Understanding Filtration

In the preceding section, we looked at how aquaponics works from a basic microbiological perspective. In this section, we look at how we optimise the conditions under which the beneficial bacteria work - in the best interests of fish health and well-being.

A Matter of Life and Death

While fish and plants are the visible elements in any aquaponics system, the bacteria that facilitate the conversion of fish wastes into plant food are clearly the key to the whole arrangement…..and that brings us to the subject of filters.

At this point, it's probably useful to point out that solid wastes take three forms:

- Sedimentary – usually comprise fish faeces and uneaten food which will settle out if water velocity is low.
- Suspended – small particles of food or faeces which are neutrally buoyant – they neither sink nor float but are carried in the water flow.
- Dissolved – usually comprises urine or ammonia discharged from the gills – in solution.

Filters are the mean by which we optimise water quality for our fish….by capturing solid wastes and/or converting the dissolved wastes - which would otherwise eventually prove toxic to them.

The filters that we use to oxidise dissolved wastes are biological filters and those that capture solids are mechanical filters.

Biological filters are simple devices that facilitate the colonisation of the beneficial bacteria that are central to aquaponics through:

- Removal of dissolved organic matter
- Conversion of ammonia to nitrites
- Conversion of nitrites to nitrates
- Other bio-filter functions that positively impact the well-being of our fish include:
- Oxygenation of the water
- Removal of CO2
- Flashing off of nitrogen

The beneficial bacteria are known as *Nitrosomonas* and *Nitrobacter*. They are both *autotrophic* bacteria and will both grow and colonize an aquaponics system as long as there is a food source (dissolved wastes) and sufficient oxygen available.

The presence of sedimentary and (above certain levels) suspended solids in an aquaponics system encourages the growth of a different type of organism…….*heterotrophic* bacteria.

While *Nitrosomonas* and *Nitrobacter* are slow growing, *heterotrophic* bacteria are fast-growing and will breed up in much greater numbers if the feedstock is available…...and herein lies a problem.

The *heterotrophic* bacteria will compete with the *autotrophic* bacteria for oxygen and may actually inhibit nitrification.

This problem can be avoided in one of two ways: Stocking rates can be limited so that only modest levels (relative to the overall bio-filtration capacity) of sedimentary and suspended solids are produced…..or you can capture and remove the solids.

Where practicable, I prefer to remove the fish solids before they get into the bio-filters.

This is achieved through the use of sedimentation tanks, clarifiers, swirl filters, screens or similar mechanical filtration devices. For very small systems, mechanical filtration may be as simple as running the water from the fish tank through a piece of filter foam or even an orphan sock.

Now, this viewpoint flies in the face of some aquaponics fundamentalists who argue that the solids somehow contribute to the overall nutrient mix in an aquaponics system. They contend that the solids will be trapped in the grow bed, mineralised by worms and eventually become part of the nutrient mix.

While I don't argue with the basic mineralisation proposition, here's why I suggest that solids be removed:

- Bio-filters (including grow beds) function more efficiently when solids are removed.
- Both fish and nitrifying bacteria require oxygen. Large amounts of fish wastes or uneaten food consume oxygen and, in extreme situations, will result in low dissolved oxygen levels.
- Built up fish wastes create pockets of anaerobic (without oxygen) activity resulting in denitrification. Denitrification causes the pH of the system to rise. Ammonia in the presence of high pH levels is toxic to fish.
- Grow beds will require less frequent maintenance if solids are removed. Regardless of how many worms you have in a grow bed, there will still be some sediment left in the bed. Over time, this sediment will (unless removed) build up and will eventually impair the biological functionality of the bed.
- Working with clean grow beds (and clean hands) is a more pleasant task.

There are far more efficient ways to mineralise fish solids than leaving them in an aquaponics unit. I'd rather use an aerobic digester or put the solid wastes into a worm farm and then add compost tea (made from the worm castings) back into the system.

Where a lightly stocked flood and drain aquaponics system might be able to function without removing the solids, when using nutrient film technique (NFT) or deep water culture (DWC) growing systems there is no argument - solids must be removed.

Mechanical Filters

Earlier in this section, I referred to mechanical filtration methods including:

- **Sedimentation tanks** - serve to reduce the velocity of the water flow so that sedimentary solids will settle to the bottom where they can be removed.
- **Clarifiers** – are another form of sedimentation tank.

- **Swirl tanks** – rely on centrifugal action to force heavy particles (solids) to the outside of the tank where they then settle to the bottom for easy removal. The dump valves on sedimentation tanks, clarifiers and swirl tanks are operated regularly (sometimes several times a day in a highly stocked system) to ensure that solids are removed before they begin to attract the attention of *heterotrophic* bacteria.
- **Screens** - range from inexpensive pieces of filter foam to very expensive stainless steel mesh strainers. They work by trapping the solids. A simple screen filter can be made from an orphan sock. Attach the sock to the end of the discharge pipe and remove and empty at regular intervals.
- **Mineralisation Tanks** – are a combination biological and mechanical filter. They comprise a tank containing a media substrate (often coarse filter pads or nylon bird netting) to which bio-film attaches. Bio-film is an aggregation of micro-organisms (and a slimy matrix that they produce) that builds up on all exposed surfaces in the water column. As the water from the fish tank flows through the mineralisation tank, the suspended solids adhere to the bio-film and are retained long enough for decomposition and the subsequent release of organic compounds (nutrients) to occur.

Each of these mechanical filtration methods performs a similar function – to remove solids from your system.

Biological Filters

Having got the sedimentary and suspended solids out of the system, it's then time to facilitate nitrification – to convert the ammonia into nitrites - and subsequently into nitrates – and this is where the bio-filter enters the picture.

For backyard aquaculture purposes, there are 4 main types of biological filter:

- Media-Based Grow Bed
- Trickling Bio-filter
- Submerged Bed Filter
- Aquatic Plant Filter

There are other types of biological filters including rotating biological contactors, bead filters, and fluidised bed sand filters….but those that I've listed are those best suited to backyard fish farmers (in the short term at least).

A good bio-filter will be:

- Made of inert, non-toxic materials
- Inexpensive to build
- Easy to operate and maintain
- Reliable
- Portable
- Space-efficient
- Versatile…..achieving as many water quality functions as possible.

Media-based Grow Bed

The most widely used backyard aquaponics system comprises a fish tank, a pump, a few fittings and a grow bed filled with gravel or expanded clay pebbles.

For practical purposes, the grow bed in a basic flood and drain system serves three functions:

1. To capture solids – mechanical filtration.
2. To oxidise and mineralise solids – bio-filtration.
3. To support plants

While being able to use a grow bed to perform these functions is an advantage, it can also be a weakness.

The biggest issue is that the mechanical and biological filtration functions are at odds with each other.

There are also occasions where it is desirable to be able to separate the aquaculture unit from its growing system.

Some of the more common fish ailments require the use of salt as a treatment. While the fish can tolerate high concentrations of salt for short periods, most plants cannot.

Similarly, if your plants contract a disease or become infested with some pest or the other, they may require treatment with an herbicide or pesticide….and even organic preparations may prove toxic for fish.

Sometimes, the choice of growing system will discriminate in favour of using separate bio-filters. People who rent their houses may rely on lightweight growing systems like nutrient film technique or deep-water culture. These are only practical on a small scale when used in conjunction with a bio-filter.

The advantages and disadvantages of gravel grow beds (as growing systems) are canvassed in greater length in the section on growing systems.

Trickling Bio-filter

Trickling bio-filters have been around for more than 100 years. They are widely used in wastewater treatment plants.

The huge trickling bio-filters, upon which I worked during the 1970's, used rock as media and a rotating boom arrangement ensured that the effluent was distributed evenly across the media.

The rock media served as the substrate to which the bio-film attached and the nitrifying bacteria lived in the bio-film.

The charm of trickling filters is that they are simple to build and easy to operate and maintain. They work well across a wide range of nutrient levels.

The percolating action of the water as it trickles down through the media provides for excellent aeration. It also facilitates the removal of carbon dioxide and nitrogen (in gaseous form) from the water.

Trickling filter design will be driven by your circumstances……a tall, narrow filter will save space but will require more energy to pump the water…..and a wide, low filter will use less energy but take up more space.

Choosing the right media is also an important design consideration. Media options include:

- Gravel
- Scoria or lava rock
- Light expanded clay aggregate (clay pebbles)
- Structured plastic media
- Oyster Shells

We've used various media including oyster shells (cheap but heavy), expanded clay pebbles (lighter but a lot more expensive) and plastic media (lighter again but very expensive).

Oyster shells are still my favourite media. They offer reasonable balance between cost, surface area, void space, weight and overall effectiveness.

Good nitrification will depend on effective water distribution throughout the filter. Large commercial bio-filters may feature a rotating spray arm. Small units will often have a deflector arrangement that spreads the water across the top of the filter media.

We make an inexpensive water distributor out of a plastic bowl in which we drill holes. It functions like an oversized shower nozzle spreading the water evenly over the media. Another option is to drill 8mm holes in a PVC end cap (like a crude shower fitting) and mount the cap so that it sprays the water across the media.

Submerged Filters

A trickle bio-filter consists of a vessel filled with media and water is introduced at the top so that it trickles down through the media and exits from the bottom.

A submerged filter, in its most fundamental form comprises a drum filled with media and water flows upwards through the media.

The under-gravel filters found in many aquariums are also submerged filters. The gravel media used in under-gravel filters is supported by a plastic platform over a void space. Water is drawn down through the gravel and is discharged at the surface.

These basic submerged filters are relatively easy to clean at the aquarium level but rather less so as their size increases.

More sophisticated versions of the submerged filter, like the fluidised bed sand filter and the bubble bead filter, have overcome the cleaning issue (and are very much more efficient), but they are also quite expensive.

The Moving Bed bio-filer filter is a more recent variation on the submerged filter theme and is arguably the state-of-the-art in terms in terms of its nitrification efficiency and its ability to self-clean.

It utilises *Kaldnes* manufactured plastic media - which floats. The media is designed in such a way that it provides (relative to its size) a large surface area for the nitrifying bacteria to attach to.

Air is used to "churn" the media, which achieves two things:

- It provides an oxygen rich environment for the nitrifying bacteria.
- It causes the media to make contact - sloughing off the dead bacteria and making way for fresh bacteria - it is self-cleaning.

Moving Bed filters offer unexplored potential to backyard aquaculturists. They are quickly becoming our bio-filter of choice because:

- They are simple to build and easy to operate.
- They will never clog – and are self-cleaning.
- We can stand them on the ground.
- They are far more efficient that trickling bio-filters.

Aquatic Plant Filter

While plants are not generally used for bio-filtration in regular aquaculture systems, their effectiveness at removing nitrates is the key to their use in aquaponics. The integration of recirculating aquaculture and hydroponics produces several tangible benefits including:

- Removal of nitrogen and phosphates from water
- Reduced water use
- Production of plants for use by humans and animals.

By definition, any aquaponics growing system is a plant filter.

A duckweed tank is also an aquatic plant filter. Researchers claim that duckweed will consume ammonia directly in its un-ionised state, which is particularly handy for aquaponicists. In any case, if you grow duckweed in water and you harvest the duckweed, you effectively harvest nutrients from that body of water.

These same features, however, first attracted the attention of NASA researchers over 30 years ago. In their quest to find the means to purify water on long space journeys, they discovered that the water hyacinth was able to convert sewage effluents to relatively clean water…..at a fraction of the cost of conventional sewage treatment.

Disneyworld used NASA’s water hyacinth know-how to build a wastewater treatment plant at their Florida theme park and many cities throughout the world have adopted the plant as their principal wastewater treatment strategy.

Once the water hyacinth has taken up the pollutants, it can be harvested for fertiliser. Other experiments have established its potential for methane gas production and even livestock feed.

Water hyacinth would be an exceptional plant filter for use in aquaponics.

Note: Water Hyacinth is a prohibited plant in Australia.

Another variation on the aquatic plant filter idea is the water garden. Various water plants including Chinese water chestnuts, kangkong and watercress can all be grown in pots in water.

Gaining a thorough understanding of how biological and mechanical filters work, and how to use them, is essential if you are going to optimise water quality and fish health.

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