Appendix 8 – Step-by-step guide to constructing small-scale aquaponic systems

This step-by-step guide describes how to build the media bed, nutrient film technique (NFT) and deep water culture (DWC) systems for the small-scale aquaponic units described in Chapter 4 of this publication.

INITIAL COMMENTS ON THE THREE SYSTEM DESIGNS

The actual design theory for the three systems is explained in Chapter 4 of this publication. This appendix focuses solely on how to construct them using cheap materials that are widely available. In addition, it provides brief explanatory comments for some of the most complicated components of each system. 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. The main material used for fish tanks, media beds and DWC canals is the intermediate bulk container (IBC). This is a container with a capacity of about 1 000 litres used to transport different liquids worldwide. However, for all components of each unit design, local/cheaper materials can be substituted, but the recommendations for alternative materials stated in Chapter 4 of this publication should be followed.

There are three major sections to the appendix. The first section shows how to build the media bed unit using fabricated IBC containers for the fish tank, media beds and sump tank. The second section describes how to build an NFT unit. This includes how to set up the fish tank (same as the media bed unit), how to make and install a mechanical separator and a biofilter using polyethylene barrel containers and how to install the NFT grow pipes using standard 4 inch (110 cm) PVC drainage pipe. The third and final section shows how to build the DWC unit. The same fish tank design is employed along with the same swirl clarifier and biofilter described for the NFT unit. The other parts show how to set up the DWC canals and prepare rafts using polystyrene sheets.

An index of all materials and tools used for each section is given in the following pages which should be referred to for each of the major unit construction sections.

TABLE OF CONTENTS (Appendix 8)

INDEX OF MATERIALS

TABLE A8.1
Index of materials

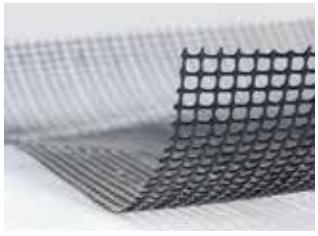
1	IBC tank		8	Ecological soap or lubricant	
2	200 litre barrel (blue)		9	Polystyrene sheet	
3	Shade material		10	Teflon (plumber's) tape	
4	Plastic netting		11	Cable ties	
5	Concrete block		12	Electric box (waterproof)	
6	Lumber (8×1 cm)		13	PVC pipe (110 mm)	
7	Submersible water pump (min. 2 000 litre/h)		14	PVC pipe (50 mm)	

TABLE A8.1 (CONTINUED)

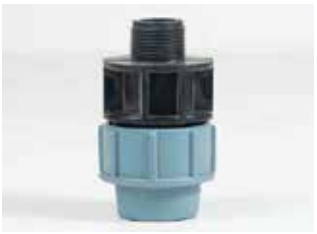
15	**PVC pipe (75 mm) with flaired end + PVC endcap (75 mm) + rubber washer (75 mm)**		22	**PVC adaptor (20 mm × 3/4 in) male**	
16	**PVC pipe (25 mm)**		23	**PVC elbow (25 mm ×1 in) female**	
17	**Polyethylene pipe (25, 20 mm)**		24	**PVC elbow (25 mm × 3/4 in) male**	
18	**Uniseal®** (50, 110 mm)		25	**PVC adaptor (25 mm × 3/4 in) female**	
19	**Sealing rubber washer (50, 110 mm)**		26	**PVC tap "push-on" (20 mm)**	
20	**PVC enlarger (40–25 mm)**		27	**PVC or metal tap (3/4 in) male to female**	
21	**PVC (25 mm ×1 in) female**		28	**Bucket (20 litre)**	

TABLE A8.1 (CONTINUED)

29	**Air pump (10 watt/h) with 2 exits**		36	**Net pot**	
30	**Air tubing**		37	**PVC elbow (50 mm)**	
31	**Plastic bottle**		38	**PVC coupler, straight (50 mm)**	
32	**Air stone**		39	**PVC connector, T (50 mm)**	
33	**Fish net**		40	**PVC endcap/ stopper (50 mm)**	
34	**Biofilter medium (Bioball® or bottle caps)**		41	**PVC elbow (110 mm)**	
35	**Gravel, volcanic (8–20 mm)**		42	**PVC connector, T (110 mm)**	

TABLE A8.1 (CONTINUED)

43	**PVC coupler, straight (110 mm)**	
44	**PVC reducer (110–50 mm)**	
45	**PVC barrel connector, B-type (1 in)**	
46	**PVC barrel connector, V-type (1 in)**	
47	**PVC or metal tap (1 in) male to female**	
48	**PVC elbow "push-on" (20 mm)**	
49	**PVC elbow (25 mm × 3/4 in) female**	
50	**PVC connector, T "push-on" (20 Mm)**	
51	**PVC endcap/stopper (110 mm)**	
52	**PVC adaptor (25 mm × 3/4 in)**	
53	**PVC connector, T (25 mm ×1 in) female**	
54	**PVC elbow (25 mm)**	
55	**PVC connector, T (25 mm)**	
56	**PVC elbow (25 mm ×1 in) male**	
57	**PVC connector, T (25 × 3/4 in) female**	

INDEX OF TOOLS

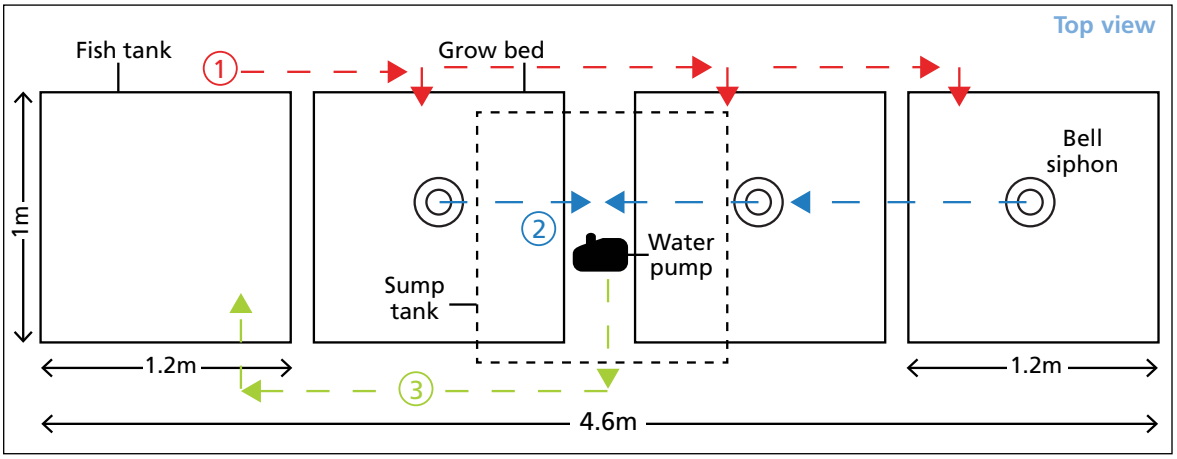
TABLE A8.2
Index of tools

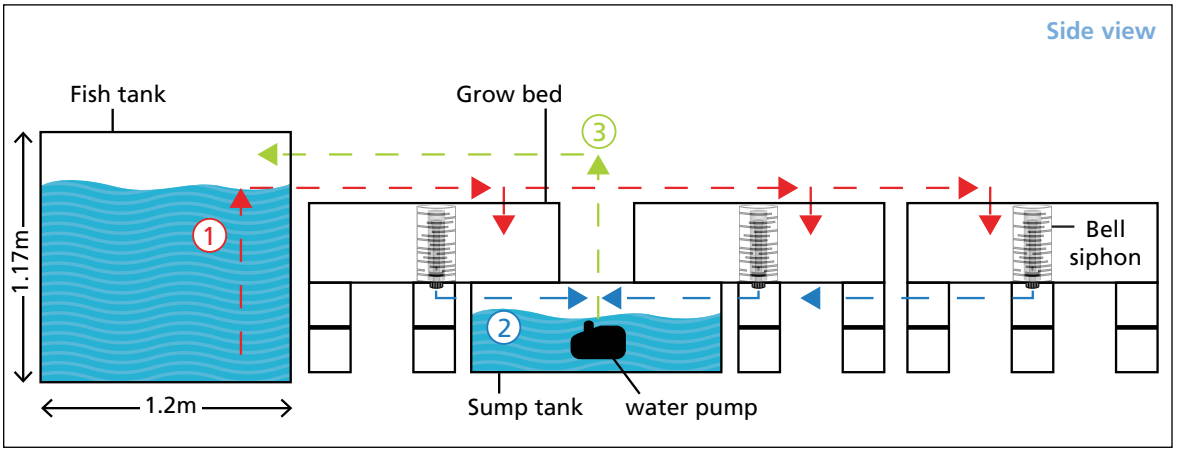
1	Ear protection		6	Pipe wrench	
2	Work gloves		7	Saw	
3	Safety goggles		8	Hammer	
4	Spirit level		9	Pliers	
5	Measuring tape		10	Screw driver	

TABLE A8.2 (CONTINUED)

11	**Electric drill**		
12	**Conical drill (0–1 in)**		
13	**Jigsaw**		
14	**Knife**		
15	**Marker**		
16	**Circular drill bit (hole saw)**		
17	**Angle grinder**		
18	**Star-headed key**		

SECTION 1 – THE MEDIA BED UNIT





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.

TABLE A8.3
List of items for the media bed unit

	Item name	Item No. from Table A8.1	Quantity
1	IBC tanks	1	3
2	Submersible water pump (MIN. 2 000 litres/h)	7	1
3	Air pump (10 watt/h) with 2 exits	29	1
4	Air tubing	30	3 m
5	Air stone	32	2
6	Concrete block	5	48
7	Lumber (8×1 cm)	6	21 m
8	Gravel, volcanic (4–20 mm)	35	750 litre
9	Shade material	3	2 m^2
10	Teflon (plumber's) tape	10	1 roll
11	Cable tie	11	15
12	Electric box (waterproof)	12	1
13	Ecological soap or lubricant	8	1
14	Plastic bottle	31	1
	PVC PIPE AND FITTINGS		
15	PVC pipe (50 mm)	14	7.5 m
16	Sealing rubber washer (50 mm)	19	1
17	PVC elbow (50 mm)	37	5
18	PVC coupler, straight (50 mm)	38	6
19	PVC connector, T (50 mm)	39	2
20	PVC endcap/stopper (50 mm)	40	4
21	PVC barrel connector, B-type (1 in)	45	3
22	PVC or metal tap (1 in) male to female	47	3
23	Uniseal® (50 mm)	18	1
	BELL SIPHON		
24	PVC pipe (110 mm)	13	0.9 m
25	PVC pipe (75 mm) with flaired end + PVC endcap (75 mm) + rubber washer (75 mm)	15	3
26	PVC pipe (25 mm)	16	0.8 m
27	PVC barrel connector, V-type (1 in)	46	3
28	PVC enlarger (40–25 mm)	20	3
29	PVC (25 mm × 1 in) female	21	3
30	PVC elbow (25 mm × 1 in) female	23	3
31	Polyethylene pipe (25, 20 mm)	17	9 m

1. PREPARING THE FISH TANK

1.1 – Remove the two horizontal steel lengths attached to the top surface of the IBC tank holding the inner plastic container in place. The steel lengths are fixed with 4 star-headed screws. Remove these four screws (Figure 1) using a star headed screwdriver (Figure 2) or star-headed key (Figure 3). Once the steel lengths are removed, pull out the inner plastic tank

If there is no star key, cut the screws with an angle grinder.


1


2


3

1.2 – After pulling out the tank, draw a rough square shape on the top surface of the tank 5 cm from the 4 sides of the tank (Figure 4). Then, using the angle grinder (Figure 5), cut along the square shape and remove the cut piece from the top (Figure 6). Once removed, wash the inside of the container thoroughly with soap and warm water and leave to dry for 24 hours (Figure 7).

The cut piece removed can be used as the fish tank cover.


4


5


6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2. INSTALLING THE FISH TANK EXIT PIPE

2.1 – On one side of the IBC tank, mark a point 12 cm from the top and 12 cm from the side of the tank (Figure 8), and drill a hole at that point using the 57 mm circular drill bit (Figure 9). Insert a 50 mm uniseal (Figure 10) inside this hole.

Attention: the circular drill bit size should be 57 mm and not 50 mm (see Figure 8).


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2.2 – The fish tank exit pipe is made of 2 lengths of PVC pipe (50 mm) combined using a PVC elbow (50 mm) and PVC coupler/straight connector (50 mm) (Figure 11). The length of PVC (50 mm) along the bottom surface of the tank is cut with horizontal slits 2–3 mm wide by using the angle grinder (Figure 12) to allow solid waste to enter the pipe but to prevent fish from doing so. The open end of the PVC length along the

bottom surface of the fish tank is sealed with a PVC endcap/stopper (50 mm). Slot a short length of PVC (50 mm) through the uniseal (50 mm) and attach to a PVC elbow (50 mm) on the inside end (Figure 11) and then attach the other (vertical) pipe length to the elbow that is now connected to the uniseal (50 mm). Finally, drill a 2–3 cm diameter hole into the PVC elbow (50 mm) attached to the uniseal (50 mm) (Figure 13). 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 is also called an accidental siphon. This step is not optional.


11


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3. PREPARING THE MEDIA BEDS AND SUMP TANK

To make the 3 media beds and 1 sump tank, the 2 other IBC tanks are needed: the first to make the sump tank and 1 media bed, and the second to make the two remaining media beds. Take the 2 IBC tanks and remove the 4 steel profiles and pull out the plastic containers as shown before in Figures 1–3.

4. MAKING TWO MEDIA BEDS FROM ONE IBC

First, stand the plastic inner container upright (Figure 14) and mark, using a metre stick and pencil, two bisecting lines 30 cm from both sides of the tank (as seen in Figure 15). Make sure to mark the exact lines (shown in the Figure 15). Take the angle grinder and carefully cut along both bisecting lines marked out to create two uniform containers with a depth of 30 cm (Figure 16). Then, take both containers and wash them thoroughly using natural soap and warm water and leave them out to dry in the sun for 24 hours.


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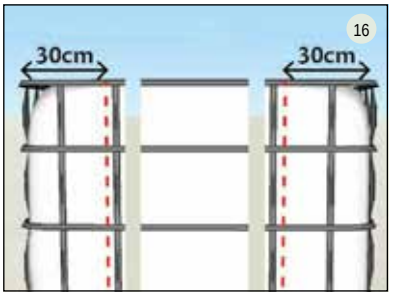


16

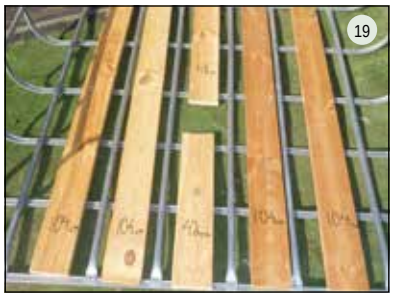
5. METAL SUPPORTS FOR BOTH MEDIA BEDS

5.1 – Take the IBC metal support frame and cut out two support frames by following the same bisecting lines shown in Figure 14 using the angle grinder (Figure 17). When cutting the two 30 cm sides of the support frame, make sure to keep the two horizontal steel profiles intact as they will provide excellent support to the sides of the beds once they are full of water and medium (Figure 18).


17


18

5.2 – Then, take both support frames and lay them out on the floor. Take the wood lengths (4 lengths of 104 cm, 1 length of 42 cm and 1 length of 48 cm) and place them on top of the support frame as shown in Figure 19. These wood lengths keep the media bed horizontal, which is vital for the functioning of the bell siphons. Next, take the washed media beds and place them on top of the support frame and wood lengths (Figure 20). Finally slot in the remaining wood lengths in between the plastic media bed and support frame on both sides of each bed to provide further support (Figure 21).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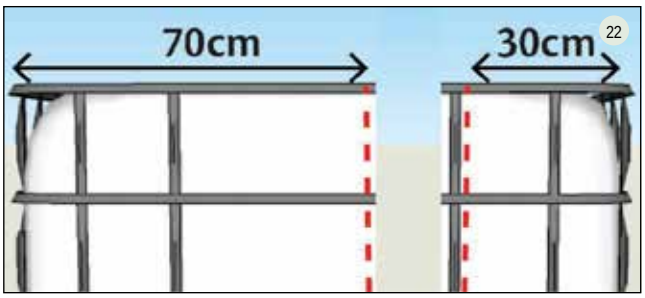
6. MAKING A SUMP TANK AND ONE MEDIA BED FROM AN IBC

6.1 – Take the remaining IBC, place it upright and mark out, using a metre stick and pencil, only one 30 cm bisecting line as seen in Figure 22. Then, take the angle grinder and cut the inner plastic container and metal support frame at once by following the bisecting line (see Figure 22). Remove the 30 cm container (third media bed) from the remaining 70 cm container (sump tank) (Figure 23). Wash out both containers thoroughly with natural soap and warm water and leave in the sun for 24 hours.



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6.2 – For the third media bed, follow the same steps regarding the wood lengths as detailed above for the first two. Finally, take the sump tank container and drill two holes (25 mm diameter) using the conical drill bit as shown in (Figure 25) (25 mm pipes will be inserted into both of these holes later, the pipes will drain water from each media bed).


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7. PREPARING THE BELL SIPHONS

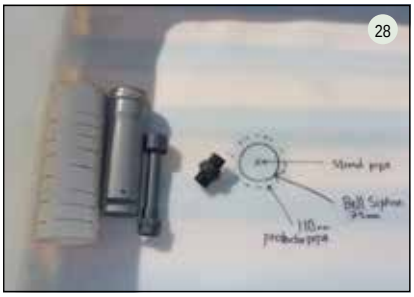
As explained in Chapter 4 of this publication, bell siphons are simple mechanisms used to automatically flood and drain each media bed. The following materials are needed to make one siphon, so 3 of each are needed in total:

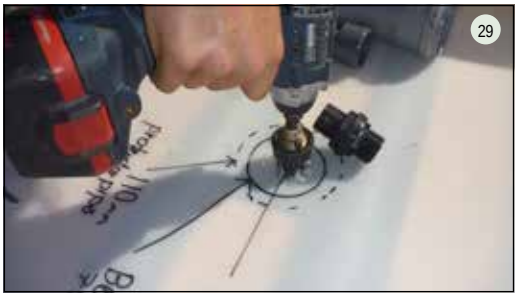
- 35 cm media guard (110 mm PVC pipe)
- 27 cm bell [PVC pipe (75 mm) with flaired end + endcap/stopper (75 mm) + rubber washer (75 mm)]
- 16 cm standpipe (25 mm PVC pipe)
- Barrel connector (25 mm)
- PVC reducer (40–25 mm)
- PVC female adaptor (25 mm × 1 inch)
- PVC elbow (25 mm × 1 inch female)

7.1 – First, create the bell. Take a 27 cm section of PVC (75 mm) and cut out 2 pieces as shown in Figure 26 using the angle grinder. Then, drill a hole (10 mm in diameter) using a drill bit about 1.5 cm from the two cut pieces as shown in Figure 26. Finally, seal one end of the bell using the PVC endcap/stopper (75 mm) and rubber washer (75 mm).

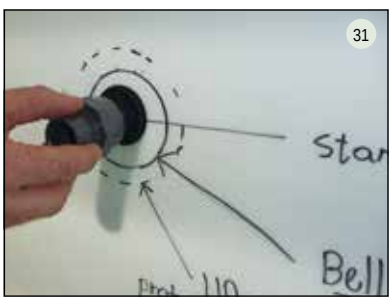
7.2 – Next, make the media guards from the 35 cm length of PVC pipe (110 mm) and cut 5 mm slots along their entire length using the angle grinder (Figure 27).

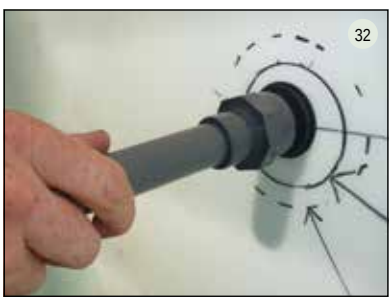
7.3 – Now, take each media bed and mark their centre points in-between the two wooden lengths below as shown in Figure 28. Drill a hole (25 mm in diameter) at each centre point (Figure 29) and insert the barrel connector (25 mm) with the rubber washer placed inside the media bed. Tighten both sides of the barrel connector using a wrench (Figure 30).





7.4 – Screw the PVC adaptor (1 inch – 25 mm) onto the barrel connector (25 mm) inside the media bed and then slot the standpipe into the PVC adaptor (1 inch – 25 mm). After, attach the second PVC adaptor (25–40 mm) to the top of the standpipe (Figures 31–33). The purpose of this adapter is to allow a larger volume of water to initially flow down

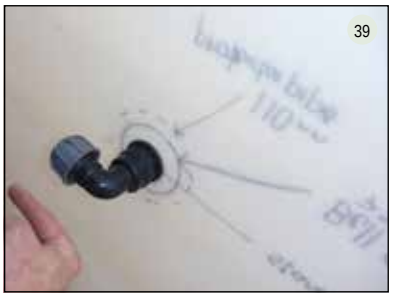




the standpipe when the water has reached the top. This helps the siphon mechanism to begin draining the water out into the sump tank.

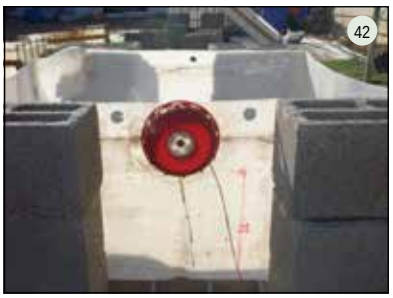
7.5 – Place the bell siphons and the media guards over the standpipes (Figures 34–36).

7.6 – Finally, connect the PVC elbow (1 inch–25 mm) to the other end of the barrel connector underneath the media bed, which allows the water to flow out of the media bed (Figures 37–39).



8. ASSEMBLING THE MEDIA BEDS AND SUMP TANK

8.1 – First, place the sump tank and brace it with six concrete blocks from each side (12 blocks in total) as shown in Figures 40 and 41. Make sure the blocks do not cover the holes already drilled into the sump tank (Figure 42).



8.2 – Place the remaining blocks and the fish tank according to the distances described in Figure 43. The fish tank should be raised up about 15 cm from the ground. This can be done by using concrete blocks as shown in Figure 43. Place the three media beds (including the metal support frames and wood lengths) on top of the blocks (as shown in Figure 44). Make sure the grow beds are secured on top of the blocks and horizontal by verifying with a spirit level. If not, slightly adjust the layout of the blocks underneath.

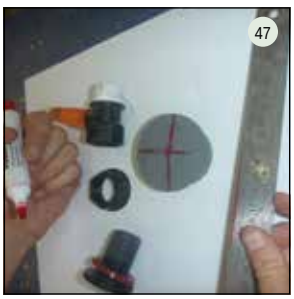
9. PLUMBING THE UNIT: FISH TANK TO THE MEDIA BEDS (DISTRIBUTION MANIFOLD)

9.1 – The plumbing parts needed for this section are as follows:

- Barrel connector, B-type (1 inch) × 3
- PVC tap (1 inch) × 3
- PVC endcap/stopper (50 mm) × 3
- PVC elbow (50 mm) × 2
- PVC connector, T (50 mm) × 2
- PVC coupler (50 mm) × 3
- 150 cm of PVC pipe (50 mm) × 1
- 85 cm of PVC pipe (50 mm) × 1

9.2 – Go back to the "preparing the fish tank" (2.2) instructions. The last instruction shows a length of PVC (50 mm) slotted through the uniseal (50 mm) and exiting the fish tank. Take another PVC elbow (50 mm) and connect it to the pipe slotted through the uniseal (Figure 45). Then, using a PVC straight coupler (50 mm) and another PVC elbow (50 mm), connect the fish exit pipe to the distribution pipe (50 mm) at the same height as the top of the media bed (Figure 46).

9.3 – On each media bed, a valve is used to control the water flow entering the bed. To include a valve, first take a PVC endcap/stopper (50 mm) and drill a hole (25 mm diameter). Insert a barrel connector (25 mm) into the hole and tighten both ends using a wrench. Then, wrap Teflon tape around the threads of the male end of the barrel connector and screw the tap valve (1 inch) onto the barrel connector (Figures 47–50). There is one valve for each media bed for a total of three valves.



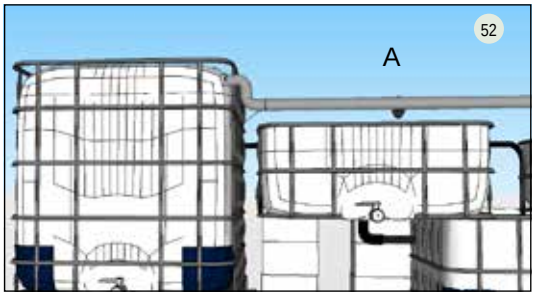
9.4 – From the PVC elbow (50 mm) attached to the fish exit pipe, follow the pipe layout shown in Figure 51 that allows water to flow into each media bed. Materials include: PVC pipe (50 mm), PVC elbow (50 mm) and PVC T-connector (50 mm). Next, attach the pipe caps fitted with the valves to the PVC T connectors and PVC elbow connectors from the distribution pipe as in Figure 51, using one for each media bed. Use a PVC straight coupler (50 mm) if necessary.

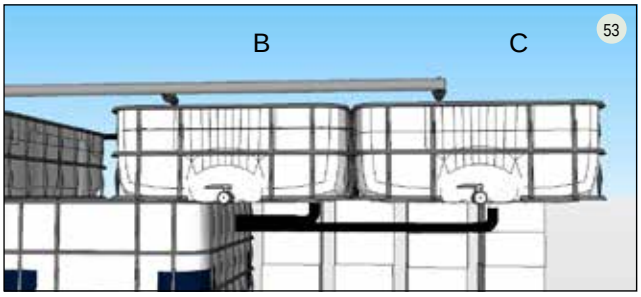
10. PLUMBING THE UNIT: MEDIA BEDS TO THE SUMP TANK (DRAIN PIPE)

10.1 – Figures 52 and 53 show the media beds marked as A, B and C. For media bed A, attach a drain pipe of 60 cm length of PVC pipe (25 mm) to the elbow connection underneath the media bed (Figure 54), which exits from the bottom of the bell siphon standpipe. Next, slot the 60 cm length of pipe into the closest drilled hole on the side of the sump tank allowing the water to flow directly into the sump.

10.2 – Attaching media beds B and C (Figure 53): Under media bed C: attach a PVC elbow connector (25 mm to 1 inch) to the end of the barrel connector (Figure 54). Then, take a 2 metre length of polyethylene pipe (25 mm) and attach it to the drilled holes at the side of the sump tank (Figure 53 and 55).

10.3 – Do the same with media bed B using 1 metre of polyethylene pipe (25 mm) (Figure 55). Now, the water exiting media beds B and C will flow through separate polyethylene pipes (25 mm) into the sump tank.





Finally, it is advisable to fix the pipes underneath the beds to the metal frame using cable ties to relieve any pressure on the pipe fittings (Figure 54).

11. PLUMBING THE UNIT: SUMP TANK TO THE FISH TANK

11.1 – Take the submersible pump and attach a polyethylene pipe (25 mm) using a PVC straight connector (1 inch – 25 mm), or any other connector that can attach the specific pump to the 25 mm pipe (Figure 56). Take a length of the polyethylene pipe (25 mm) that is long enough to reach the inside of the fish tank from the submersible pump (Figure 57). Attach one end to the submersible pump and the other into the top of the fish tank (see Figure 57–60). It is recommended to use the fewest connectors, especially elbows, between the pump and fish tank which will decrease pumping capacity.

11.2 – Place the electric box in a safe place higher than the water level and shaded from direct sunlight. Make sure it is still waterproof after plugging in the water and air pump plugs (Figure 61).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12. ADDING THE MEDIUM AND RUNNING THE UNIT

12.1 – All parts of the system are now in place except for the growing medium (volcanic gravel) in the beds. Yet before the media is added, it is recommended to fill the fish tank and sump tank with water and run the pump to check for any leaks in the system. While checking for leaks, remove the standpipe and bell siphon so the water flows straight into the sump tank. If leaks appear, fix them immediately where they arise by tightening the plumbing connections, re-applying Teflon to the treaded connections and making sure all taps are in their ideal position (Figures 62–67).

12.2 – Once all the leaks are fixed and the water is flowing smoothly through all components of the unit, re-assemble the siphon bell and standpipes fill the beds with medium to a depth of 30 cm (Figures 68–69)


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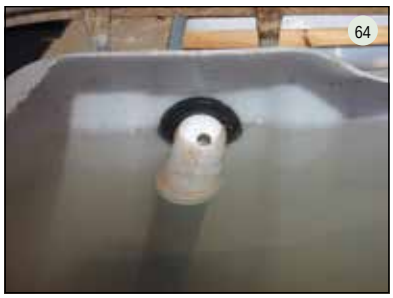
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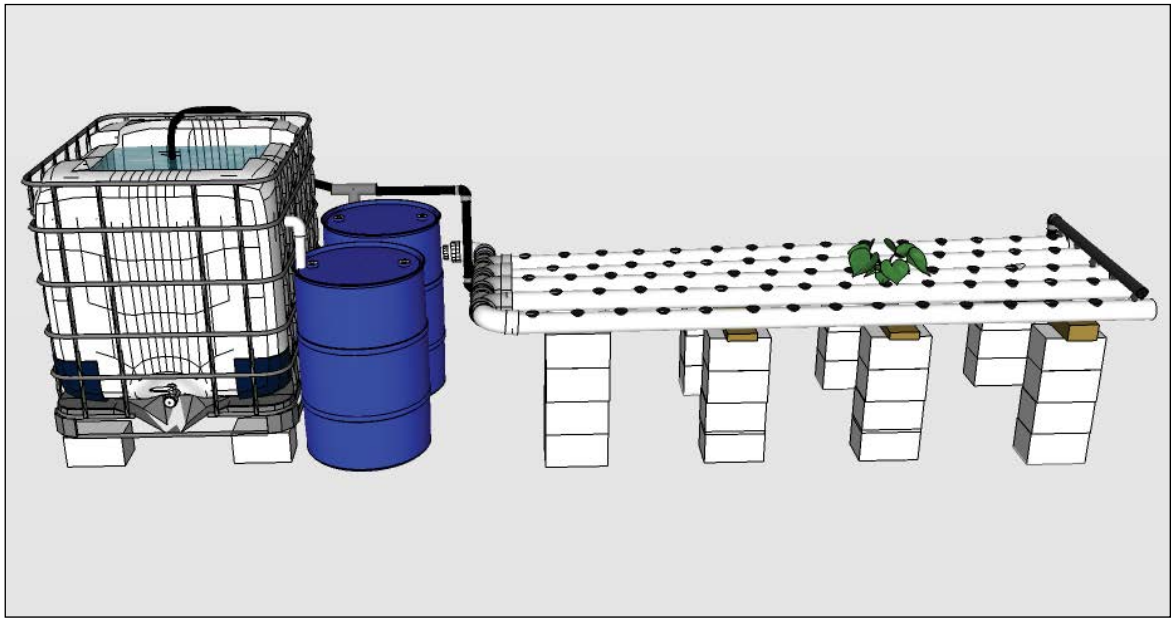
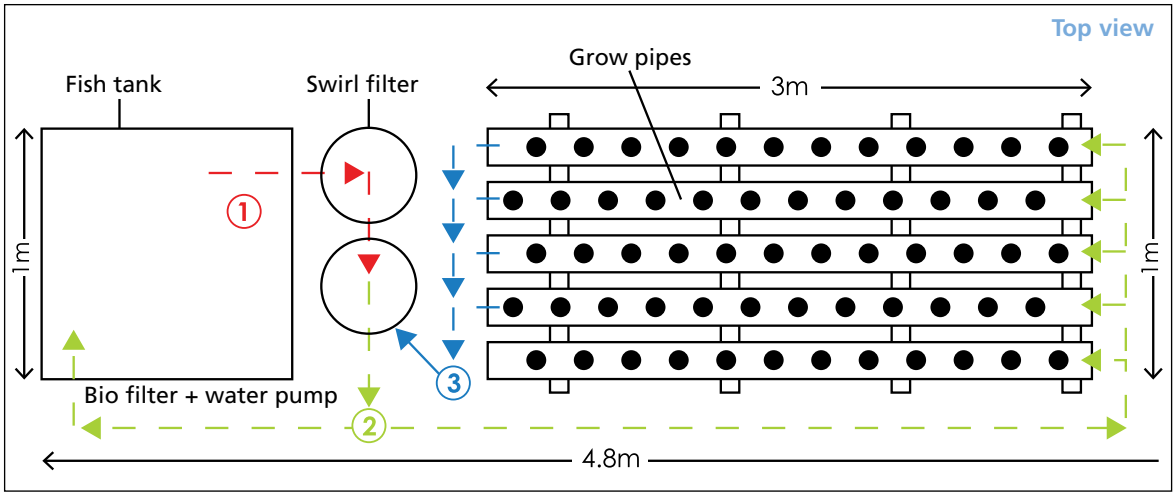
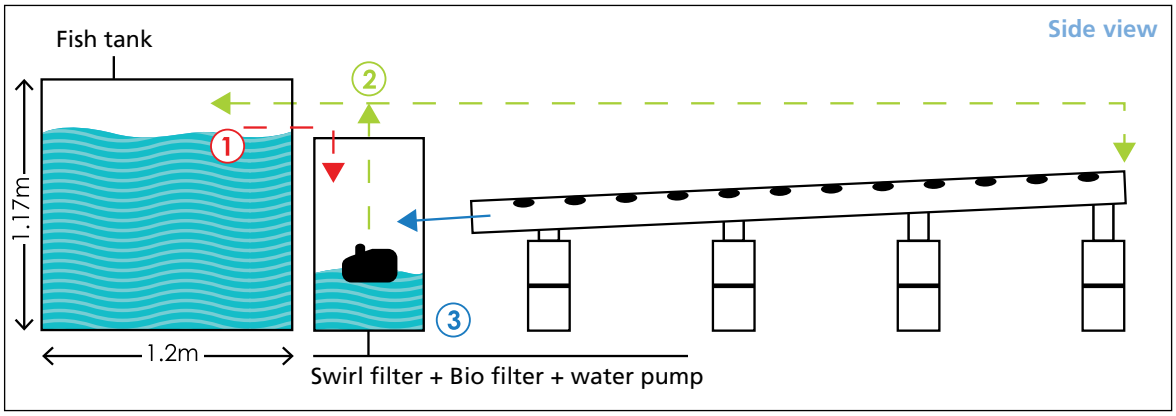
SECTION 2 – THE NUTRIENT FILM TECHNIQUE (NFT) UNIT







Water flow diagram

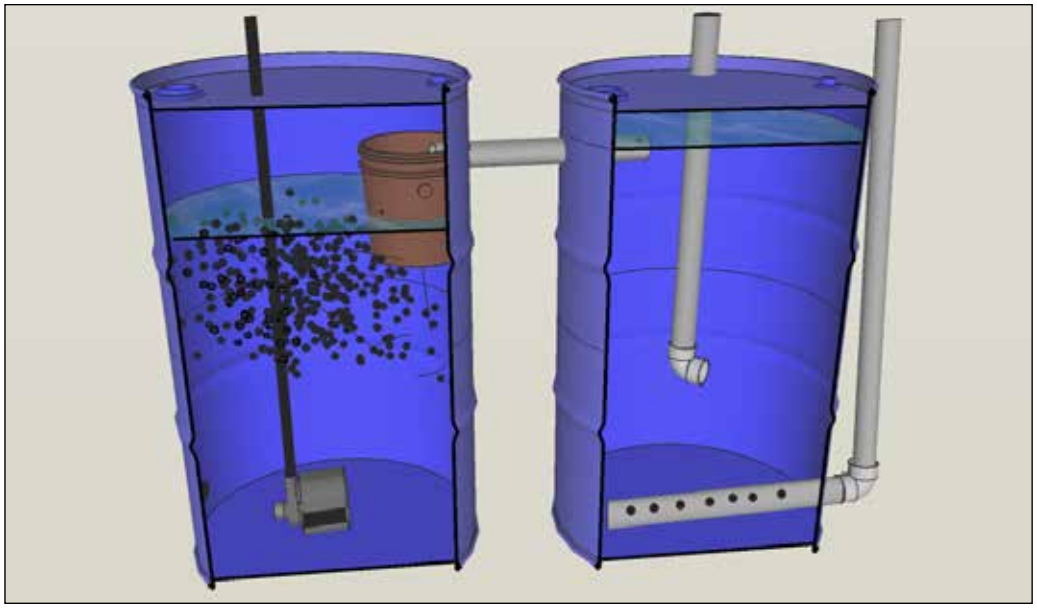
1. Water flows by gravitation from the fish tank to the swirl filter and biofilter.
2. Water is pumped, using the submersible pump, from the biofilter to the fish tank (80% of the flow) and the NFT pipes (20% of the flow).
3. Water flows back from the pipes to the biofilter.

TABLE A8.4
List of items for the NFT unit

	Item name	Item No. from Table A8.1	Quantity
1	IBC tank	1	1
2	Bucket (20 litre)	28	1
3	200 litre barrel (blue)	2	2
4	Biofilter medium (Bioball or bottle caps)	34	40–80 litres
5	Submersible water pump (min. 2 000 litres/h)	7	1
6	Air pump (10 watt/hour) with 2 exits	29	1
7	Air tubing	30	3 m
8	Air stone	32	2
9	Concrete block	5	32
10	Lumber (8×1 cm)	6	8 m
11	Shade material	3	2 m^2
12	Fish net	33	1
13	Teflon (plumber's) tape	10	1
14	Cable tie	11	25
15	Electric box (waterproof)	12	1
16	Net pot	36	80
17	Gravel, volcanic (4–20 mm)	35	30 litres
18	Ecological soap or lubricant	8	1
	PVC PIPES AND FITTINGS		
19	PVC pipe (110 mm)	13	16 m
20	PVC connector, T (110 mm)	42	4
21	PVC elbow (110 mm)	41	2
22	PVC coupler, straight (110 mm)	43	1
23	PVC endcap/stopper (110 mm)	51	5
24	PVC reducer (110–50 mm)	44	1
25	Sealing rubber washer (110 mm)	19	20
26	PVC pipe (50 mm)	15	5 m
27	Uniseal® (50 mm)	18	5
28	PVC elbow (50 mm)	37	6
29	PVC coupler, straight (50 mm)	38	4
30	PVC endcap/stopper (50 mm)	40	1
31	Sealing rubber washer (50 mm)	19	8
32	Polyethylene pipe (25 mm)	17	8 m
33	PVC connector, T (25 mm)	55	2
34	PVC elbow (25 mm × ¾ in) female	49	2
35	PVC adaptor (20 mm × ¾ in) male	22	1
36	Polyethylene pipe (20 mm)	17	2 m
37	PVC connector, T "push-on" (20 mm)	50	4
38	PVC elbow "push-on" (20 mm)	48	1
39	PVC tap "push on" (20 mm)	26	5

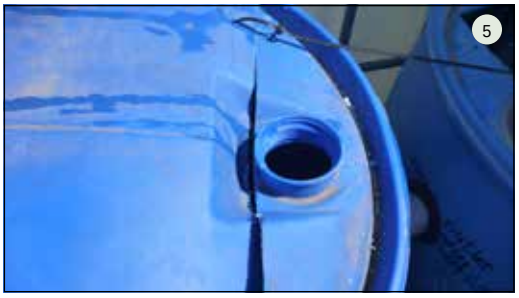
1. PREPARING THE FISH TANK (SAME AS IN MEDIA BED UNIT, SECTIONS 1–2)

2. PREPARING THE MECHANICAL SEPARATOR AND BIOFILTER



2.1 – Take two blue barrels (200 litre) (Figure 1) and cut out the shapes marked in the figures below (Figures 2–4) using the angle grinder. Afterwards, wash both barrels with soap and warm water thoroughly and leave to dry in the sun for 24 hours.

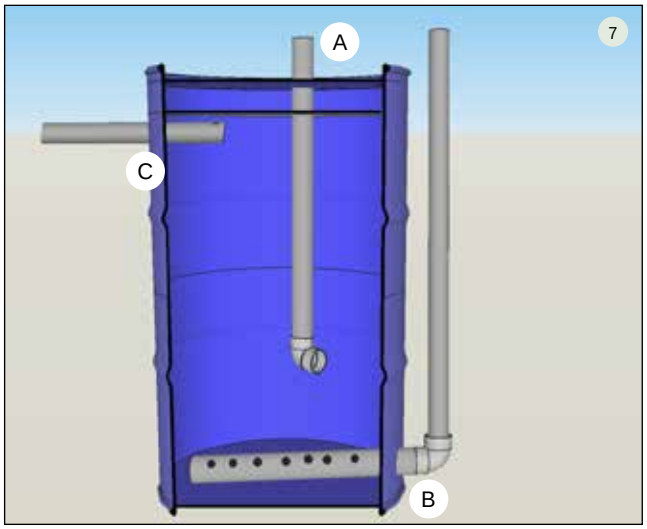
2.2 – The cut pieces of both barrels can also be used as barrel covers. They can be fixed to the top of the barrel using cable ties (see Figures 5–6).

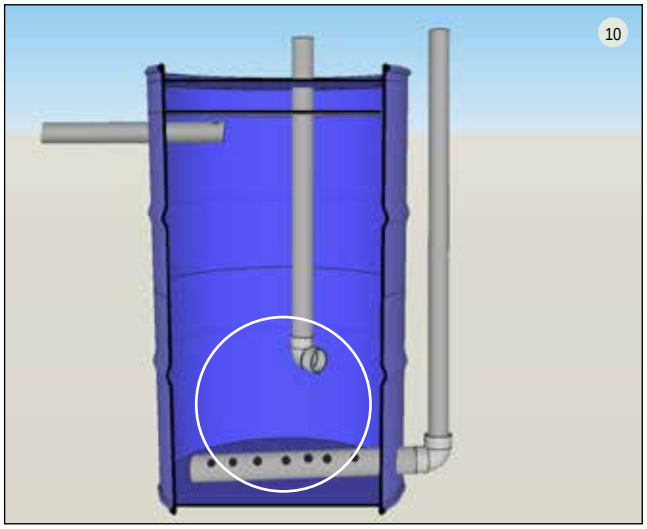


3. BARREL No. 1 – MECHANICAL SEPARATOR

Inlet / outlet pipes of the mechanical separator

A. Inlet pipe from the fish tank.
B. Drainage pipe at the bottom of the mechanical separator.
C. Outlet pipe into the biofilter.





Inlet pipe from the fish tank

3.1 – Drill a hole (50 mm) using the 50 mm circular drill bit at the top surface of the barrel and slide in the fish tank exit pipe (Figures 8–9).

3.2 – Extend the exit pipe of the fish tank to 30 cm above the bottom of the mechanical separator container. Attach a PVC elbow (50 mm) to the bottom of the exit pipe so the water flows tangentially to the container forcing the water to circulate (Figure 10).

Drainage pipe at the bottom of the mechanical separator

3.3 – Next, take a length of PVC pipe (50 mm) and cut 2–3 mm horizontal slits along the entire length using the angle grinder (Figure 11). Drill a hole (57 mm) on the outside of the barrel, 5 cm above the bottom, and insert a uniseal (50 mm) (Figure 12). Slide the drain pipe (50 mm PVC pipe cut with slits) through the uniseal and connect a PVC elbow (50 mm) to the end of the pipe outside the barrel. Finally, attach another PVC pipe (50 mm) that is 60–70 cm in length to the elbow and make sure that the end of the pipe is above the maximum water level of the barrel (Figure 13). The slits on the drainage pipe will allow solid waste to enter it and be flushed out by reclining the other vertical pipe attached outside of the barrel and pouring out the water from its end.

Transfer pipe connecting the mechanical separator to the biofilter

3.4 – Take a 65 cm length of PVC pipe (50 mm) and cut the same horizontal slits as above (3.3) for only the first 25 cm of the pipe using the angle grinder (Figure 14). Seal the slotted end of the pipe (50 mm) using a PVC endcap/stopper (50 mm). Next, drill a hole (57 mm) with the 57 mm circular drill bit 70 cm from the bottom of the barrel, and insert a uniseal inside the hole. Slot the transfer pipe (50 mm) through the uniseal, making sure the end with 25 cm slits is completely inside the mechanical separator barrel (Figures 15–16).


14

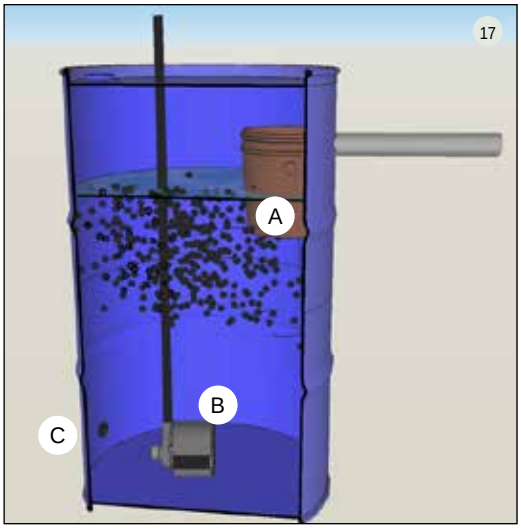

15


16

4. BARREL No. 2 – BIOFILTER

Inlet/outlet pipes of the biofilter

A. Inlet pipe from the mechanical separator (Figure 17).
B. Water outlet from the water pump.
C. Drainage tap.



17

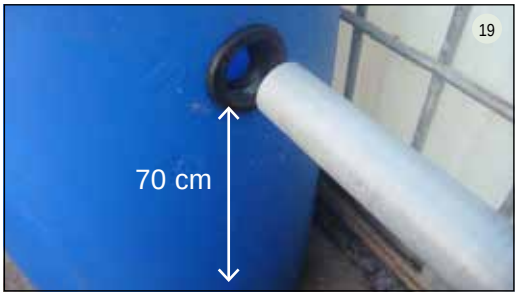
25 mm drain tap

4.1 – Drill a hole (25 mm) at the very bottom of the biofilter barrel and insert a barrel connector (V type, 25 mm) into the hole and fasten it tight. Attach a tap (25 mm) to the barrel connector on the outside of the barrel making sure the connecter is wrapped with Teflon to make a water tight seal (Figure 18). The tap is used to flush out any solid waste accumulating at the bottom of the biofilter container.


18

Inlet pipe from the mechanical separator

4.2 – Drill a hole (57 mm) using the 57 mm circular drill bit 70 cm from the bottom of the barrel and insert a uniseal in the hole (Figure 19). Place the biofilter barrel adjacent to the mechanical separator barrel. Take the 65 cm PVC pipe length already attached to the mechanical separator barrel and slot it through the uniseal in the biofilter barrel as well. Now, both barrels are joined together using this transfer pipe (Figure 20).



19


20

Preparing the solids capture bucket

4.3 – Drill a 50 mm hole in the 20 litre bucket 5 cm below the top rim of the bucket (Figure 21)

4.4 – Drill at least 20 holes (8 mm diameter) into the bottom of the bucket using an 8 mm drill bit to allow water to drain into the biofilter (Figure 21).

4.5 – Insert and slide the bucket along the 65 cm transfer pipe inside the biofilter (the same 65 cm pipe that connects both filter barrels (Figures 22–23)

4.6 – Drill a 20 mm hole into the transfer pipe and insert 6–10 cm of PVC (20 mm) (Figure 23) to prevent the solids capture bucket from sliding off the transfer pipe.

4.7 – Place filtration media (in this configuration we use volcanic gravel but perlon, sponge or other filters may be utilized) inside the bucket to capture any remaining solid or suspended waste (Figure 24).

4.8 – Fill the biofilter with biofilter medium (Bioballs or bottle caps)

5. POSITIONING THE NFT PIPES

The materials needs for this section are as follows:

- 48 concrete blocks
- 1 m wood length (30 mm thick) × 1
- 1 m wood length (20 mm thick) × 1
- 1 m wood length (10 mm thick) × 1

5.1 – Place the concrete blocks according to the distances in Figure 25. Each stand is made of 8 blocks (two columns, each column 4 blocks high. Place the wood lengths on

to the blocks: place the 3 cm thickness length along the column of blocks furthest away from the tank, the 2 cm thickness length on the middle columns and the 1 cm thickness length on the closest columns. This arrangement will create a small slope allowing the water to easily flow through the pipes and return to the biofilter barrel (Figure 25).

6. CONNECTING THE NFT PIPES AND COMMUNAL DRAIN

The materials needs for this section are as follows:

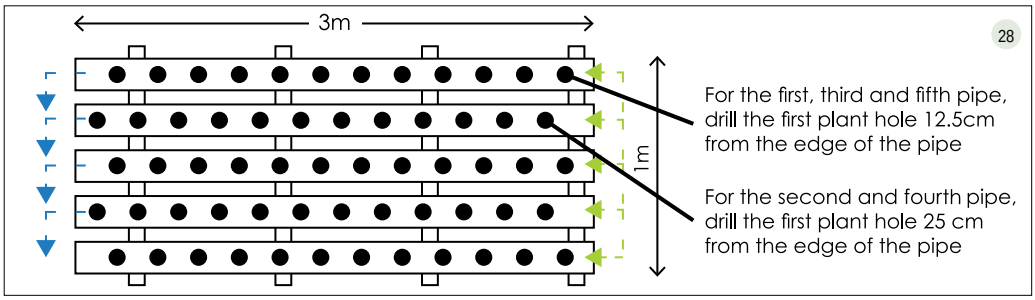
- 3 m of PVC pipe (110 mm) × 5
- PVC elbow (110 mm) × 2
- PVC T connector (110 mm) × 4
- PVC endcap/stopper (110 mm) × 5
- Rubber washer (110 mm) × 15
- Natural soap

6.1 – Connect the pipe system according to Figure 27. Make sure that each pipe and pipe fitting has a lubricated rubber seal fitted inside using the natural soap as a lubricant (Figure 26).


26


27

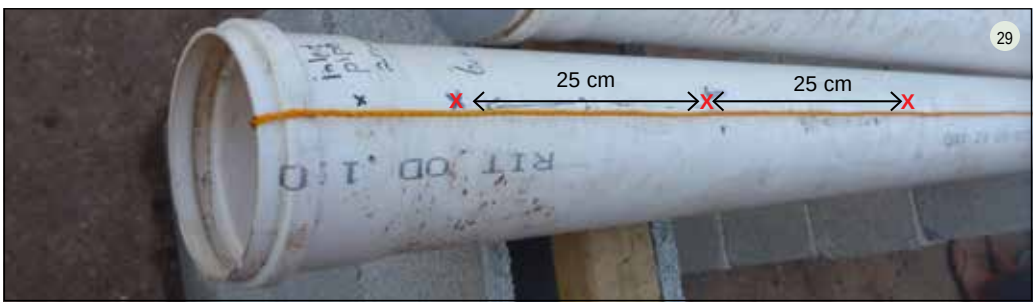
7. MARKING THE PLANT HOLES



28

7.1 – Place the NFT pipes on top of the blocks and wood lengths and fit the five end caps (110 mm) to the ends of the pipe furthest from the fish tank (Figure 30). One effective method for marking the plant holes is to stretch and secure a thin piece of rope along the top of each pipe to mark uniform distances accurately.

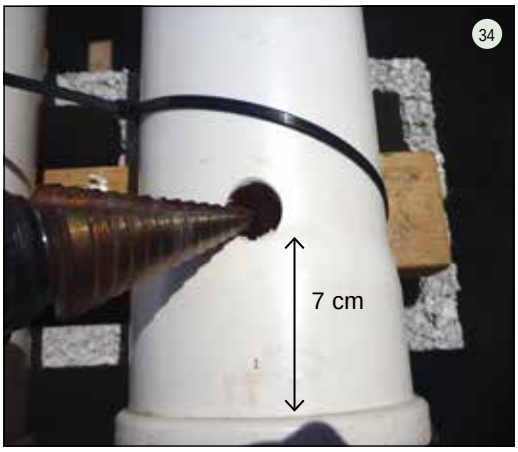
7.2 – Mark a point every 25 cm along the rope (Figure 29) which will be the centre point for the holes. Drill the holes (Figure 33) according to the size of the net pots.



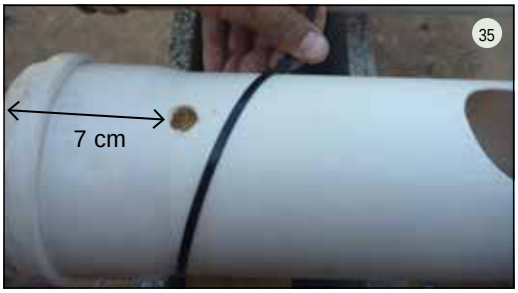
29

For optimal plant growing space, follow the triangular pattern shown in Figures 28 and 31.

7.3 – Finally, drill 20 mm holes, 7 cm from the ends of the pipe farthest from the fish tank to allow water to enter the NFT pipes (Figure 34).



7.4 – Secure the NFT pipes to the wood length using plastic cable ties (Figure 35).



8. CONNECTING THE END OF THE GROW PIPES BACK TO THE BIOFILTER

8.1 – Take a PVC straight coupler/connecter (110 mm) and attach it to the final PVC elbow (110 mm) of the common gutter of the NFT pipes (Figure 27), which is made with a series of PVC T connections (110 mm). Then, attach a PVC reducer (110–50 mm) to the PVC straight coupler/connecter (110 mm). This communal drain must connect to the biofilter. Drill a 50 mm hole on the outside of the biofilter, 10 cm lower than the bottom of the grow pipes. Fit a PVC elbow (50 mm) into this hole. Use PVC pipe (50 mm) to connect the elbow (50 mm) to the reducer (110–50 mm) allowing the water to flow from the NFT pipes back into the biofilter barrel. (Figures 36–38).

9. INSTALLING THE DISTRIBUTION PIPING FOR EACH NFT PIPE

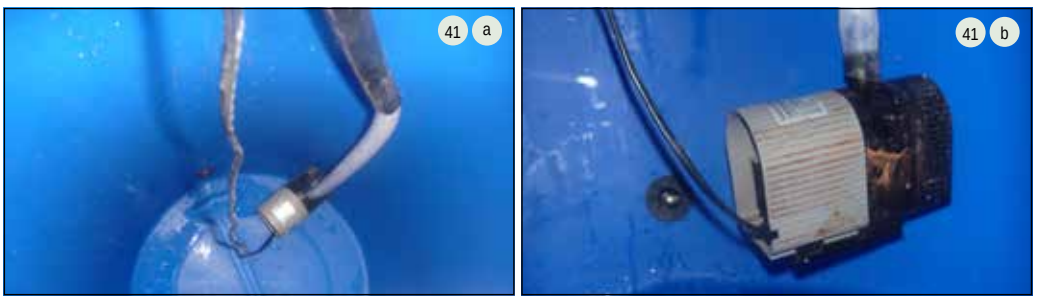
The materials needs for this section are as follows:

- PVC "push on" taps (20 mm) × 5
- PVC "push on" T connectors (20 mm) × 4
- PVC "push on" elbow connectors (20 mm) × 2
- Polyethylene pipe (20 mm)
- PVC adapter (20 mm – ¾ inch × 1
- PVC elbow female connector (25 mm – ¾ inch) × 1
- Plumber's tape (Teflon)

9.1 – Connect all of the pipe and fittings according to Figures 39 and 40.

10. ADDING THE SUBMERSIBLE PUMP

10.1 – For this unit, the submersible pump is placed at the bottom of the biofilter barrel (Figures 41a and 41b). Water is pumped from there to two locations: the NFT pipes and the fish tank. 80–90 percent of the water flows to the fish tank while 10–20 percent flows into the NFT pipes. The taps are used to control the water flow at each location.

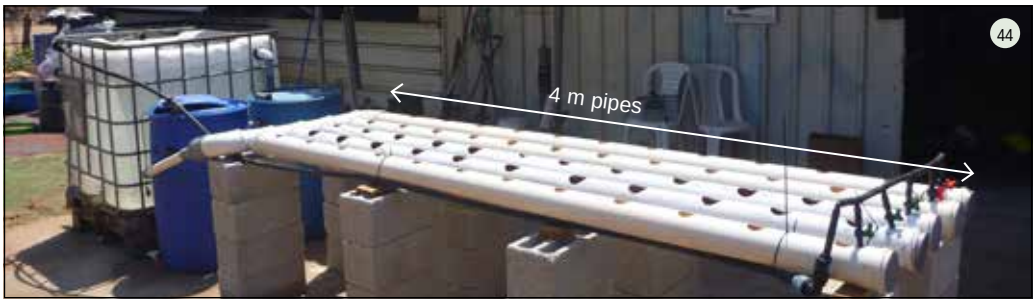


11. PUMPING TO THE FISH TANK

11.1 – Connect the submersible pump to a length of polyethylene pipe (25 mm) using a PVC adaptor, female (25 mm – 1 inch), or any connection that fits the pump. The polyethylene pipe (25 mm) should be at least 1 m long. Place a PVC T connection (25 mm) at the end of the pipe to allow water to flow to the fish tank and the NFT pipes (Figures 42–43).

11.2 – Attach a PVC pipe (25 mm) to one end of the T connection (Figure 42) long enough to reach the fish tank (Figure 44). Use a flexible pipe, if possible, to remove the need for additional connectors, which would reduce the pumping capacity of the pump. Attach a tap (25 mm) to the end of the pipe to control the incoming water flow into the fish tank (Figure 44).

11.3 – Next, take about 4 metres of PVC pipe (25 mm) and attach to the other end of the PVC T connector (25 mm) coming from the water pump pipe inside the biofilter. Attach this pipe (25 mm) to the distribution manifold through the PVC elbow female connector (25 mm – ¾ inch) seen in Figure 40, which will supply water to each NFT pipe (Figure 44).

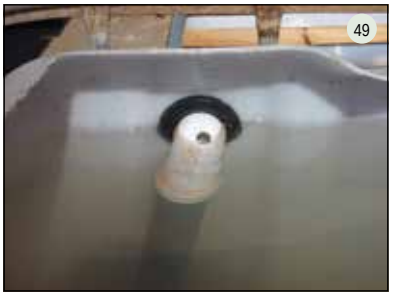


12. ELECTRIC BOX + AIR PUMP

12.1 – Place the electric box in a safe place higher than the water level and shaded from direct sunlight (Figure 45). 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 (Figure 46).

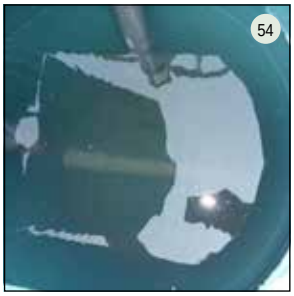
13. FINAL CHECKS

13.1 – All parts of the system are now in place. Before adding ammonia for cycling, fish or plants, fill the fish tank and both filters with water and run the pump to check for any leaks in the system. If leaks appear, fix them immediately (Figures 47–49). The following steps show this process.



Mechanical separator drainage check (Figures 50–52).

- Fill the biofilter with media and water (Figures 53a and 53b).
- Fill the mechanical separator with water (Figure 54).
- Mechanical separator and biofilter (Figure 55).



- Tighten the plumbing connections.
- Check all uniseals and taps for both filters.
- Re-apply Teflon to threaded connections.
- Make sure all valves are in their ideal position.

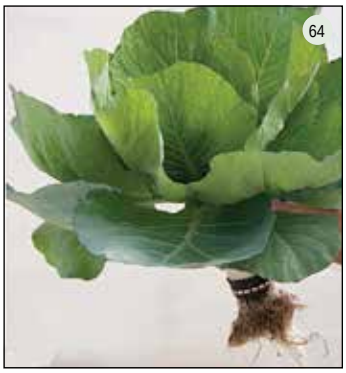
Finally, check the flow rate of the water flowing into each NFT pipe. The flow rate can be measured with a stopwatch and an empty 1 litre plastic bottle. A flow rate of 1–2 litres/minute, which is the standard in NFT pipes, should fill the bottle in 1 minute (1 litre/minute) or 30 seconds (2 litres/minute) (Figure 56).

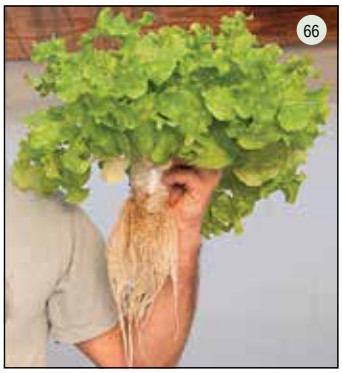
Once all the leaks are fixed and the water is flowing smoothly through all components, it is possible to start cycling the unit using ammonia (see Chapter 5 of this publication for more details on this process).

14. PLANTING – MAKING THE PLANTING CUPS

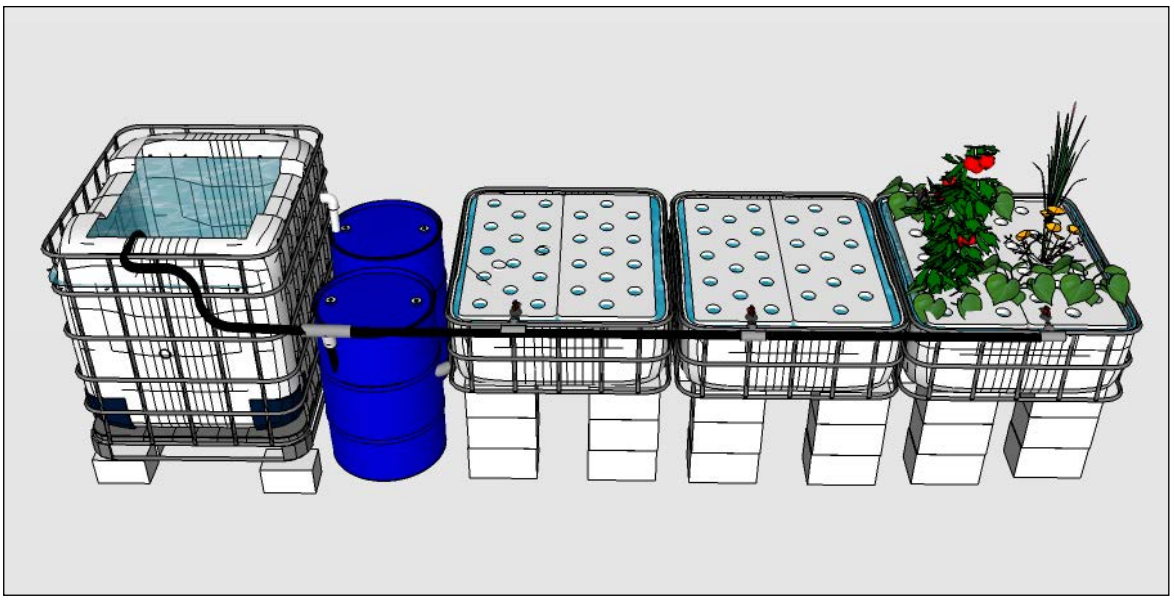
14.1 – For planting, follow what is shown in the following figures. Make sure the plant cup has enough holes to allow the root system to grow out into the pipe but also to prevent the growing medium from falling out. A plant cup made from a net cup and 10 cm of PVC pipe (50 mm) (Figures 57–59).

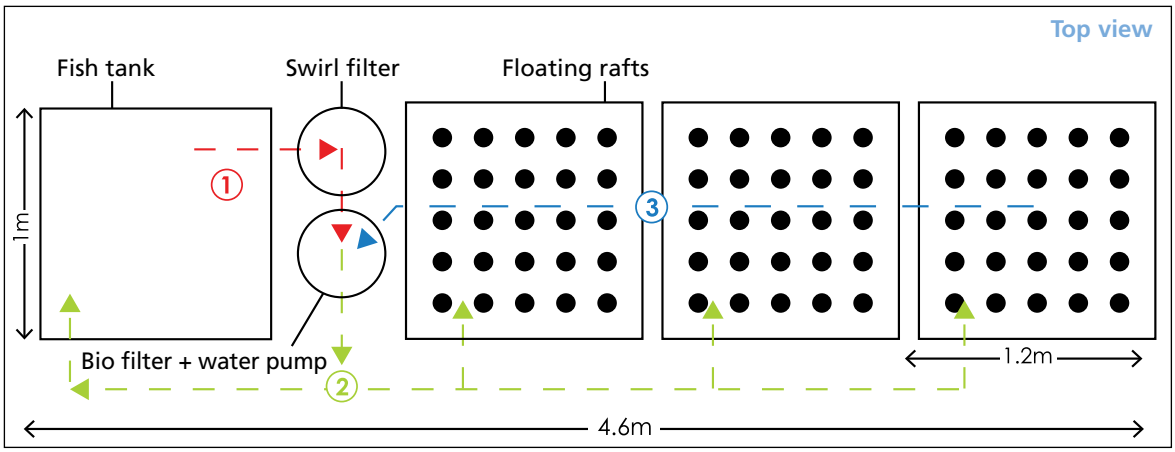
A plant cup made from simple plastic/paper cups and a plastic bottle (Figures 60 and 61). Plant roots clearly visible (Figures 62–66).

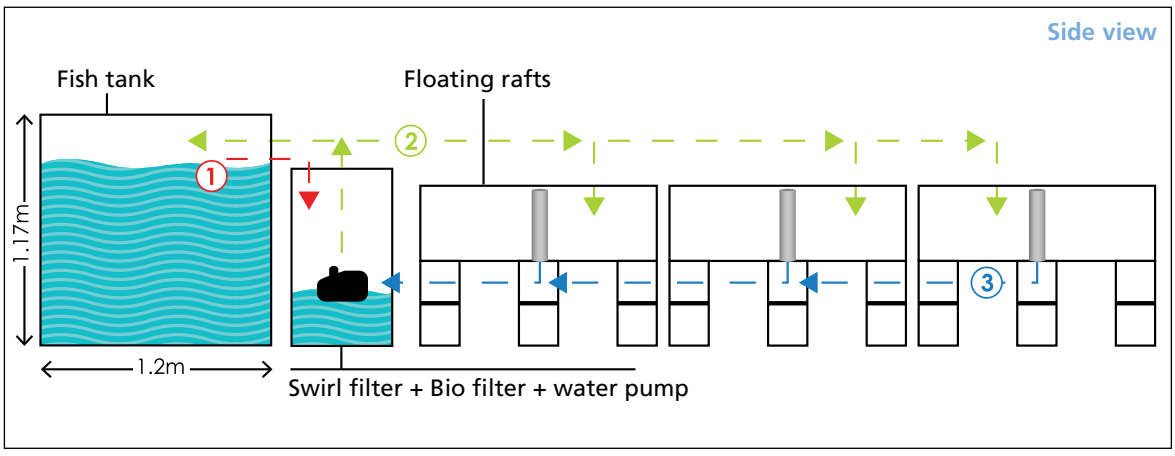




SECTION 3 – THE DEEP WATER CULTURE (DWC) UNIT







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.

TABLE A8.5
List of items for the DWC unit

	Item Name	Item No. from Table A8.1	Quantity
1	IBC tank	1	3
2	Bucket (20 litre)	28	1
3	200 litre barrel (blue)	2	2
4	Biofilter medium (Bioball® or bottle caps)	34	40–80 litres
5	Submersible water pump (min. 2 000 litres/h)	7	1
6	Air pump (10 watts/hour) with 4 exits*	29	1* (2)
7	Air tubing	30	10 m
8	Air stone	32	4
9	Concrete block	5	40
10	Lumber (8×1 cm)	6	8 m
11	Shade material	3	2 m^2
12	Fish net	33	1
13	Teflon (plumber's) tape	10	1
14	Cable tie	11	25
15	Electric box (waterproof)	12	1
16	Net pot	36	80
17	Gravel, volcanic (4–20 mm)	35	30 litres
18	Polystyrene sheet	9	3 m^2
19	Ecological soap or lubricant	8	1
	PVC PIPES AND FITTINGS		
20	PVC or metal tap (¾ in) male to female	27	4
21	PVC or metal tap (1 in) male to female	47	1
22	PVC elbow (25 mm × ¾ in) male	24	3
23	PVC elbow (25 mm × ¾ in) female	49	1
24	PVC connector, T (25 mm ×1 in) female	53	2
25	PVC connector, T (25 mm × ¾ in) female	57	2
26	PVC elbow (25 mm ×1 in) female	23	2
27	PVC elbow (25 mm × ¾ in) female	49	1
28	PVC adaptor (25 mm × ¾ in)	52	1
29	PVC (25 mm ×1 in) female	21	3
30	PVC barrel connector, V-type (1 in)	46	5
31	Polyethylene pipe (25 mm)	17	8 m
32	PVC connector, T (25 mm × ¾ in) female	59	1
33	PVC pipe (25 mm)	16	0.9 m
34	PVC pipe (50 mm)	14	2 m
35	Uniseal® (50 mm)	18	5
36	PVC elbow (50 mm)	37	6
37	PVC coupler, straight (50 mm)	38	5
38	PVC endcap/stopper (50 mm)	40	1
39	Sealing rubber washer (50 mm)	19	10

1. PREPARING THE FISH TANK (SAME AS MEDIA BED SECTIONS 1 AND 2).

2. PREPARING THE MECHANICAL SEPARATOR AND BIOFILTER (SAME AS NFT UNIT SECTIONS 1–4).

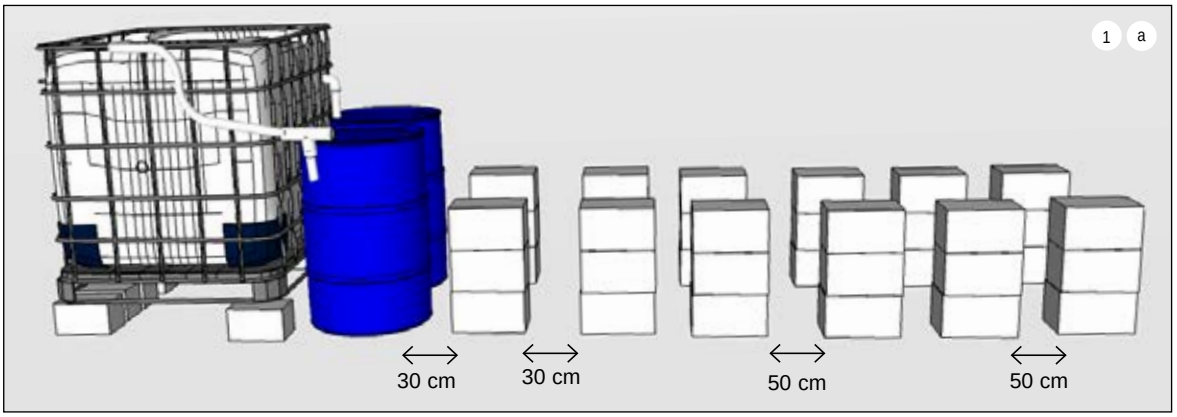
3. MAKING 3 DWC CANALS FROM 2 IBC TANKS (SAME AS MEDIA BED SECTION 4).

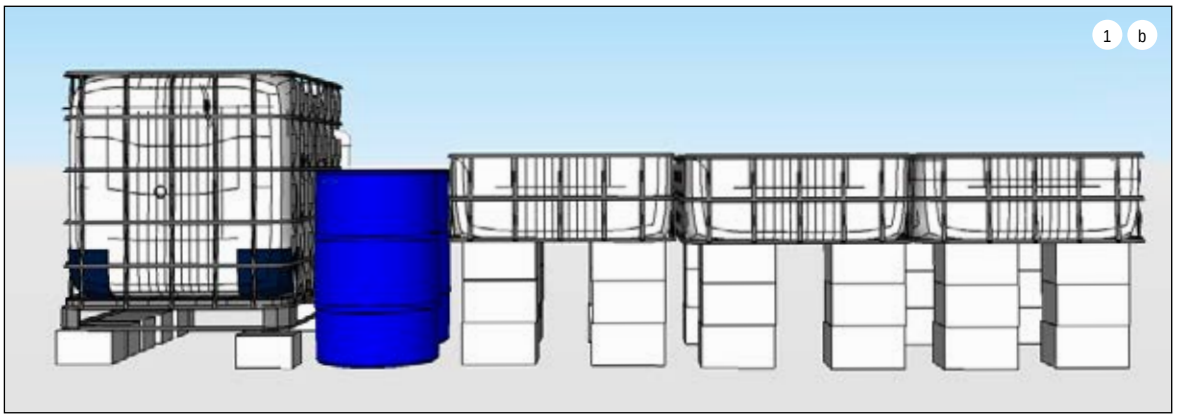
4. INITIAL STEPS IN BUILDING A DWC SYSTEM

Follow the steps contained in the previous sections to set up the fish tank, the mechanical separator, the biofilter and 3 DWC canals from 2 IBCs. Once completed, proceed to assembling the DWC canals. For the DWC system, the cut IBC bed used as a sump tank in the media bed unit can be used as the 4th canal. Extra blocks and plumbing are required to install the 4th canal.

5. ASSEMBLING THE DWC CANALS

5.1 – Place the concrete blocks according to the distances described in Figure 1a. The fish tank should be raised up about 15 cm; do so by using concrete blocks. Then, place the three grow beds (including the metal support frames) on top of the blocks as shown in (Figure 1b) (Make sure the grow beds are secure on top of the blocks. If not, slightly adjust the layout of the blocks underneath).





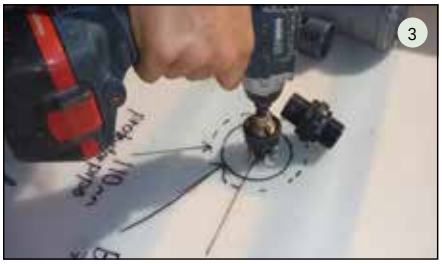
6. PREPARING THE DRAINAGE PIPES INTO THE BIOFILTER

The following materials are needed to make three drainage pipe units:

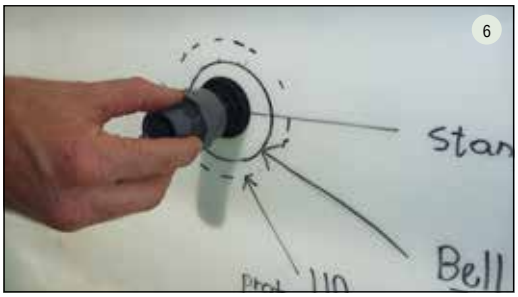
- 24 cm of PVC pipe (25 mm) × 3
- Barrel connectors (25 mm) × 3
- PVC adaptor, female (1 inch – 25 mm) × 3
- PVC elbow, female (1 inch – 25 mm) × 1

- PVC T-connector (25 mm – 1 inch [female] – 25 mm) × 2
- Rubber washer (25 mm) × 3

6.1 – Take each DWC canal and mark their centre points in the bottom of the canal. Drill a 25 mm diameter hole at each centre point and insert the 25 mm barrel connector (25 mm) with the rubber washer placed inside the grow bed. Tighten both sides of the connector using a wrench (see Figures 2–4).



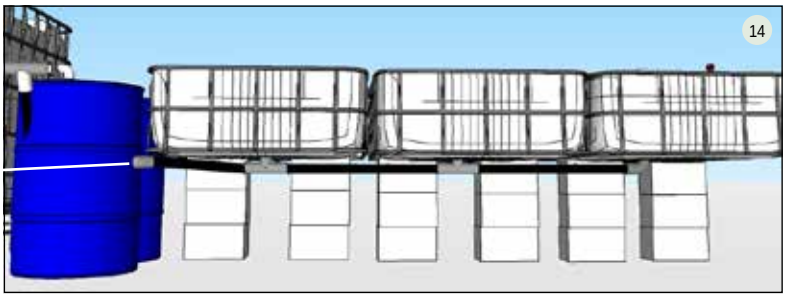
6.2 – Screw the PVC adapter, female (1 inch – 25 mm) on to the barrel connector (25 mm) inside the tanks and then slot the standpipe into the adapter. Make sure to cut five longitudinal slots on the upper end of the standpipe to prevent the pipe from clogging (Figures 5–6).



6.3 – Next, connect the PVC elbow, female (25 mm – 1 inch) to the end of the barrel connector underneath the DWC canal that is farthest from the fish tank (Figures 7–10). Then fix the remaining two PVC T connectors (25 mm – 1 inch [female] – 25 mm) to the barrel connectors underneath the other two canals. Take three pieces, each 1 m in length, of PVC pipe (25 mm) and connect the elbow to the two T-connectors underneath the canals (Figures 11 and 12).

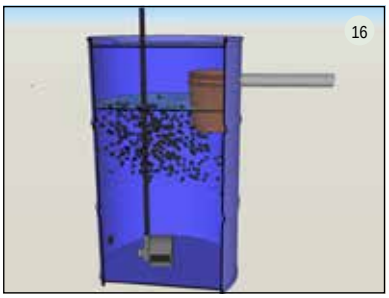
Connection between canals A, B and C

6.4 – Finally, drill a 25 mm hole into the side of the biofilter barrel using the circular drill bit at least 15 cm below the standpipe height in the canals and insert a barrel connector (1 inch) in it. Then, connect a PVC elbow (25 mm – 1 inch) to the barrel connector and then take one more piece of PVC pipe (25 mm) and connect the PVC elbow (25 mm – 1 inch) where it exits the biofilter to the final T-connector underneath the tank A and slot the other into the 25 mm hole in the biofilter (Figures 13 and 14).



7. ADDING THE SUBMERSIBLE PUMP

For this unit, the submersible pump is placed at the bottom of the biofilter barrel (Figures 15 and 16).



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 (Figure 17).

8. PUMPING TO THE FISH TANK AND DWC CANALS

8.1 – Connect the submersible pump to a length of polyethylene pipe (25 mm) pipe length using an adaptor (1 inch female – 25 mm), or any other connection that fits to the pump. The pipe should be at least 1 m long. Place a T-connection (25 mm) at the end of the pipe allowing water to flow to the fish tank and the canals (Figure 18).

8.2 – Attach a pipe (25 mm) to one end of the T-connection long enough to reach the fish tank. Use flexible pipe if possible as this removes the need for elbow connections, which reduce the pumping capacity of the pump (Figure 19). Attach a tap (25 mm) to the end of the pipe to control the water flow into the fish tank.

8.3 – Next, take about 3.5 metres of polyethylene pipe (25 mm) and attach one end to the remaining exit of the T-connection (25 mm) coming from the pump in the biofilter. Then, take the 3.5 metre pipe and lay it along the DWC canals. At each canal, add a T-connector (25 mm – ¾ inch – 25 mm), a tap (¾ inch male – ¾ inch female), and a PVC elbow (25 mm – ¾ inch male) allowing water to flow into each canal at an angle (Figures 20–22). At the final canal furthest from the fish tank use a PVC elbow (25 mm – ¾ inch female) instead of the T-connector. Be sure to secure the pipes to the metal frame by means of plastic cable ties.

9. INSTALLING THE AIR PUMP AND STONES

9.1 – 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 (ideally attached to the side of the fish tank) (Figure 25). Take 4–6 m of 8 mm air pipe. Attach one end to the air pump and lay the rest of the 8 mm pipe along the side of all the DWC canals. On each tank, drill an 8 mm hole just below (1–2 cm) the top and slot the 8 mm pipe into each hole.

9.2 – Attach the air stones to the 8 mm pipe and place them next to the inlet water stream to ensure full oxygen saturation in the canal. Repeat the same air pipe connection for the fish tank (Figures 23, 24 and 26).


23


24


25


26

9.3 – Connect the pipes to the metal frame with plastic cable ties.

10. MAKING THE RAFTS

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

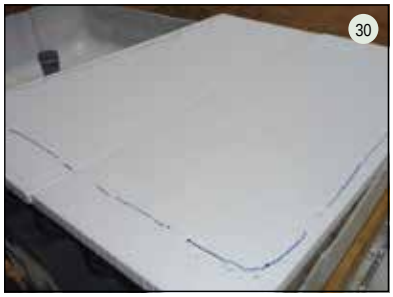
- All water in the canals should be fully covered (no exposure to light).
- Choose polystyrene sheets that are at least 3 cm thick to hold the weight of the vegetables.
- The polystyrene must not release any toxins to the water (make sure it is safe for food production or food-grade quality). Painted plywood can also be used.
- Plant hole sizes and spacing are dependent on the type of vegetables to be planted. The planting hole size can range from 16 mm (for planting seedlings directly into the rafts without cups [Figure 28]) to 30 mm. This depends on the size of net cups available (Figure 27).


27


28

10.1 – Place the polystyrene on top of the DWC canals and mark the edge lines. With a knife, cut the outline of the canal (Figures 29–31).


29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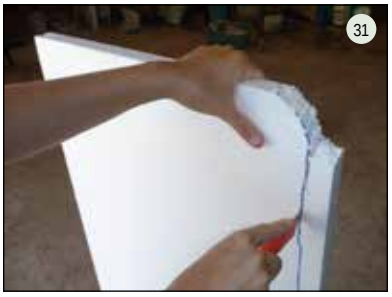
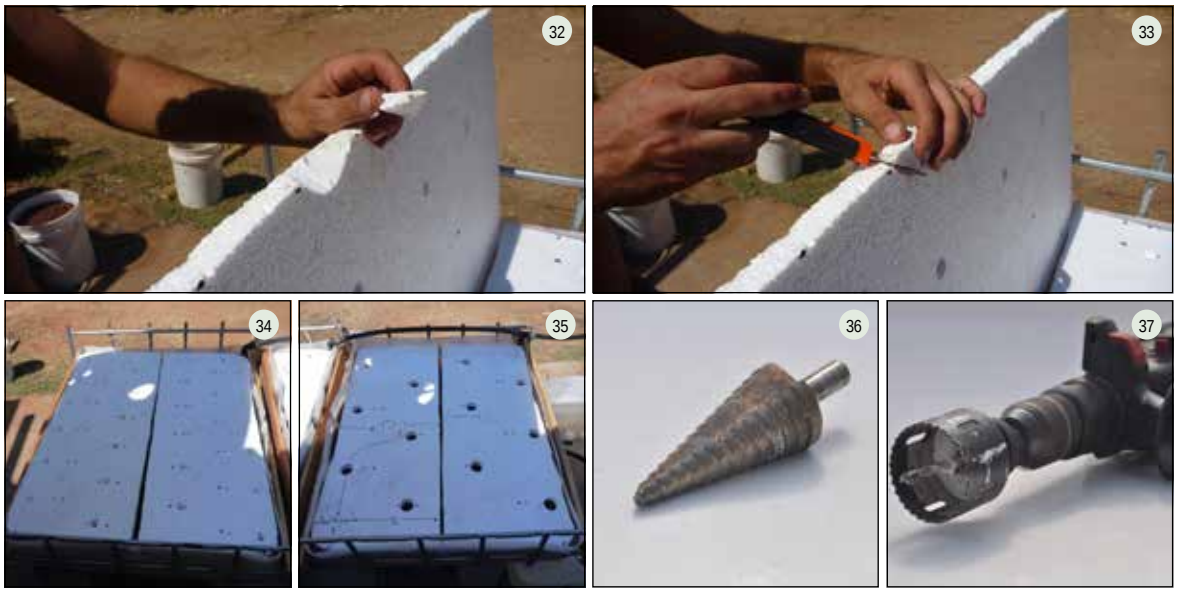

31

10.2 – Drill the plant holes (Figures 34 and 35) using a circular drill bit (Figures 36 and 37). Along with planting holes, make sure to cut one hole for the standpipe of each canal (Figures 32 and 33).



11. FINAL CHECKS

Once all parts of the system are in place, fill the fish tank, both filters and DWC canals (Figures 38–43) 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.
- Re-applying Teflon to threaded connections.
- Making sure all valves are in their ideal position.

Secure all the remaining pipes with plastic cable ties (Figures 45–46).

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 mentioned in Chapter 4 of this publication. Water inflow can be measured by using a stopwatch and an empty 1 litre plastic bottle (Figure 44) At 75 litres/hour the 1 litre bottle should fill up in 48 seconds, at 300 litres/hour in 12 seconds. Once all the leaks are fixed and the water

is flowing through all components of the unit, begin cycling the unit by using ammonia to stimulate nitrifying bacteria colonization (see Chapter 5 of this publication).

Planting process with cups (Figures 47–51) and without cups (Figure 52)

Finished system.