

Fig. 4.11-4.15 the Deep Water Culture (DWC) method

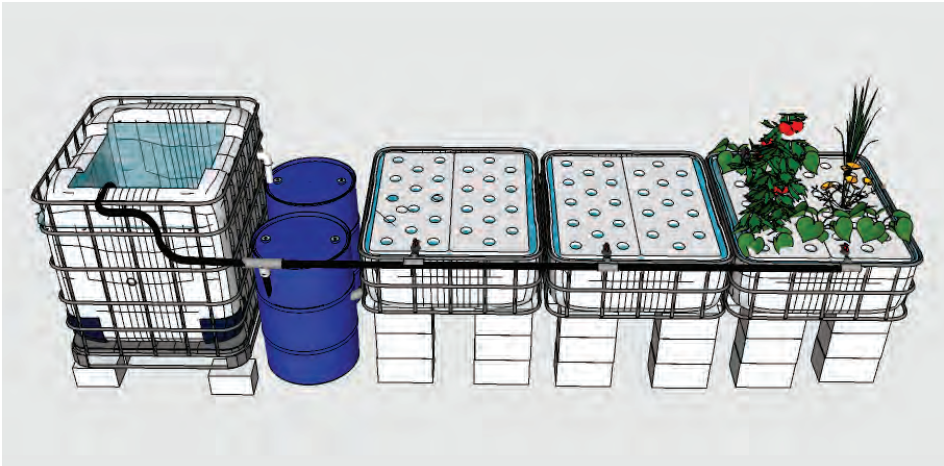


Fig.4.12



Fig.4.13



Fig.4.14



Fig.4.15



1) Site Selection

Site selection is an important aspect that must be considered before you install your aquaponics unit. In this section we will be referring mainly to units that are housed outdoors without a greenhouse - yet towards the end, we will add brief comments about greenhouses and shading net structures (also see annex 3 for further recommendations on site selection) In beginning, remember that some of the system's components are heavy and hard to move.- making it difficult, although possible, to move it once it is constructed. Bearing that in mind, what do we need to take into consideration before placing the system?

A) Stability

Make sure that the site you choose to place the system is stable and level. Some of the major components of an aquaponics system are heavy, leading to the potential risk of one of the legs of the system sinking into the ground. This could lead to an unbalanced media bed (meaning not level) which can easily disrupt the auto-drainage mechanism, ultimately causing a lack of oxygen in the root zone of the plants.

Recommendations:

- Find the most level and solid ground available on which to build the system. (If built on concrete you are unable to bury, or partially bury, some components underground).
- Put concrete or cement blocks under the legs of the media beds to improve stability.
- Put a base under the fish tank to secure its stability and to isolate it from the ground.

B) Wind, Rain & snow

Strong prevailing winds can have a considerable negative impact on plant production. Plants can invest 15% - 50% of their energy in building up wind resistance instead of investing that energy in growth. These plants will develop small, thick stems and will slowly dry up. Additionally, strong rain can harm the plants and can cause damage to unprotected electrical sockets. Large amounts of rain that collect in the fish tanks and other components can slightly dilute the nutrient rich water, and can flood a system if no overflow mechanism is integrated into the unit.



Fig.4.16 Deep Water Culture-System Damaged by Snow

Recommendations:

- Place the system in a wind-protected zone. If possible (though not compulsory), protect your system from rain by placing it under a clear nylon or plastic cover. This will also allow you to collect the rainwater in order to use it to replenish the unit at a later period.

C) Sunlight and Shading for Plants & Fish

As we will learn in chapter 6 (Plants), the sun is critical for the photosynthesis process for plants, and as such, we need to make sure the plants in the unit are getting the optimum sunlight during the day. In general, most edible plants like sunlight, so we do not need to worry too much about sun exposure in the summer, as it is easy to manage. The easiest way to deal with too much sun is to add shading nets to reduce the sunlight. Too much sun can cause damage to plants, while not enough sun can cause slow growth rates.

Recommendations:

- **Knowing the sun path:** the sun path goes from east to west and we need to place the system in such a way so that the lengths of the media beds or grow pipes will be facing the north east side to make the most use of the sun during the day.

Fig. 4.17 95% Shading Material for Fish

- **Shading for fish:** Although it's not essential to provide permanent shading over the plants, it is crucial for the fish tanks to be in the shade (see fig. 4.4). Normally, the fish tanks are covered with a removable shading material that is placed on top of the tank. However, if possible, it is ideal to isolate the fish tanks using a separate shading structure. This will prevent algae growth that can cause system malfunction (see chapter 3 for algae removal) and will help maintain a stable water temperature during the day.



- Finally, it is recommended to avoid locating the system near low hanging trees or bushes as falling leaves are unwanted organic matter than can end up in the media beds.

D) Rooftop Aquaponics:

If building a system on a rooftop you need to consider the weight of the system and whether or not the roof is capable of supporting it. It is always worth consulting an architect or civil engineer before building a rooftop system. Also, make sure that you can transport materials both safely and with ease the rooftop site.

Fig. 4.18



Fig. 4.19



Fig. 4.20



Fig. 4.18 - 4.20 Rooftop Aquaponics in Jerusalem

Other factors to be considered when choosing a site:

- Access to electricity
- Access to water – via the municipal water or a local well
- Installation of a surrounding fence – particularly if local animals and/or birds will be problematic

E) Greenhouses & Shading Net Structures

Speaking generally, Greenhouses are not essential for small-scale aquaponic units yet they may be critical in some regions if year long production is required. This is particularly true in temperate and other cooler regions around the world as they can be used to maintain a warm water temperature during winter months allowing a grower to produce throughout the year. Growers will find it economically advantageous to produce crops in winter months when available prices for fresh produce are higher.

Fig. 4.21& 4.22Aquaponics Systems in Greenhouses

A greenhouse is a metal, wood or plastic frame structure that is covered by transparent nylon, plastic or glass. The purpose of this structure is to allow to sunlight (solar radiation) to enter the greenhouse and then trap it so it begins heating the air inside the greenhouse. As the sun begins to set, the heat is retained in the greenhouse by the roof and walls, allowing for a warmer and more stable air temperature during a 24-hour period.



Fig. 4.21

Pros and cons for using greenhouses are as follows:

Pros:

- Protection against pests and animals
- General environmental protection (wind snow, rain)
- General climate control
- More comfortable working space for the grower, particularly during rainy seasons
- The greenhouse frame can be used to support climbing vegetables (tomatoes). It can also be used to support a shading net, as well as a mesh net to remove the threats of too much direct sunlight and pests



Fig. 4.22

All the advantages listed above will result in better and higher productivity.

Cons:

- If pests infiltrate a greenhouse they will spread rapidly and will be difficult to remove
- Additional and potentially expensive capital cost
- Increased humidity, causing a greater risk of plant diseases
- Extra ventilation equipment (electric fans, greenhouse curtains etc) will be necessary to circulate the air and avoid overheating and high humidity within the greenhouse

For more information on building a small scale greenhouse please see the further reading section at the end of this manual

Shading net structures:

In tropical regions net houses may be more appropriate to use instead of greenhouses as outside temperatures in the tropics are usually within the ideal range for aquaponics (18-30 °C). Instead, net-houses are used to remove the threat of many different types of pests associated with the tropics including: small insects, birds and larger animals (i.e. monkeys). Net houses are also used to protect the plants from various fungal diseases which are more common in tropical, high humidity environments.

Net houses are usually covered with mesh netting along the four walls with a plastic roof to prevent rain entering any component of the unit. The plastic roof is particularly important in areas with intense rainy seasons as units could overflow in a matter of days. The ideal mesh size for the four walls depends on the pests you are trying to remove. If birds or large animals are the only issue the mesh size needs to be between 19mm - 40mm; for insects, the mesh size should be at least 0.5mm² or smaller (i.e. Mesh 50).

Fig. 4.23 Shade Net Structure



For more information on building small scale net houses please see the further reading section at the end of this manual.

2) Essential Components of an Aquaponics Unit

Now that we know where to place our units, we can begin discussing the essential components for aquaponic units. As mentioned in the introduction of this chapter, there are 3 main methods of aquaponics: Media Bed units, NFT units and Deep Water Culture (Raft) units, all with different component styles to suit the needs of each method. However, there are common and essential components that must be integrated into all 3 methods. These are as follows:

- I. **The fish tank(s),**
- II. **Filtration (Mechanical and bio-filtration)**
- III. **The hydroponic component (plant growing space).**

In this next section, we briefly discuss these 3 mandatory components while making comments on other mandatory materials including, water & air pumps etc. Following this, we will discuss 1) Medi-aBed units & 2) NFT & DWC units together in greater detail.

A) Fish Tank & Fish Tank Design

Fish tanks are a crucial component to every unit and can cost up to 10-20% of the entire unit cost. Seeing as fish are sensitive creatures requiring certain living conditions in order to survive, there are important considerations/rules to take into account when purchasing or using existing fish tanks:

- **Tank Shape:** Cylindrical-shaped fish tanks are recommended; square tanks with flat bottoms will also work but they will not be as effective as cylindrical tanks in terms of solid waste removal. It is also beneficial if the tank has a lot of horizontal space, as opposed to vertical space, as this will help the fish to grow faster.
- **Material:** Strong inert plastic or fiberglass are both preferable to use as they will have a long lifespan.
- **Colour:** White or any other light colours are strongly advised as they allow you to easily check fish behavior and the amount of waste settled at the bottom of the tank. White tanks will also reflect the sun's rays, keeping the water cool. Alternatively, you can paint the outside of darker coloured tank with white paint. If using white plastic containers, make sure that they are UV resistant.
- **Secondhand Containers:** It is possible to use secondhand containers as fish tanks, but it's very important to make sure the container was not used to store toxic material. Although cleaning secondhand containers thoroughly with soap and water before use can be of value, it's important to realize that there are contaminants, such as solvent-borne chemicals, that will have penetrated into the porous plastic itself, and these are impossible to remove with washing. Thus, choose used containers carefully, and know the seller if possible.
- **Fish Tank Shading:** All fish tanks must be covered with shading material to prevent algae growth. Agricultural shading nets block 80-90% of sunlight and are therefore the most effective.

Fig. 4.24 -4.26 White Plastic Fish Tank (1000 – 2000 liters)



Fig. 4.24



Fig. 4.25



Fig. 4.26

B) Filtration (Mechanical & Biofiltration)

Mechanical filtration, which is the removal and/or separation of solid and suspended fish waste from fish tanks, is essential as harmful gases are released by anaerobic bacteria if solid waste is left to decompose inside the fish tanks.

As discussed in Chapter 2, **biofiltration** by living bacteria is also essential for aquaponics as the bacteria convert ammonia and nitrite, which are toxic even at low concentrations, into nitrates - the most accessible form of nitrogen for plants. Within an aquaponics unit, the **bio-filter** is the component where the vast majority of the living bacteria are housed. It is in this space that they can freely consume the dissolved fish waste mostly as ammonia.



Fig. 4.28

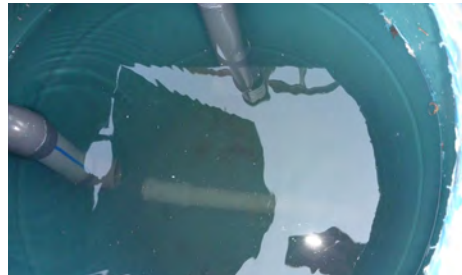


Fig. 4.29

Fig. 4.27



Fig. 4.27 -4.29 Different Mechanical & Biofiltration in Aquaponics Systems

Both methods of filtration will be explained further when we discuss the 3 methods of aquaponics. We'll come to learn that for Media Bed units mechanical and biofiltration techniques are actually combined using large volumes of bio-filter media (i.e volcanic gravel) in media bed containers. For NFT and DWC units, both filtration methods can be split into two separate containers; the first being a mechanical separator which traps and removes solid waste, and the second being a bio-filter where floating media are used to host bacteria which consume the dissolved ammonia waste.

There are different types of bio-filter media to use for all 3 methods of aquaponics, but all of them share some essential characteristics that nitrifying bacteria need to thrive:

- **Material with a high surface area** - for the bacteria develop a large colony
- **Air** - or more specifically, oxygen, for the bacteria to breathe
- **Moisture** - an essential factor for bacteria to grow



Fig. 4.30 Volcanic Tuff (Top left); Fig. 4.31 Bioballs

C) The Hydroponic Component

The hydroponic component is the term to describe the plant growing sections in the unit. In this manual we will discuss the 3 different plant growing methods in detail:

Fig. 4.32



Fig. 4.33



Fig. 4.32 & 4.33 Plants Growing in Media Filled Media Bed Units

Fig. 4.34



Fig. 4.34 & 4.35 Plants Growing in Grow Pipes Using the NFT Method (plants grow in pipes that have a small film of water constantly flowing along the bottom of the pipe)

Fig. 4.35



Fig. 4.36



Fig. 4.37



Fig. 4.36 & 4.37 Plants Growing in DWC troughs placed into floating Polystyrene Sheets

Other Essential Components:

I. Water Pump:

A submersible water pump is the heart of the unit as it allows the water to flow from the sump tank into the fish tanks, the bio-filter and on into the media beds or grow pipes. This movement of water is fundamental for keeping all organisms alive in aquaponics.

Thus, it's recommended to only use quality water pump brands that will guarantee a long pump lifespan (roughly 3-5 years) and energy efficiency (a helpful rule of thumb regarding energy efficiency for submersible pumps is as follows: min. 40 liters per Watt; some pump models claim to pump up to 100 liters per Watt). Top quality pumps will maintain their pumping capacity and efficiency for least 1-2 years. Inferior products will lose their pumping power in a shorter time meaning significantly reduced water flows which have a negative impact of the rate at which nutrients are passed to the plants and the dissolved oxygen levels in the water. Pumping power is also reduced at every pipe fitting; as a rule of thumb for small scale units, up to 5% of the total flow rate can be lost at every elbow or Tee connection water is forced through. Thus, use the minimal amount of connections between the pump and the fish tanks to avoid unnecessarily large pumps.

When installing a unit, make sure to place the submersible pump in an accessible location within the sump tank as you'll need to wash it and remove any clogged material every 2-3 weeks. The pump will also break down if it's running with no water to pump.

Regarding flow rate, the small scale units described in the step by step manual need a flow rate between 2000-4000 liters per hour; a pump submersible pump of this size should be 25-50 Watts maximum. A helpful 'rule of thumb' when designing a small scale unit is as follows: the flow rate per hour should be at least double the volume of the fish tank.

II. Air Pumps & Air Stones

Air pumps inject air into to the water through air pipes and air stones that lie inside the water tank. Air pumps and air stones will increase the dissolved oxygen levels in the water. As we will come to learn in the following sections of this chapter, it is a vital component of the NFT and DWC units – as it ensures a stable amount of dissolved oxygen in the system.

- For small scale units of roughly 1000 litres fish tank space, it's recommended that at least 2 injectors with air stones (pumping at a rate of 4-8 liters per minute) should be placed into the fish tank and 1 injector into the bio filter container (this is only the case for units that need to use bio filter containers).

If possible, it is preferable to use an AC & DC pump in case of electricity shortages. The charged DC batteries can easily continue working for roughly 8 hours without electricity.

Fig. 4.38 Submersible Water Pump



Fig. 4.39 Small Scale Air Pump

Air stones: Air stones at the end of the air pipe diffuse the air into smaller air bubbles thus creating more surface area for air to realize oxygen into water. It is recommended to buy quality air stones to avoid having to clean them regularly.

**Fig. 4.40 Air Stone:
Diffusing the Air Into
Fine Bubbles**



III. Sump Tank.

The sump tank acts a water collection tank and often as the place where the submersible pump is located. It is normally a third to a half the volume of the fish tanks. All the water from the system drains into the sump tank before being pumped back into the fish tank. External sump tanks are mainly used in Media Bed unit; however for DWC units the actual hydroponic canal can be used as a sump tank/pump house also. Although helpful, it is not an essential system component as many designs do not employ an external sump tank (see the step by step annex for more information on sump tanks for each aquaponic method).



Fig. 4.41 Sump Tank

IV. Plumbing Materials

Every system needs a selection of pipe lengths, connections and fittings so the water can easily flow into each component (the Step by Step annex has the entire list of materials needed for each unit). Make sure that the pipes and plumbing that you use in the system were not previously used to hold toxic substances. It is also important to use pipes that are black and/or non-transparent to light. This will stop algae from growing. Note: it is also important that plumbing used is of 'food-grade' quality to prevent possible leeching of chemical into the system water.



**Fig. 4.42 A Selection of
Essential Plumbing Materials**

V. Testing Kits and Measurements Tools

Water test kits are essential for testing pH, ammonia, nitrite and nitrate. Be sure that the manufacturers are reliable and that the expiration date is still valid. You will also need a thermometer to measure water temperature.

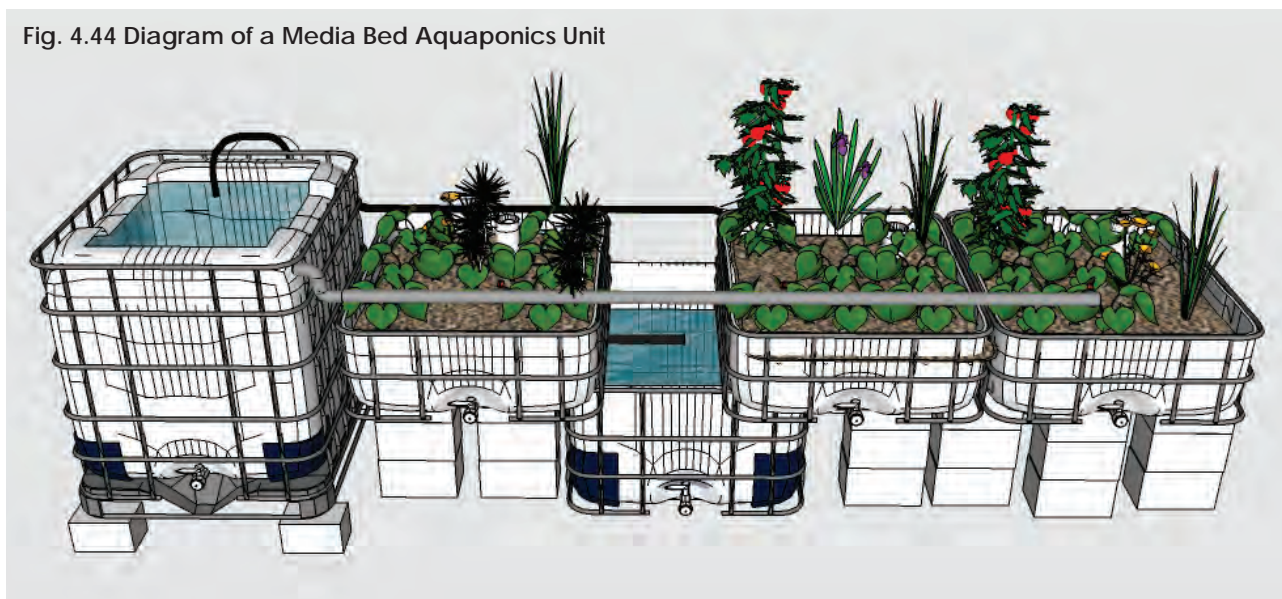


**Fig. 4.43 Water Test Kit including tests for:
Ammonia, Nitrite, Nitrate and pH**

3) The Media Bed Unit

Media-filled Bed units are the most popular design for small-scale aquaponics as they are efficient with space, relatively low cost and suitable for beginners as they are a very simple design. In media bed units, the media used to support the roots of the plants *also* functions as the means of filtration. This double-function is the main reason why media bed units are the simplest; as we'll see in the section on NFT & DWC units, both other methods require isolated and more complicated components for filtration and vegetable production space.

Fig. 4.44 Diagram of a Media Bed Aquaponics Unit



Water Flow Dynamics

The figure above shows the main components of the media bed units, including: the fish tank, the media beds, the sump tank and water pump, along with concrete blocks for support. While following the water flow in the figure you'll see that the water is moved by gravity from the fish tanks into the media beds. These media beds are full of porous bio-filter media (often volcanic gravel) that physically capture the solid and suspended waste, to be biologically broken down, while hosting a colony of nitrifying bacteria to consume the dissolved ammonia waste. Following this, the water exiting the media beds back down to the sump tank will be relatively free of solid or suspended waste. This is to avoid water with solid waste particles entering the sump tank directly, which would eventually clog the pump. This will also help to avoid solid or suspended waste being pumped back into the fish tank.

The following sections capture the theory for all the key technical aspects needed to understand how to design a media bed unit:

- I. Media bed materials, Shape and Depth
- II. Filling Your Bed with Media
- III. Filtration
- IV. Understanding the Processes at all 3 Zones of the Media Beds
- V. Methods to Flood and Drain the Media Beds

A) Media Bed Materials, Shape and depth

1. Materials

Media beds can be made from plastic, fiberglass or a wooden frame with water-tight rubber sheeting on the base and inner-side of the walls. The most popular DIY (Do It Yourself) media beds are made from plastic containers, modified IBC (Intermediate Bulk Container) water tanks or even old bathtubs. It is possible to use all of the above as beds and other kinds of tanks so long as they meet these following demands:

- Strong enough to hold water and growing media such as gravel, expanded clay or lava rock, without breaking. They also need to withstand difficult weather conditions.
- Made of material that is safe for the fish, plants and bacteria.
- Can be easily connected to other unit components through simple plumbing parts
- Can be placed in close proximity to the other unit components

2. Media Bed Shape & Depth

Shape: The standard shape for media beds is a rectangle, with a width of roughly 1 meter and a length of 1-3 meters. If the media beds are any larger, you will have to include a lot of support (i.e. concrete blocks) into the design, in order to hold the weight.

Depth: Media bed depth is important as it controls the amount of root space volume in the unit. The amount of root space volume in the bed determines the types of vegetables you can grow. If you wish to grow all kinds of vegetables (leafy greens and larger fruiting vegetables, such as tomatoes) the media bed must have a depth of 30cm (see fig. 4.46). If the depth is anything less than 30cm, larger vegetables will not have sufficient root space. If you plan on growing leafy green vegetables, or if you are limited to media beds with a fixed depth of less than 30cm, a depth of 15-20 cm will be sufficient. Any depth below 15cm and most vegetables will suffer from deficiencies towards the end of their life cycle, due to root matting on the media bed floor (See Chapter 6 for root matting).

B) Filling Your Bed with Media

The essential criteria for applicable grow media are as follows: 1) high surface area for bacteria growth; 2) Natural pH and inert (meaning the media will not leach out any potentially toxic substances; 3) Good drainage properties; 4) Easy to work with and 5) Sufficient space for air and water to flow within the media. Below is a list of the most popular and most applicable grow media to fill the beds with:

Fig. 4.45 Media Beds Made From IBC Plastic Containers



Fig. 4.46 Fiberglass Bed with a 30cm Depth

1. Volcanic Gravel (Tuff)

Volcanic gravel is the most popular media to use for media bed units and it comes recommended. There are 3 reasons for this:

1) Volcanic gravel has a very high surface area. It contains 300 m² of surface area per m³ (depending on the particle size); 2) It is relatively cheap and available various regions round the world; 3) Once washed, volcanic gravel is almost completely inert, except for small releases of micro-elements such as iron and magnesium and the absorption of phosphate and potassium ions within the first few months of starting a unit.



Fig. 4.47 Volcanic Tuff

The recommended size of volcanic gravel in 30cm beds is 4 -20 mm. If it is possible to buy to different sizes within this range it makes sense to fill the bottom half the media bed with 8-20mm gravel, as this size is more suitable for air and water flow. The upper half of the bed can then be filled with 4-8mm tuff as it is more user friendly/comfortable to work with.

2. Limestone

Limestone is a sedimentary rock that can also be used as grow media, but is less preferable than volcanic gravel as it is composed of soluble minerals (meaning they dissolve in water), which over time will have a negative impact on water quality. It will increase the hardness concentrations in the water, which will also increase the pH (See Chapter 3, Hardness).

Limestone is not so comfortable to work with in terms of planting and harvesting, but it is the cheapest and most common form of gravel to buy. Limestone also has a much lower surface area than volcanic gravel (200 – 300m²/ m³) and it is much heavier. As such, it requires more support underneath the bed.



Fig. 4.48 Limestone Gravel

3. Leca: Expanded Clay Pebbles

Leca are expanded clay pebbles that are round in shape and very lightweight compared with other substrates. Thus, they are very comfortable and ideal for rooftop production. Leca have a surface area of roughly 250–300m²/ 1m³ yet it is relatively expensive and not widely available around the world. Leca comes in a variety of sizes. For aquaponics, the larger diameter of 8-20 mm is recommended.

Other possible media alternatives include: **riverbed gravel** (which are made up of limestone and have surface area depending on the granulometry) or **pumice** (white/grey volcanic material also popularly used as grow media in hydroponics).

Even recycled plastic can be used as media, but given that plastic will float, you need to place large amounts of gravel on top (e.g. 150mm plastic and 150 mm heavy gravel). Below is a table summarizes the major characteristics for all grow media mentioned above:

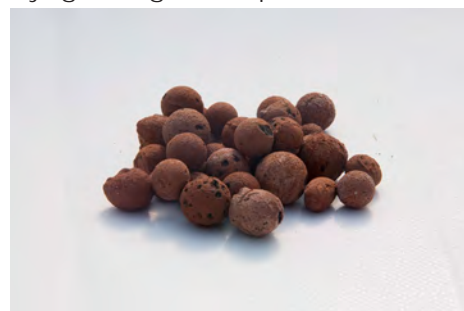


Fig. 4.49 Expanded Clay Pebbles

Characteristics of Different Grow Media								
Media Type	Surface area m ² m ⁻³	Ph	cost	Weight	lifespan	Water Retention	Plant Support/ anchorage	Ease to work with
Volcanic Gravel (Tuff)	300-400	Neutral	Medium	Medium	Long	Medium - poor	Excellent	Medium
Volcanic Gravel (Pumice)	200-300	Neutral	Medium - expensive	Light	Medium-long	Medium	Medium-poor	Easy
Limestone Gravel	150-200	Basic	Cheap	Heavy	Long	Poor	Excellent	Difficult
River Bed Gravel	100-150	Neutral	Cheap	Heavy	Long	Poor	Excellent	Difficult
Expanded Clay	250-300	Neutral - inert	Expensive	Light	Long	Medium - poor	Medium	Easy
Plastic Bottle Caps	50-100	Inert	Cheap	Light	Long	Poor	Poor	Easy

Preparing your grow media:

It is important to wash your gravel thoroughly before you place it into the beds. In particular, volcanic gravel and limestone have a lot of dust and tiny particles that can cause two problems: 1) this dust can build up at the bottom of the bed and clog parts of it; 2) Media bed dust can be pumped into the fish tanks and potentially clog fish gills.

C) Media Bed Filtration

As briefly outlined in the first section on media bed units, the list below describes the 3 filtration processes taking place in the beds:

- **Biological Filtration** – The grow media (volcanic gravel, Leca or limestone) has a large surface area where nitrifying bacteria develop a colony and begin the vital process of converting the dissolved fish waste, in ammonia form, into a nitrate for plants.
- **Solids Capture** – The media filled bed functions as a large physical filter capturing and containing the solid and suspended fish waste and other floating organic debris.
- **Mineralization**- Over time, the solid and suspended fish waste and all other debris are slowly broken down by biological and physical processes into simple nutrients (in molecules and ion form) that the plants can easily absorb (This process will be described in more detail in the next section and in Chapter 5-Bacteria).

The individual filtration methods (mechanical and biological) for NFTs and DWC units may be able to provide 1 or 2 of the functions listed above, but only a bed containing media with a large surface area, such as volcanic gravel, can provide all three.

Adding a Solids Removal Device to the Media Bed Unit

As mentioned above, solids capture takes place within the grow bed allowing the biological and physical (dynamic water flow) processes to break down the solid waste. Yet media beds can become overloaded with solid waste, depending on the stocking density and the amount of fish feed given per day. This leads to the creation of anaerobic zones within the bed that produce hydrogen sulphide (H_2S) which is tremendously toxic to fish.

To avoid these anaerobic zones while still maintaining a high fish stocking density, another solids capture device can be integrated into the unit design. It is recommended to do so if the stocking density is above **10 kgs per cubic meter** and/or if the feeding rate is above **50 grams/sq.meter/day**. This additional solids capture device removes the need to wash the gravel which would be mandatory every 3-6 months if a unit carried the stocking density and feed rates mentioned above.

The additional device can vary depending on the amount of management and cost a practitioner wants to spend. A very rudimentary and cheap technique is to simply fix an old sock to the water entry tap which can be removed each day to be cleaned out. Another more elaborate method is to place a 3-5 litre bucket inside the grow bed with several 6-8mm holes drilled into the side surfaces (see fig 4.50). Sponge, perlite or even grow media (volcanic gravel, Leca) tied in a porous, inert net bag can be placed into the bucket to trap the solid waste which can then be removed periodically to be washed out and placed back in. Finally, a more sophisticated method is to integrate a swirl clarifier container in between the fish tank and grow beds. More details on this method can be found in the NFT and DWC filtration section below and in the Step by Step annex.



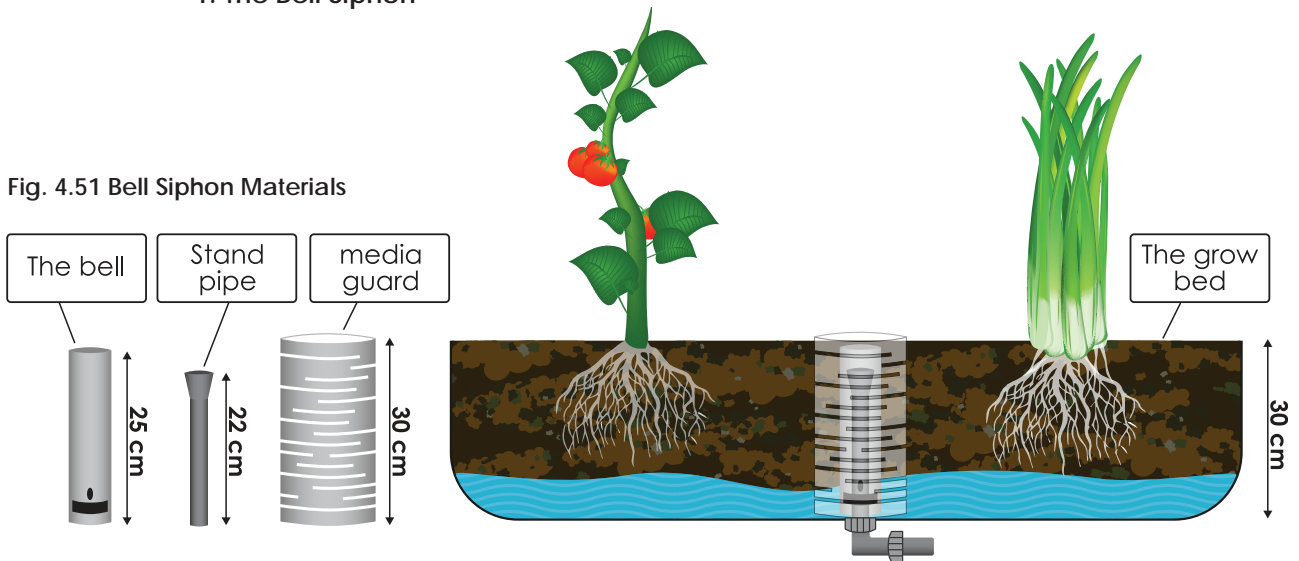
Fig. 4.50 Solids Removal Device in Media Bed Unit

D) Flooding and Draining The Media Beds

It is very important that the media bed floods with water from the fish tank and drains back in the sump tank every hour. This allows the plants to be irrigated with fresh nutrients and enables air to flood into the root zone, replenishing the oxygen levels for plants and bacteria. It also ensures enough moisture is in the bed at all times so the bacteria can thrive in their optimum conditions. This manual will briefly discuss 2 popular methods for flooding and draining a bed:

1. The Bell Siphon

Fig. 4.51 Bell Siphon Materials



The bell siphon (or auto-siphon) mechanism is a method that combines a few physical laws that allows the media bed to flood and drain automatically, periodically. The exact timing of the siphon is dependent on the water's flow rate into the bed.

The Main Parts of the Bell Siphon for a media bed with dimensions of 1-3m x 1m x 30 cms:

- **Media Guard:** 11 cm diameter PVC pipe, 30 cm in height with holes drilled in the sides, protects the bell and stand pipe from the gravel in the Grow Bed (GB) and without obstructing the flow of water.
- **Stand Pipe:** This pipe has a diameter of 2.5cm and is 22cm high. The stand pipe is connected to the bottom of the GB and connects to the pipes leading to the sump tank.
- **The Bell:** The bell is a pipe with a diameter of 7.5cm and a height of 25cm; It has an air-sealed cap on the top. Two rectangular gaps of 1cm X 4cm are located 1.5cm the bottom of the bell from 2 sides of it. A final 1cm hole drilled 5cms from the bottom.

N.B: Pictures of Bell Siphon materials are in the step by step annex at the end of the manual.

The Bell Siphon Mechanism

Water flows into each GB at a slow flow rate of 200-500 liters per hour. As the water fills up and reaches the top of the **stand pipe**, it will begin to drip through the **stand pipe** back to the sump tank. Water falls by gravitation through the stand pipe covering the whole surface area of the stand pipe. The bell, which covers the stand-pipe, acts as an **air tight lock** which produces a siphon effect (suction) inside the bell. All the water from the bed starts to rapidly flush down the standpipe as the bell keeps its air tight seal. When the water drains all the way down to the 1 cm hole drilled into the bell air rushes back into the bell and immediately stops the siphon. The water then slowly fills back up and repeats the whole cycle again continuously. Please see the further reading section at the end of this manual for more information on bell siphons.

2) Timer Mechanism

For this method of flooding and draining there is no bell or water siphoning. Instead the water pump is connected to a timer which cuts off periodically allowing water to flow down through a small hole in the standpipe.

The materials involved for this method are as follows: pipe of 11cm diameter and a 30cm long (Media Guard); a 2.5 cm diameter and 23 cm height stand pipe with a dripping hole of 8 mm just above the bottom of the GB.

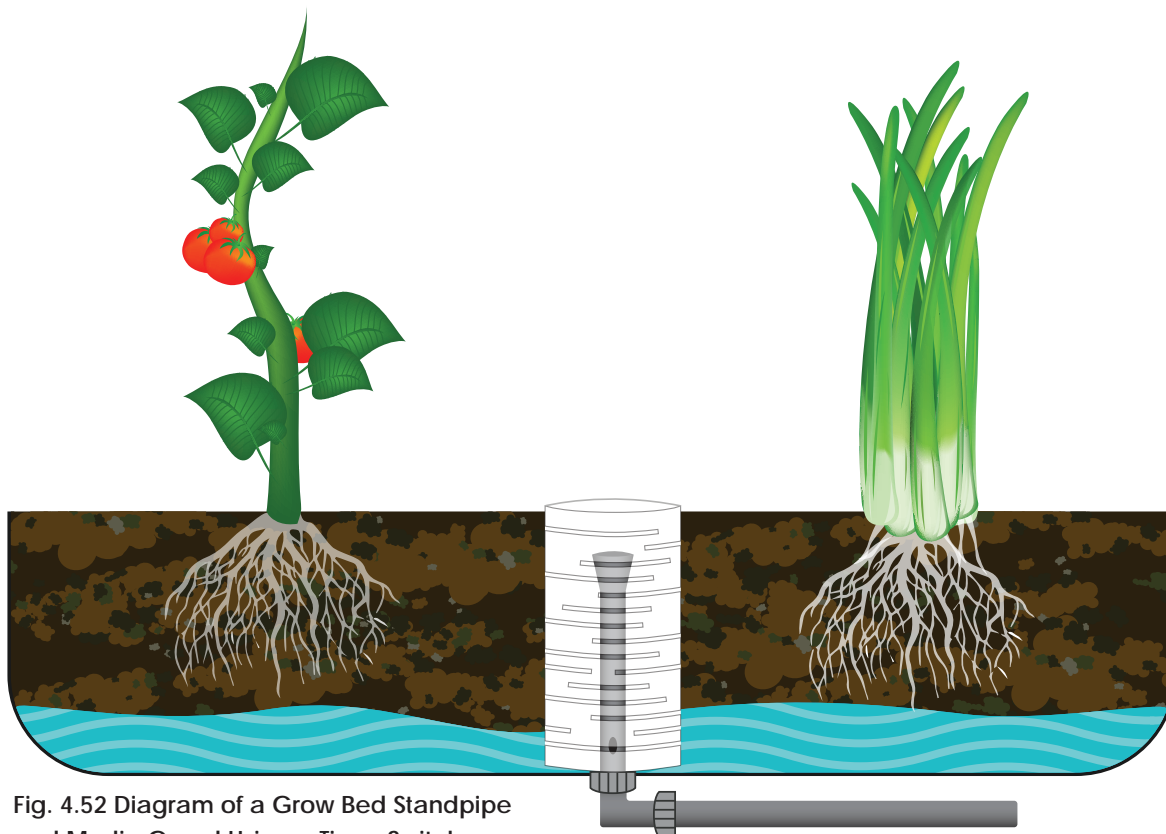


Fig. 4.52 Diagram of a Grow Bed Standpipe and Media Guard Using a Timer Switch

Water flow dynamics

Water flowing into the bed floods the bed until the water reaches the top of the 25 mm stand pipe. The water then starts to drain through the top of the stand-pipe and down into the sump tank. It also drains through the 8mm hole drilled into the standpipe @ 2.5cms. At this point the timer cuts the power to the water pump. Water in the media bed begins to flow out through the 8mm (which can be 6-12mm, depending on the in-flow) hole and continues flowing until the water level reaches down to the 8mm hole. At this point the water pump is automatically switched back on and begins refilling the bed with fish tank water **It is very important that the water flowing into the media bed is greater than the water flowing through the 8mm hole in the stand pipe so the bed will fully flood again.** The flooding and draining cycle length and the diameter of the dripping hole will be determined by the size of the media bed and the flow rate.