levelled with themselves on both axes.



Figure 10: IBCs laid out in position

Roughly position the fish tank at one end of the row of growbeds as per Figure 7 and Figure 10.

3.4: System assembly

To facilitate cleaning, or any future modifications or relocation of the aquaponic system we would advocate minimising the use of glue or sealants, particularly PVC solvent cement which permanently welds PVC parts together. Assembling the system and checking for leaks will highlight areas that would benefit from gluing or sealing; if not completely necessary, then do not glue. All screwed connections will benefit from the use of PTFE tape, which lubricates and seals the joint.

3.4.1: Installing the autosiphons

Take one flood and drain growbed and drill a $\frac{3}{4}$ " hole in a flat area of the bottom, near a corner adjacent to the raft/sump tank and approximately 10-15 cm from the front and side walls of the growbed. Using an angle grinder, make an opening in pallet base in line with this hole, to allow for passage of the pipework (Figure 11). Place a 32mm to $\frac{3}{4}$ " thread PVC adaptor through the hole in the plastic liner such that the thread extends to the outside (bottom) of the liner. Seal the flange to the inside of the growbed using Sikaflex™ or equivalent.



Figure 11: cutting a hole in the pallet to make space for the pipework

Secure the adaptor in place with a $\frac{3}{4}$ " FF connector, and connect another 32mm to $\frac{3}{4}$ " adaptor to the vacant side of the $\frac{3}{4}$ " FF connector, using PTFE tape to seal the threads.

On the inside of the growbed, connect the siphon standpipe (pipe SS) to the PVC adaptor, and connect the 50mm/32mm reducing coupling to the top of this pipe. On the underside of the growbed, connect an elbow to the PVC adaptor using a 5cm "connector" section of PVC pipe. Connect the siphon drain pipe (pipe SD) to the elbow (see Figure 12, and drill a 32mm hole through the wall of the raft/sump tank to enable passage of this pipe. Cut the siphon drain pipe to extend just 3cm into the sump/raft tank, and connect a final elbow to direct the water flow vertically into the raft/sump tank. It is important to ensure that the siphon drain pipe runs **horizontally** or slightly downhill from the bottom of the siphon assembly to the raft/sump tank.



Figure 12: Siphon standpipe (top) and drain pipe (bottom) assemblies

Make the siphon bell tube (Figure 13) from the $\varnothing 75$ mm drainpipe length: Place the rubber grommet and cap into the wider end of the pipe (the "top") and cut the pipe 30cm from the sealed top. Drill four, evenly spaced 32mm holes around the bottom of the bell tube, as close to the bottom as possible. Place this tube in the growbed, around the siphon standpipe. Make a splash guard by taking the 20cm offcut

of 75mm pipe, and drilling a 32mm hole through the side near one end. Place this on the siphon drain pipe, sandwiched between the wall of the raft/sump tank and the elbow.

Make the siphon shroud pipe (Figure 13) from a 35cm long section of $\varnothing 110$ mm drainpipe, with multiple 8mm holes drilled around the bottom 10 cm of the pipe. Place this pipe around the siphon bell tube inside the growbed.

Repeat for the remaining two growbeds.



Figure 13: Siphon bell tubes (front) and shroud pipes (rear)

3.4.2: Connect the raft/sump tanks

Drill facing 60mm holes in the first and second sump tanks, as low down and as close to the back (adjacent to the flood and drain growbed) as possible. Fasten a 2" wall connector through each hole; screw a 2" FF adaptor on to each wall connector (on the outside of the raft/sump tank), and screw a 50mm to 2" PVC adaptor to each 2" FF adaptor. Use 50mm pipe (pipe H) to make the connection between the first and second raft/sump tanks. Repeat to connect the second and third raft/sump tanks.

3.4.3: Pump and growbed supply pipes

Using the schematic presented in Figure 14 assemble the 32mm pipework supplying the growbeds and fish tank.

- Pipe A connects to the $\frac{1}{2}$ " thread on the pump via a 32mm to $\frac{3}{4}$ " PVC thread adaptor followed by a $\frac{3}{4}$ " FF connector and a $\frac{1}{2}$ " to $\frac{3}{4}$ " FM adaptor.
- The pump is located **inside** the raft/sump tank nearest to the fish tank
- Drill a 32mm hole in the wall of the raft/sump tank for pipe B to pass through
- Connect the taps using 32mm to 1" thread PVC adaptors at points marked **Z** on Figure 14
- Use 5cm long connecting pieces at points marked **X** on Figure 14
- Pipe E supplies the fish tank; drill a 32mm hole in the top edge of the fish tank, approximately 3cm below the edge, to accommodate this pipe.
- The three taps leading from junctions between pipes F and G supply the flood and drain growbeds. Drill a 25mm hole in the back wall of each growbed, and sandwich the tap to the growbed by placing the 32mm to 1" thread connector (**Z**) on the **outside** of the growbed, and screwing the tap to it from the **inside**.
- It is important that pipes F and G, and the three taps, are completely level.
- The taps on pipes C and D enable isolation of the fish tank, and supplying the flood and drain growbeds directly from the raft/sump tanks should it be necessary.
- The vacant side of the 50mm tee fitting will be connected to the fish tank in the next step.

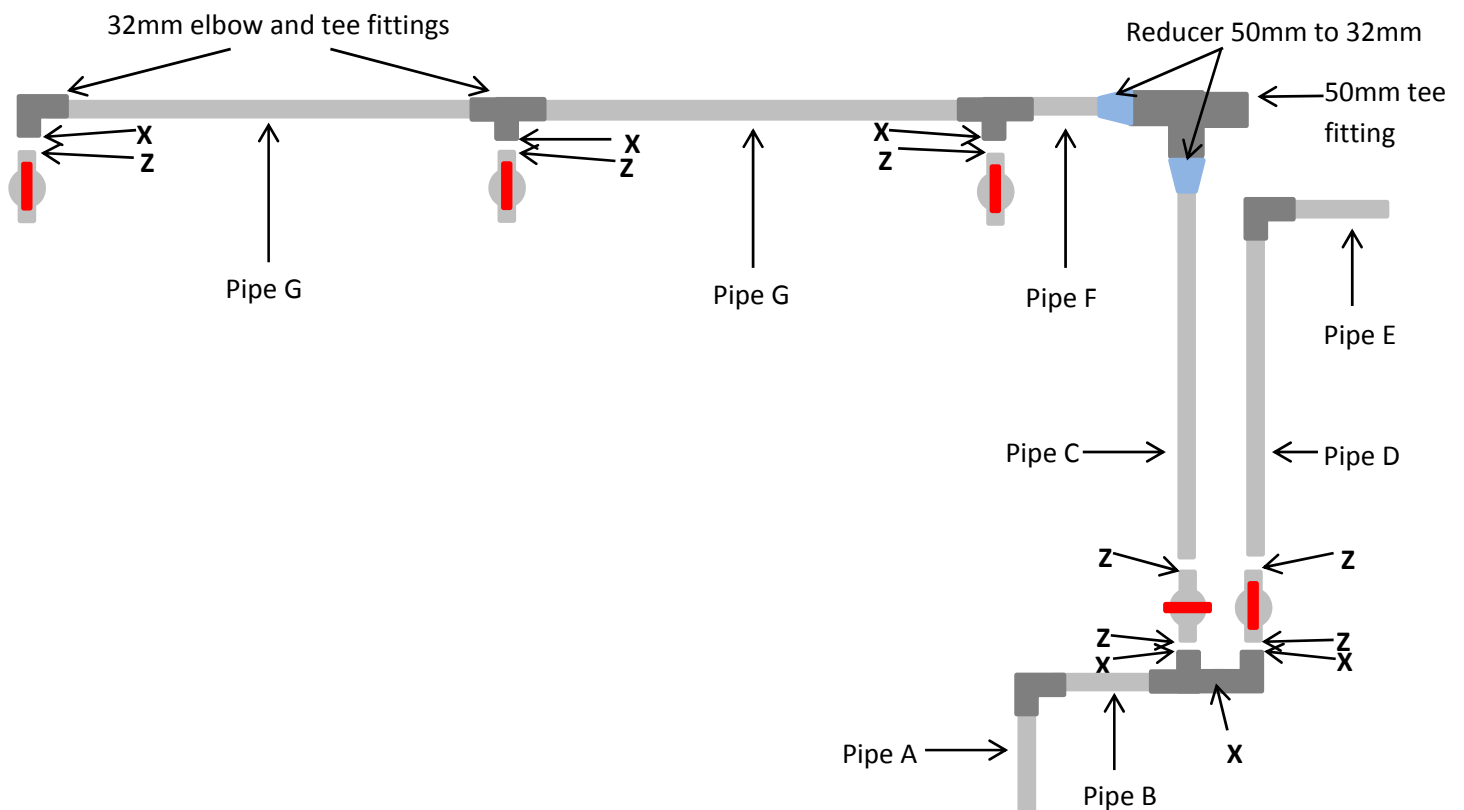


Figure 14: Pump and growbed supply pipe schematic

3.4.4: Fish tank drain pipe

The fish tank drain pipe supplies the growbeds with “dirty” water drawn off from the bottom of the fish tank (see Figure 15). Using a $\varnothing 50\text{mm}$ 6cm connecting pipe section, connect a 50mm PVC elbow to the vacant side of the 50mm PVC tee fitting from the previous stage. Using another $\varnothing 50\text{mm}$ 6cm connecting pipe section, connect a 50mm to 2” thread PVC adaptor to the elbow, and screw the 2” tap to this. Screw the 2” FM threaded elbow to the other side of the tap, and position the vacant end on the side of the fish tank, approximately 10cm below the top edge of the fish tank. Mark the position accurately, and drill a 60mm hole at this point. Connect the external plumbing through the wall of the fish tank using a 2” wall connector.

Loosely connect the 2" threaded tee to the 2" wall connector on the inside of the fish tank. Screw a 50mm to 2" thread PVC adaptor to one of the vacant sides of the tee. Select one of the pipes "J", and liberally perforate it with 8mm holes. Cap one end with the PVC 50mm pipe cap, and connect the other end to a 50mm elbow. Connect the un-perforated "J" pipe to the other side of the elbow, and connect this pipe to the tee assembly on the fish tank wall.



Figure 15: Fish tank drain pipe

3.4.5: Connecting to domestic water and electricity supplies

Drill a $\frac{1}{2}$ " hole in the wall of the raft/sump tank nearest the fish tank, approximately 20cm above the floor, and close to the pump. Through this hole, connect the ballcock valve on the inside to 16mm pipe on the outside, using a $\frac{1}{2}$ " to $\frac{3}{4}$ " FM threaded connector, an $\frac{3}{4}$ " FF threaded connector, and a $\frac{3}{4}$ " thread to 16mm barbed tap. Run 16mm pipe to the domestic water supply, and connect in the most appropriate manner, ensuring to provide a tap to enable control of the supply to the aquaponic system, and not interfering with the domestic water supply.

Run an electricity cable from the most appropriate socket in the house to the aquaponic system, and connect a triple socket for use by the aquaponic system. Locate the socket under a growbed to protect it from drips.



Figure 16: Raft/sump tank detail showing siphon drain pipe and splash guard (bottom left); pump plumbing assembly (top left) and ballcock valve (to the right of pump)

3.4.6: Air pump

Connect a short length of airline tubing, and an airline control valve to each of the 10 outlets on the air pump. Connect round airstones to 4 lengths of airline, long enough to reach from the control valves to the floor of the fish tank. Send two airlines from the control valves to each raft/sump tank, routing the airline through the raft/sump connecting pipes. In each raft/sump tank, connect two long airstones to the two airlines coming from the pump. Use a tee junction to enable connection of airline to each end of the long airstones.

3.4.7: Insulating and filling the system

Cut the aluminium coated bubble wrap into strips as follows:

- Three strips of 50cm x 410cm (for the raft/sump tanks)
- Three strips of 35cm x 410 cm (for the flood and drain growbeds)
- One strip of 100cm x 410cm (for the fish tank)

Place the bubble wrap, reflective side facing out, between each plastic tank and its metal frame. Cut holes to accommodate pipework where necessary.

The assembled system can now be filled with the growing medium and water. Rinse and sieve the volcanic rock to remove small particles and dust – the ideal grain size is no smaller than 1.5cm. Fill each flood and drain growbed with the rinsed volcanic rock to a depth of 30cm.

Fill the system with water, ensuring that there is enough water to keep the pump submerged.

3.4.8: Switching on

Connect the water pump to the electricity supply and ensure that water flows from the raft/sump tanks to the fish tank, from the fish tank to the three flood and drain growbeds, and from that the autosiphons in each flood and drain growbed function correctly. Identify and fix any leaks with PVC solvent cement, Sikaflex™ or silicone as appropriate.

Connect the air pump to the electricity supply, and adjust the control valves to ensure that the fish tank and each raft/sump tank is receiving adequate aeration.

3.4.9: Floating rafts

Cut the Styrofoam sheets to the size of the raft/sump tanks, allowing two sheets per tank. Drill 45mm holes through the Styrofoam in a staggered grid pattern, allowing approximately 20cm between holes. Float the sheets on the water in the raft/sump tanks.



Figure 17: Drilled Styrofoam sheet floating in raft/sump tank

4: Cycling the system and pH correction

Once the aquaponic system is constructed it is necessary to provide a source of ammonia to encourage the growth of the necessary bacteria in the growbeds. Dried goat manure is readily available in many communities in the oPt; a medium sized handful can be placed in each flood and drain growbed, under the water inlet. Now commences the daily monitoring of water quality, with a particular focus on ammonia ($\text{NH}_3/\text{NH}_4^+$), nitrite (NO_2) and nitrate (NO_3). After a few days, ammonia levels will spike and then start to drop off. Following the ammonia spike, nitrite levels will spike, and then also begin to drop off, and nitrate levels will rise. Once ammonia and nitrite levels are 0mg/l, and nitrate is increasing, the system is ready to be stocked. This process can take up to two months, but can be accelerated by bringing water and/or growing medium from an established system.

Concurrently with cycling the system, the water pH should be adjusted to the range of 6.8-7. If using rainwater this may not be necessary. However, groundwater in the oPt has a high pH (around 8.4) and a high alkalinity (KH over 280mg/l). The pH can be reduced by the careful addition of phosphoric acid (H_3PO_4) at a rate not to exceed 250ml/24 hours if there are no fish in the system, or 125ml/24 hours if the system has already been stocked with fish.

5: Stocking, feeding and planting

It is advisable to stock the aquaponic system in batches. After stocking fish it is important to monitor water quality on a daily basis for the next week, or until ammonia and nitrite levels return to 0mg/l. Only once ammonia and nitrite levels are 0mg/l should the next batch of fish be stocked. The system design presented here can be stocked with 50-60 fingerlings spread over two batches of 25-30 fingerlings, at least a week apart.

Fingerlings should be fed pellet feed at a rate of approximately 5% body weight per day, with the total feed distributed over two to three feeding sessions each day. If the fish do not consume all the food after about 30 minutes, excess food should be removed, and a lower amount provided at the next feeding. If the fish rapidly consume all the food then the weight of food given per day should be increased slightly. The maximum feed rate for the system presented here is 240g per day.

Plant growth is dependent on nutrient availability, and so the number of plants in the system should be increased gradually to reflect the increasing level of fish food being fed. Seeds can be sown directly into the flood and drain growbeds. Alternatively, seedlings can be transplanted to the flood and drain growbeds, or to perforated small plastic cups and placed in the holes in the Styrofoam.

6: Operation and maintenance

6.1: Daily tasks

- Visual inspection – check that the pump and aerator are working; check that water is flowing properly into each growbed; check that the sump tank water level is OK; check that the autosiphons are flowing properly.
- Feed the fish – make sure not to overfeed.
- Check the plants for pests and diseases, and treat appropriately.
- Harvest anything that is ready.
- Check and record water pH.

6.2: Weekly tasks

- Harvest, prune and support plants as necessary.
- Transplant seedlings to replace whole plants harvested (e.g. lettuces removed).
- Plant new seeds to replace seedlings transplanted.
- Check and record all water quality parameters (including pH and KH).
- If necessary, add acid or base to modify pH.
- Harvest fish as necessary.
- Apply foliar feed or safe pesticides such as molasses spray to all plants if necessary.

6.3: Monthly tasks

- Check siphon shroud pipes for plant roots, and if necessary clean them by running a knife around the inside.
- Clean all the pipework (growbed supply pipes, pump to fish tank pipe) using a large bottlebrush. Rinse them off and re-assemble.
- Net some fish for a visual health check.
- Stock new fish if necessary.
- Check buffering medium (eggshells etc.) if used, and add more if necessary.

7: System production potential

As aquaponic systems can be used to grow a variety of crops it is difficult to estimate the potential yields, as this depends on the nature of the crops grown, their value, growth rates and individual yields. However, it is possible to suggest an economic production potential assuming a lettuce monoculture. Lettuce is a relatively low value crop (current price 4ILS/head) with a quick growth rate (1 month in aquaponic systems). The system designed presented here has space to grow 180 lettuces simultaneously, i.e. produce up to 720ILS/month. Stocking the systems with 60 fish, to be harvested gradually (and replaced with new fingerlings) once they reach 500g, enables a total harvest of 30kg every 6 months. In the oPt, fresh fish can cost up to 50ILS/kg; assuming a price of 40ILS/kg this equates to 1200ILS in six months, or 200 ILS/month. Accounting for running costs (electricity, water and fish food) of around 4.4ILS/day, and the cost of lettuce seedlings (0.5 - 1 ILS for 5 seedlings) and fish fingerlings (2-2.3 ILS each), then an aquaponic system managed to produce only lettuces as the vegetable crop could generate around 750 ILS/month – equivalent to 87% of the average monthly household income in the community in which the project was implemented.

8: Lessons learnt

The aquaponic system design used in this pilot project was found to be very successful, and ideal for the environment in which it was used:

- Materials have been easy and economical to source.
- Construction is straightforward and replicable.
- The design allows for good access all round for trouble-free operation and maintenance.

However, during construction and implementation of the project several points came to light that warranted further work, and should be taken into account for future projects:

- An adequate fence should be provided to protect the system from grazing animals, and to prevent children entering unsupervised and causing damage.
- A strong structure should be provided on which to place shade for the summer months, and to provide structure on which to train climbing plants.
- An additional water storage tank should be provided to households in order to enhance the resilience of the system to disruptions in municipal or tanker water supply.



Figure 18: An operational aquaponic system. Note the fence and shade structure which could benefit from improvement.

Appendix 1: Parts list for domestic scale aquaponic system construction

Item	Quantity	Unit
IBC – 1m ³	4	Item
Breeze blocks – 15cm x 15cm x 40cm	24	Item
Volcanic rock	1.5	m ³
Aluminium coated bubble wrap	15	m ²
Water pump – Atman AT-105	1	Item
Air pump – Atman HP4000	1	Item
PVC elbow 32mm	10	Item
PVC elbow 50mm	2	Item
PVC tee 32mm	3	Item
PVC tee 50mm	1	Item
PVC 50mm to 32mm reducer	5	Item
PVC cap 50mm	1	Item
PVC 32mm to 1" thread adaptor	7	Item
PVC 32mm to ¾" thread adaptor	7	Item
PVC 50mm to 2" thread adaptor	6	Item
2" FF threaded tap	1	Item
1" FF threaded tap	5	Item
2" FM threaded elbow	1	Item
2" FFF threaded tee	1	Item
2" FF threaded connector	4	Item
2" wall connector	5	Item
¾" FF threaded connector	5	Item
½" to ¾" FM threaded adaptor	2	Item
¾" to 16mm barb tap	1	Item
75mm drain pipe, 0.5m length	3	Item
75mm drainpipe cap	3	Item
75mm rubber grommet	3	Item
110mm drainpipe	1.05	m
PVC pipe - 32mm		
A – 20cm	1	Item
B – 15cm	1	Item
C – 110cm	1	Item
D – 70cm	1	Item
E – 15cm	1	Item
F – 20cm	1	Item
G – 180cm	2	Item
SS – 18.5cm	3	Item
SD – 25cm	3	Item
Connector piece – 5cm	9	Item
PVC pipe – 50mm		
H – 60cm	2	Item
J – 73cm	2	Item
Connector piece – 6cm	2	Item

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