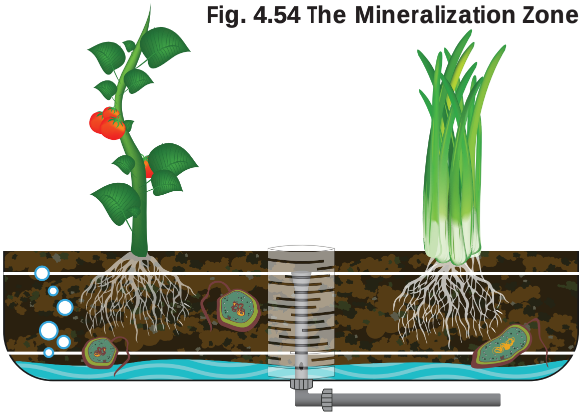
3) Mineralization Zone (The Wet Zone):

This zone, the bottom 3-5cm of the bed, remains permanently wet. In this zone, all the bacteria, red worms, water flies and other microorganisms thrive and consume all the solid waste, breaking it into smaller fractions and molecules that can be absorbed by the plants.

Fig. 4.54 The Mineralization Zone of a Grow Bed



4) Nutrient Film Technique (NFT) and Deep Water Culture (DWC) Units

Fig. 4.55 NFT Unit in a Greenhouse; Fig. 4.56 Large DWC Trough in a Greenhouse

The Nutrient Film Technique (NFT) unit is an hydroponic method using horizontal pipes each with a shallow stream of nutrient-rich aquaponic water flowing along the bottom for plants, inserted into each pipe, to utilize. Deep Water Culture (DWC) is a similar hydroponic method that involves suspending the plant roots in large water troughs with air supplied from the bottom of the raft at regular intervals. Both are highly popular methods for commercial operations as both are more financial viable than media bed units when scaled up (pics of both units).

Although all methods have a different approach to actually growing plants, the most important difference is the method of filtration that both the NFT and DWC units utilize compared with the media bed method. Below describes this method of filtration for NFT and DWC units in detail. Afterwards, the NFT and DWC methods will be split and discussed individually.

A) Mechanical and Biological Filtration components:

NFT and DWC units use two main filtration methods to improve water quality in the system:

1) Mechanical filtration by means of a physical trap to settle fish solid waste

2) Biological filtration to convert ammonia into nitrate by means of nitrifying bacteria.

Phase 1: Mechanical filtration

For recirculating aquaculture systems (RAS), mechanical filtration is argueably the most important aspect of the design. It is also important for aquaponics yet the fish stocking densities are much lower than RAS units so threat of fish loss if mechanical filtratiion fails is much lower. Mechanical filtration is required to trap and contain the solid and suspended fish waste making it easy to remove before water enters the NFT pipes or the DWC canals. There are several methods to do this, all varying in degree of complexity, yet as this manual is focused on small scale aquaponics, we'll describe one of the most simple systems: mechanical seperators.

Mechanical seperators (Clarifier) are installed in between the fish tank and and the bio-filter. Water flows from the fish tanks into the separator by gravity. The water is then forced down to the bottom of the container inside a pipe. The water exits the pipe which is positioned tansgentially to the container forcing the water to swirl in a circular motion inside the container. The centripetal force created by the circular motion of the water forces the solid waste in the water to the centre at the bottom of the container. A slotted pipe which is attached along the bottom of the container is then periodically opened forcing the solid waste through the slotted pipe and out of the container. A large outlet pipe is fixed at the very top of the container allowing clarified water at the top to then flow into the bio-filter.

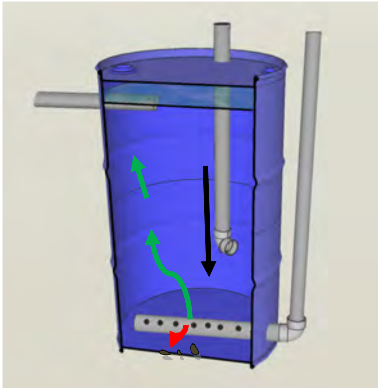


Fig. 4.57 Example of a Mechanical Separator

Phase 2: Bio-filters

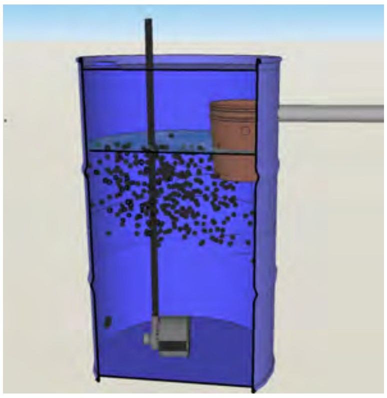


Fig. 4.58 Example of a Biofilter for Small Scale NFT & DWC units

Fig. 4.59 Bioballs (left)

The Biofilter is installed in-between the mechanical filter and the NFT or DWC canals. After passing through the swirl separator the water then flows into the bio-filter, again by gravity. This container is full of **bioballs** (max 60% of container volume) which are small, specially shaped plastic media that have a very large surface area (500-700 m^2/m^3), nearly double the surface area of volcanic gravel. Due to this, a large nitrifying bacteria colony can easily settle on the bio balls surface and start to convert the ammonia (dissolved fish waste) into nitrate. It is important to swirl the bioballs for 10 seconds at least once a week to prevent channeling of water due to cloggs. (Plastic bottle caps can also be used if bio balls are not possible to find locally. Wash the caps thoroughly before use)

Fig. 4.60 Fine Solids Screen in the Bio-filter (20 Liter Plastic bucket with Sponge)

Another mandatory component to the biofilter is an air pump with air stones placed at the bottom of the container. This is to insure the bacteria have constantly high and stable dissolved oxygen concentrations. Air pumps also help break down any solid or suspended waste not captured by the clarifier by agitating and constantly moving the floating bio balls.

It is also possible to insert a small cylindrical plastic bucket which is attached to the biofilter container (see fig. 4.60). Perlon (a white fibrous sponge-like material), sponge or a net bag full with gravel can be placed inside to act as another screen for all solid or suspended waste that escaped the swirl separator. The waste is trapped by the perlon, allowing the remaining water to flow down though the 1 cm holes drilled at the bottom of the bucket into the bio-filter chamber. The perlon should be periodically removed to be washed (with warm water only) and then replaced back into the bucket.

Placing the pump: For NFT and DWC units, the water pump can be placed at the bottom of the bio filter thus removing the need for a sump tank. When placing the pump here it assured that only clean, filtered water will be pumped into the hydroponic pipes or troughs.

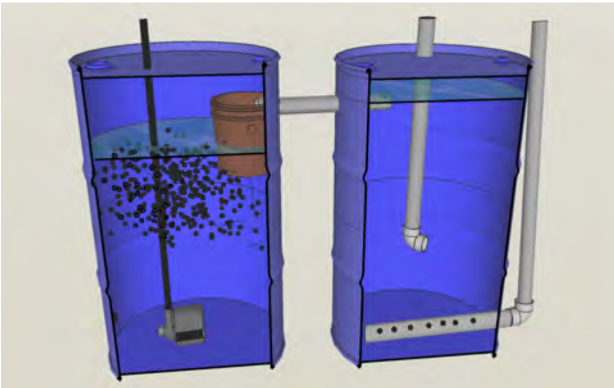


Fig. 4.61 The Mechanical and Bio- filter Containers Combined

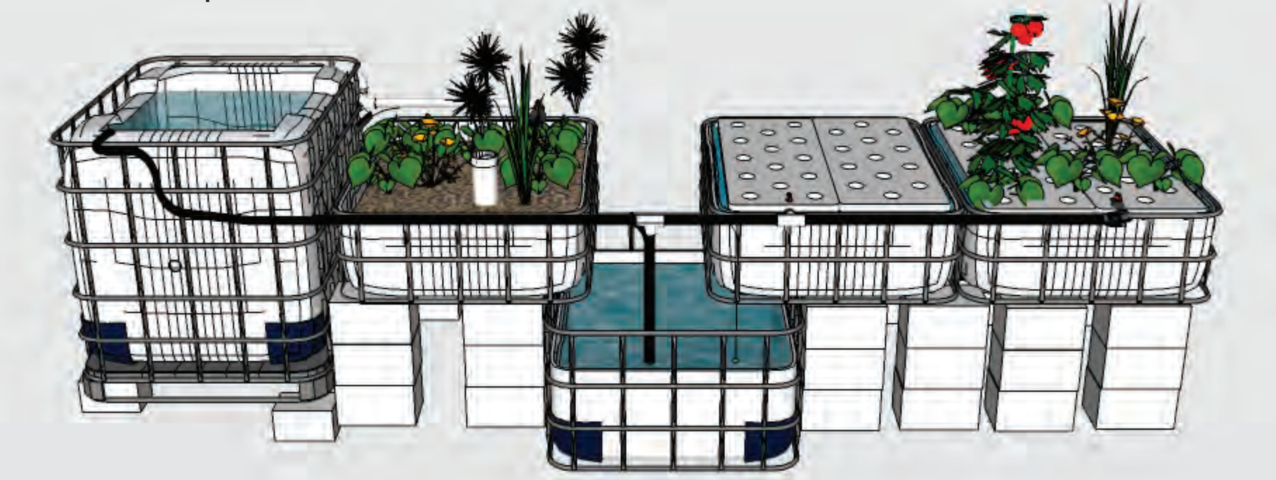
In summary, the biofiltration process for NFT and DWC units is exactly the same observed in media bed units, as nitrifying bacteria, hosted by the bioballs, convert the ammonia to nitrate. One major difference though, is the type and the amount of media used. As Bioballs, used for NFT and DWC units, have a far higher surface area than grow media, much less volumes are needed to nitrify the dissolved fish waste (See annex 4 for more details of the exact amount of filtration media needed).

The other major difference is the preliminary mechanical filtration for NFT and DWC units used to trap and remove the solid waste. Without this preliminary process, solid and suspended waste will build up in the grow pipes and canals and in-between plant roots which will damage the roof surface. Solid waste accumulation will cause blockages in the pumps, and plumbing components. They will also create hazardeous anaerobic spots in the system which produce hydrogen sulphide, a very toxic gas for fish produced from fermentation.

Using a media bed as filtration for NFT and DWC units

One final note on filtration for NFT and DWC units: It is also possible to use a media filled bed for mechanical and biofiltration if it is not possible to obtain the materials needed for a swirl separator and/or bio-filter (see fig. 4.62). As we'll learn in Chapter 8: *component calculations*, we only need roughly 200 litres of volcanic gravel to convert the ammonia produced from 200 grams of fish food per day. Therefore, a bed with dimensions of 1 meter x 1 meter x 30cm filled with volcanic gravel should be more than enough to convert the ammonia of a small scale unit with a maximum fish density of 15-20kgs (although an additional solids capture device should be placed into the bed as discussed in the *filtration* section of the media bed method above).

Fig. 4.62 Small Scale DWC Unit Using a Gravel Grow Bed for Filtration Instead of a Mechanical Separator & Biofilter



A) NFT Method for aquaponics

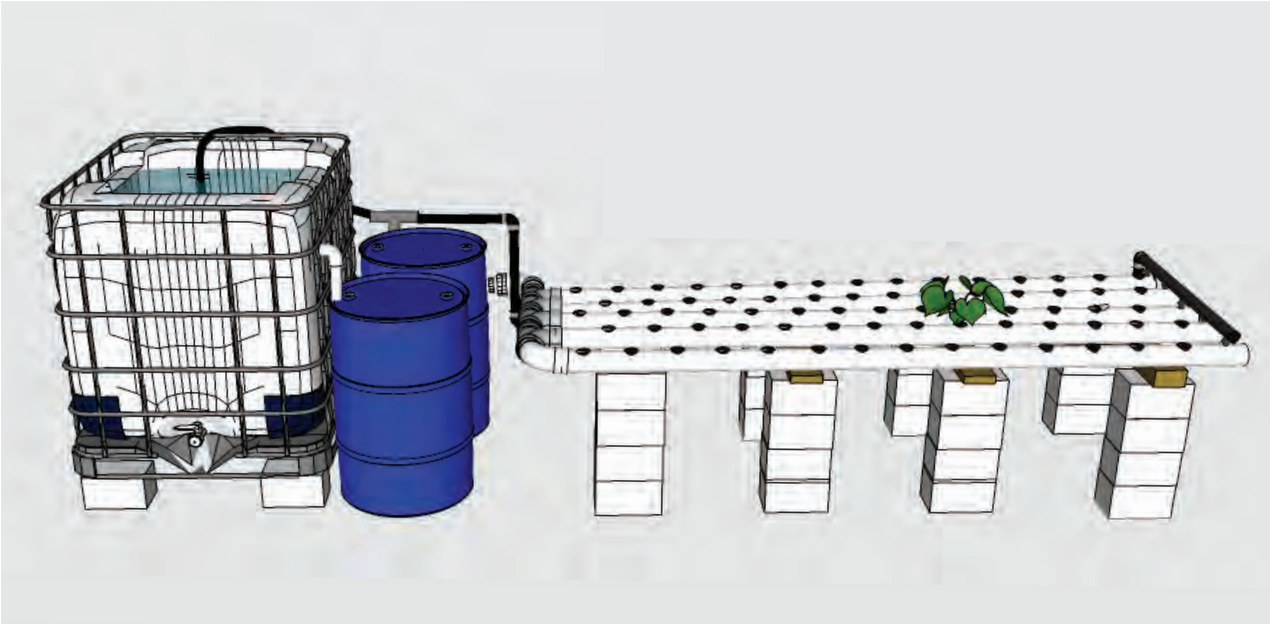
Following on from the filtration methods explained above, The Nutrient Film Technique (NFT) then employs the use of plastic pipes laid out horizontally to grow vegetables using the aquaponic water.

Water Flow dynamics: (see fig. 4.64)

The water is pumped from the biofilter into each hydroponic pipe with a small equal flow creating a shallow stream of nutrient-rich aquaponic water flowing along the bottom. The pipe contains a number of holes along the top of the pipe where plants are placed into. As the plant starts to consume the nutrient-rich water from the stream, they begin developing root systems inside the grow pipes. At the same time their stems and leaves grow out and around the pipes. The shallow film of water at the bottom of each pipe ensures that the roots receive large amounts of oxygen at the root zone along with moisture and nutrition. Keeping a shallow stream prevents the roots from being fully flooded, and thus minimizes the risk of root rotting. **Note: The water flow for each grow pipe should be no greater than 1-2 liters per minute.**

Fig. 4.63 Lettuce Growing in NFT Pipes

Fig. 4.64 Small Scale NFT Aquaponics Unit



B) Growing Plants in the Pipes

Shapes and Sizes

- The hydroponic pipe length can be anywhere between 1-12 meters in length. If the length is any longer than 12 meters, nutrient deficiencies will occur in plants towards the end of the pipes.

- When deciding what types of plants you want to grow, it is essential to choose a pipe with the opti mum diameter. For leafy green and small root vege tables, round pipes with a diameter of 7.5 cm are sufficient. For larger fruiting vegetables, 11 cm diam eter grow pipes are needed. Leafy greens as well can also be grown in 11 cm pipes. For small-scale polyculture (growing many types of vegetables) we recommend using the 11cm pipes. This will avoid plant selection limitations.

- White PVC circular pipes are recommended as they will be the most like pipe available. They will reflect the sun's rays, keeping the inside of the pipes cool.

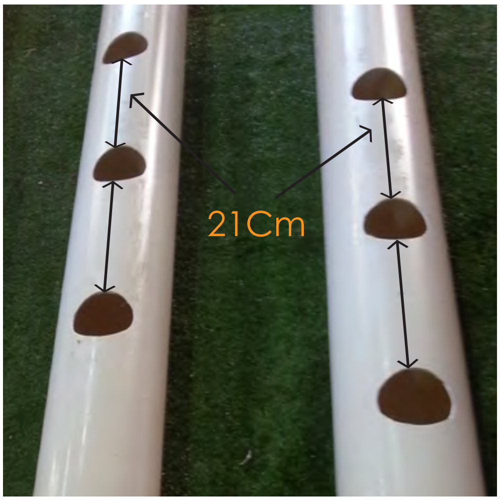


Fig. 4.65 Hole Spacing for NFT

Fig. 4.66 NFT Pipes Vertically Stacked

• Square or rectangular hydroponic pipes with dimensions of 10cms width and 7cms in height are also recommended. Professional hydroponic pipes for commercial growers are stereotypically this shape.

• A slope of roughly 1cm in height per meter of pipe length is needed to make sure the water flows through the whole pipe with ease.

Fig. 4.67 & 4.68 Square Shaped NFT Grow Pipes

Planting in Plastic or Net Cups

• Each hole drilled into the hydroponic pipe should be 7-9cm in diameter allowing plant seedlings to be placed inside them. There should be a minimum of 21cms between the centre of each plant hole to allow adequate plant space for leafy greens and larger vegetables.

• In order to provide support for the seedlings inside the pipe, place each one into a plastic net cup. Then place 4-8mm of volcanic gravel or expanded clay gravel around the seedling. Finally, 5-10 cms of 2 inch PVC pipe can be placed inside the net cup for further balance and support to the plant. For further information on planting please see the step by step annex.

Fig. 4.69 & 4.70 Plant Support Methods for NFT Planting

• If plastic net cups are not available it is possible to use regular plastic drinking cups. Follow the planting procedure as outlined in the previous paragraph making sure to add many holes to the plastic drink up so the roots have plenty of access into the NFT pipe.

• It is possible to transplant the seedlings straight into the pipes,particularly rectangle pipes (Fig 4.52). In this case seedlings are transplanted with their media, although with this solution, media can dissolve and spread into the system. Alternatively, seedlings' roots can be carefully washed before transplant, but this could increase the transplant stress . Nevertheless it is preferable to use net cups filled with media, as shown in the picture (Fig 4.70).

Fig. 4.71 Plastic Drinking Cup Used for Plant Support

Note: When initially planting the seedlings into the pipe make sure the roots can touch the stream of water at the bottom of the pipe. This will ensure that the young seedlings do not get de-hydrated. Also, it is advisable to water the seedlings with aquaponic water one week prior to transplanting them to the unit. This will help mitigate against transplant shock for the plants, as they will be accustomed to the new water.

Fig. 4.72 Planting Seedling Straight into NFT Pipes (Square)

B) Deep Water Culture Units

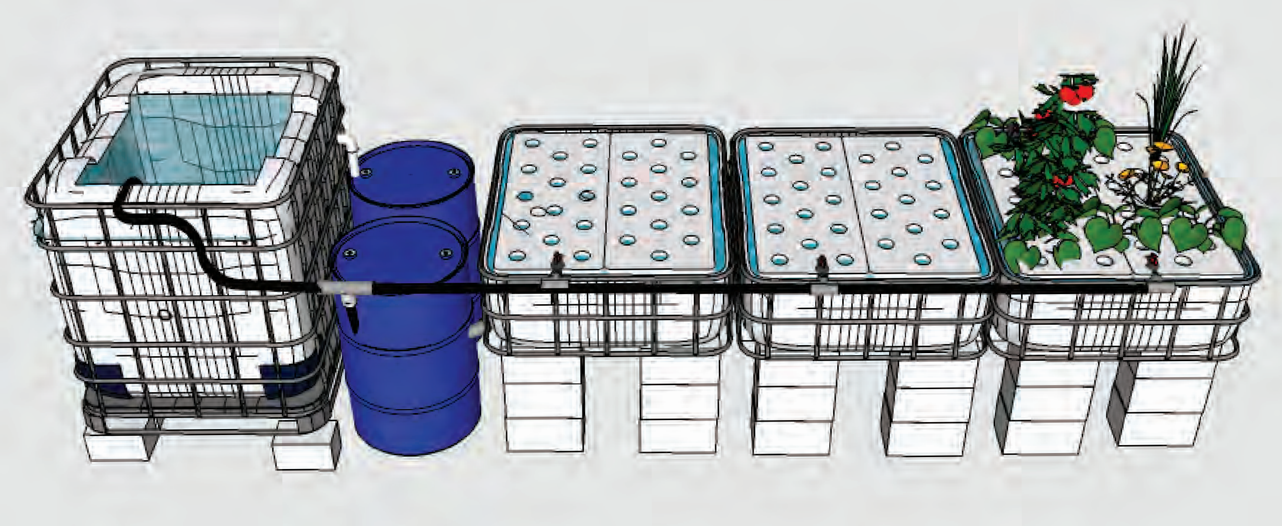
Fig. 4.73 Lettuce Growing in a DWC Trough

The final method, which is the Deep Water Culture (DWC) method, involves suspending plants in polystyrene sheets that float in troughs with air supplied from the bottom of the trough at roughly every square meter. This method is the most common for large commercial aquaponics growing one specific crop (stereotypically lettuce, salad leaves or basil).

Water Flow dynamics: (see fig. 4.74)

As with NFT units, water is pumped from the bio-filter container (the second of the two-stage filtration process for NFT and DWC units) into troughs which have polystyrene sheets floating on top supporting the plant and blocking out the light. The flow rate of the water entering each trough should be relatively low. A good 'rule of thumb' to follow is 2-4 hours **retention time** for each trough (retention time is the amount of time it takes to replace all the water in a container; i.e. if the water volume of one trough is 600 liters and the flow rate of water entering the container is 300 liters per hour, the residency time will be 2 hours - 300 liters x 2hours).

Fig. 4.74 A Small Scale DWC Aquaponics Unit



The water then flows out of the troughs and back into the biofilter or fish tank through standpipes fixed at roughly 30 cm inside the trough or a pipe fitting attached to the trough at 30 cm. Mechanical and biological filtration is essential for DWC units to make sure the water is fully filtered before it enters the water troughs, otherwise you will face the risk of clogged root pores from solid or suspended fish waste that will eventually kill the plant.

DWC Troughs:

- Each trough can be 1-30 meters in length or width but the depth must be 30 cm to allow for adequate plant root space. Similar to fish tanks, troughs can be made out of any strong, inert material that can hold water; for small scale units, popular materials include fabricated IBC plastic containers (see step by step annex for examples) or fiberglass. Much larger troughs (+ 5 meters) can be constructed using wood lengths or concrete blocks with 'food grade' waterproof liner fitted inside the trough or concrete. If using concrete, make sure it is sealed with non-tonic waterproof sealer to avoid potential toxic minerals leaching from the concrete into the system water.

Fig. 4.75 DWC Trough (15 meters long)

- Water Flow: as mentioned above, the retention time for each trough in a unit should be 2-4 hours regardless of the actual trough size, allowing for adequate replenishment of nutrients in each trough. If the flow rate is much faster than this rate it will negatively impact plant growth.

- Aeration for DWC units is vital. In a densely planted trough the oxygen demand for plants alone could cause oxygen levels to plummet below the minimum. Any decomposing solid waste present in the trough will also reduce the water's dissolved oxygen level. Thus, air stones releasing roughly 4 liters of air per minute are used for every 2-4 square meters of canal area to insure oxygen levels remain constantly high.

Fig. 4.76 Air Stone inside a DWC Trough