AQUAPONICS 101

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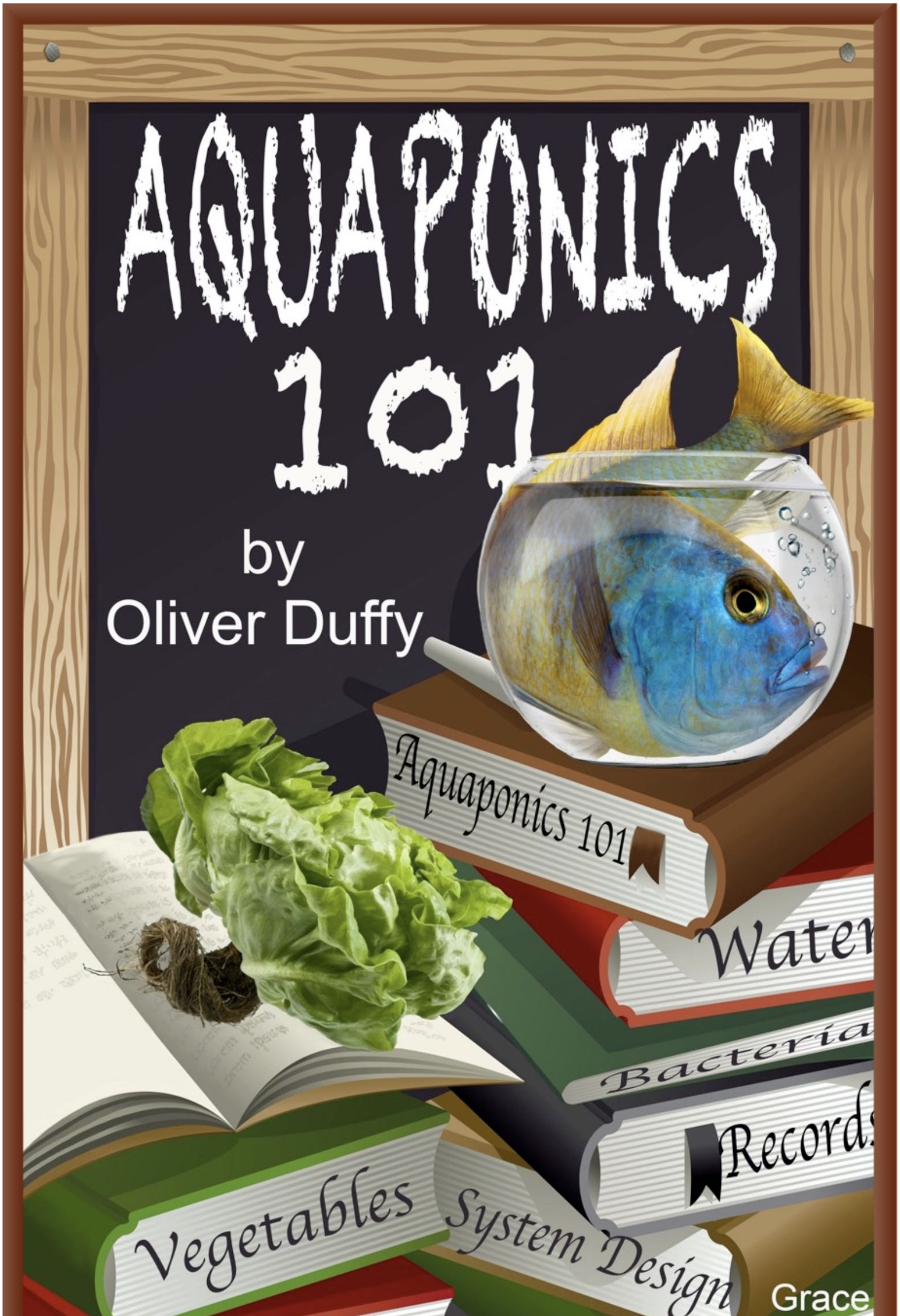
AQUAPONICSUSA.COM

By Oliver Duffy



AQUAPONICS
101
by
Oliver Duffy
Aquaponics 101
Water
Bacteria
Records
Vegetables
System Design
Grace

"Hi, I'm so pleased you've found my AP Class. Pull up a chair and get comfortable. This is Aquaponics 101. As your Instructor, I suggest that you read each of the 7 Parts a couple of times before moving on to the next Part. Let the information sink in and take notes. Better yet, print out this Class Binder and carry it around with you. This is the Lecture segment. You need to create your own Lab by either purchasing a system or building one. This is the info you need.

It is some of the most valuable information you'll see on Aquaponics, not because it's so erudite, but because it's born from Actual Experience. I'm a retired Aerospace Engineer running an R&D AP facility that's growing food in both a Greenhouse and a Growroom; and I'm learning from my own experiments, mistakes and successes. Here's your chance to learn what I've learned."
OLIVER

Aquaponics 101 Introduction:

We, here at Aquaponics USA, receive calls daily from Aquaponics enthusiasts with varying amounts of Aquaponics experience. Most are very new to this wonderful technology. When we first started out in late 2008, we were also new to Aquaponics and had to learn. Fortunately, we had lots of help on Murray Hallam's Australian forum from those more experienced folks; and, of course, Murray himself, who was a great mentor. Once we felt we had enough information we started to build our own system and that is where the learning really began.

Being a retierd Aerospace Engineer with over 45 years of experience in many aspects of that industry was beneficial in understanding and implementing the various designs I came up with and also understanding what went wrong when things didn't work the way I expected.

What follows is going to teach you most of what you will need to know about Aquaponics in order to build and maintain your own system. So, if you're curious about the most amazing food growing technology on the planet today, read and take notes on the numbers presented as they collectively are what is most important for you to build a properly designed Aquaponics (AP) system.

This was originally written to address those who are of the belief that we are about to see some serious changes in our economy, along with the price and availability of food. With this in mind, I felt it was time to write this primer as Aquaponics 101 so that those who wish to prepare could have a year-round capability for helping to feed themselves and their family.

As this tutorial progresses, I will be talking about family and school-sized systems and focusing on the type that we know best. I realize that there are a number of viable approaches to building AP systems that many Aquaponics pioneers have experimented with and developed. Due to this emerging technology, there are many differing opinions held by those involved with this wonderful gift of nature. I can only tell you what I believe to be true from all that I have read about other's efforts and from my own experience.

Historically speaking, Aquaponics as a technology has been around for hundreds of years; but ironically, it also is still in its infancy as a family and school food growing technology. There is much research yet to do in this area and much to learn.

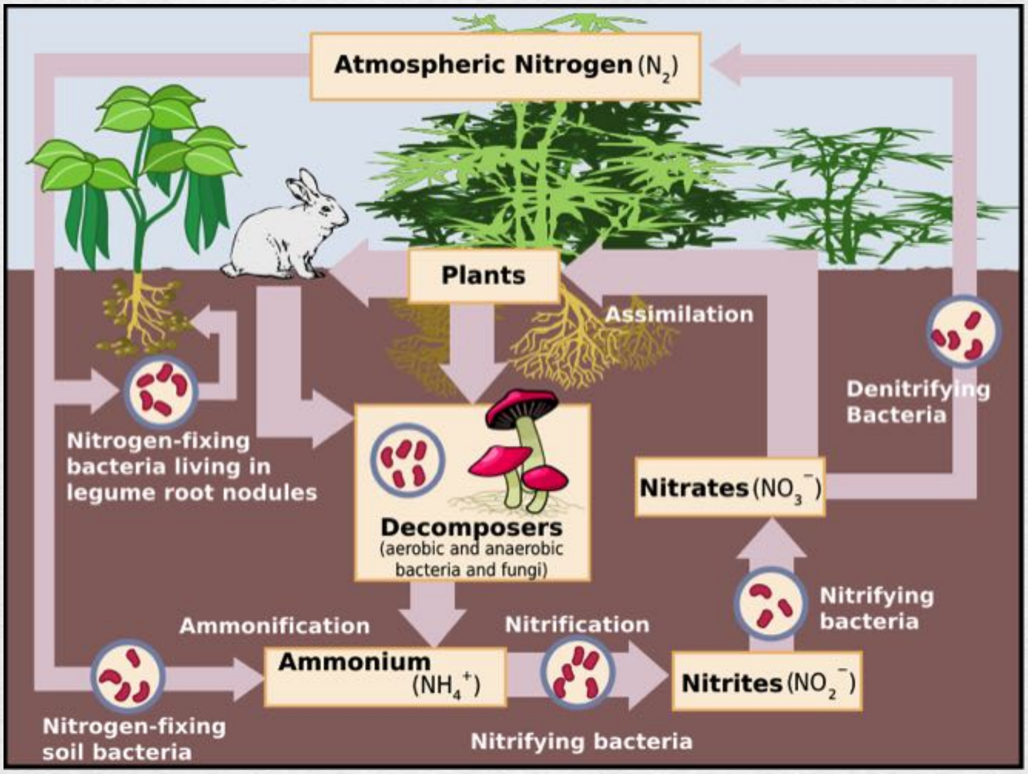
This information is aimed at those who want to build or purchase and run their first system and have the best chance of it working well and producing food.

Aquaponics 101
Part 1

Part 1 is all about the Bio-Chemical Process behind an AP System.

You need to understand the Bio-Chemical Process to understand what makes an AP System work.

You're going to learn some brand new scientific terms; but just take your time and read this Part carefully. A lot of what happens Bio-Chemically is automatic. All you need to do is know it's happening. OLIVER



Aquaponics 101 Part 1: The Bio-Chemical Process, an Introduction of the Nitrogen Cycle

What is Aquaponics and why should I care?

Aquaponics is an ancient food growing technology that has been around since the Earth has had water with fish and plants growing together naturally. Aquaponics is nature at work. In nature, the fish eat whatever they find for food, and their waste is broken down by the bacteria in the water creating nutrients for the plants. The plants that receive that nutrient rich water then absorb these nutrients; and in doing so, they help clean the water for the fish.

The word "Aquaponics" comes from two separate words. The first word is “aqua", which, of course, means water; but in this case, the "aqua" is from another compound word "aquaculture" (the raising of fish). The second word is "ponics", which is latin for work, and comes from its use in "hydroponics" (working at growing plants in water, hydro).

So, Aquaponics is raising fish and growing plants by using the nutrient rich water provided by the fish.

The reason one should care about Aquaponics is that it is a year-round food growing technology, which can supply you and your family with fresh veggies and fish regardless of the season. Most fish species take a year or more to grow out to edible size. Because of this long term growth, the system must be placed in an environment that allows for year-round operation. In tropical climates, an Aquaponics (AP) system can work outside with minimum cover. In milder climates, it must be placed in an environmentally controlled green house. In harsh climates, it must be placed indoors with grow lights to replace the sun and grow your plants.

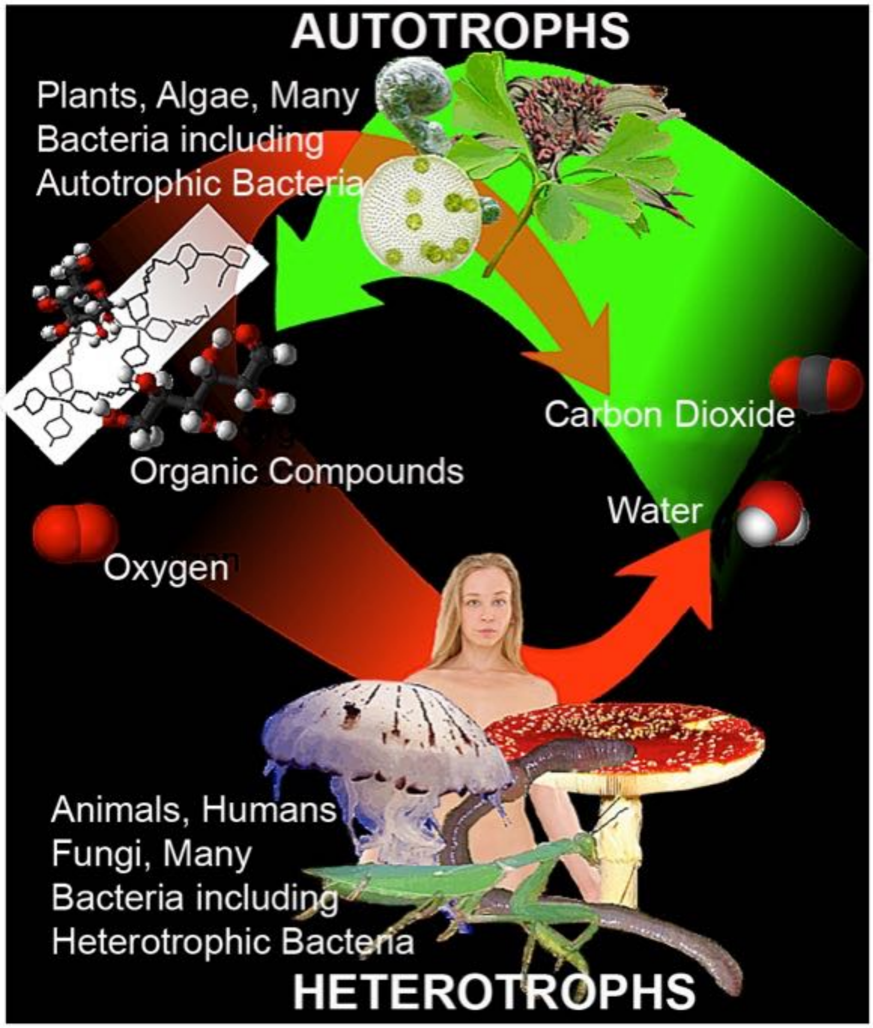
There were 5 Deep Media Grow Beds in our original Greenhouse System Design. Since these photos were taken, we have relocated and have a new Greenhouse.

The plants grown in an AP system grow out in less time, grow year round, can be planted more densely, are tastier and require 90% less water than does tillage farming. Also, if the AP system is properly designed, it takes up much less space than does tillage farming. Some plants can be grown directly in the fish tank to absorb the nitrates from the water as any one who owns an aquarium knows. Most AP farmers separate their fish tanks from their plant grow beds allowing them more flexibility in the way they grow and in what they grow. The water is circulated between the fish tank and the grow bed using a pump. This is known as a recirculating aquaculture system that contains two food sources, fish and vegetables. Some grow their fish for food while others keep their fish as pets that also serve a useful purpose, which is fertilizing the plants.

But there is a third living organism in the AP equation, the beneficial bacteria. They are the pro-biotic of the system and live in what is called a bio-filter. Just like the name says, the pro-biotic (beneficial bacteria) filters the waste in the water, not by removing it, but by converting it into nitrates. Where this takes place could be called a bio-converter, but it is generally called a bio-filter instead.

In an aquarium, where there are only a few fish for the amount of water, the bacteria live in the water, the sand on the aquarium bottom and on any surface where they can attach themselves. In an aquaponics system, the amount of fish per gallon of water is much higher than what is usually found in an aquarium. This higher fish density requires an additional amount of filtration; therefore, a bio-filter becomes an important part of the recirculating water path in the system.

Before discussing bio-filtration, I want to address the concern some may have for the high density of fish in the system. In a home or school AP system, we are talking about one pound of fish for about every six gallons of water maximum at full fish growth. Commercial fish farmers usually run much higher densities, which requires special filtration and oxygenation of the water. Even at six gallons per pound of fish in the system, the fish tend to school together somewhat because it's the nature of fish to create schools. They were introduced into the same tank when the were very small, grew up together and like to hang out with each other. When fish get stressed, you will know it by their unnatural behavior. At these densities, your fish will appear relaxed and healthy. I will be discussing the fish in much more detail in a later segment.



The Nitrogen Cycle:
The fish give off two types of waste, which, and if allowed to accumulate, is toxic to them. As with any living organism, fish cannot live in their own accumulated waste. The first type of waste is ammonia, which is secreted from the gills and found in the fish urine. The second type is fish waste solids. We refer to this as fish effluent or commonly called poo.

The required bio-filter is a part of the AP system. In many systems, media filled grow beds double as the bio-filter because the media has a large amount of surface (substrate) area and the grow beds function not only as beds within which to grow the plants but also as a place where most of the bacteria in the system live that feed on the ammonia. These bacteria, known as autotrophic bacteria, attach themselves to any surface they find. Their job is to convert the ammonia into nitrates.

This is a two step process. First, one type of autotrophic bacteria converts the ammonia to nitrites by splitting the ammonia into nitrogen and hydrogen. The nitrogen (N) is then combined with oxygen (O2) found in the water in the form of dissolved oxygen and in this process forms nitrite (NO2). For the chemists reading this, it is NH3 or NH4 + O2 -> NO2 + H2. Both the nitrite and the hydrogen are released back into the water.

The nitrites (NO_2) produced are also toxic to fish in relatively small quantities, just like the ammonia. So, the second bacteria comes into play to add some more oxygen to the nitrites converting them into nitrate (NO_3). Note the spelling, nitrite (NO_2), nitrate (NO_3). Now, nitrates (NO_3) are not very toxic to fish and generally, depending on the species of fish, they can tolerate 100 times more nitrates in the fish water than they can ammonia or nitrites.

Here's where an AP system becomes symbiotic (mutually beneficial). Plants need and love (absorb) nitrates, so the nitrates won't stay or accumulate in the water to high levels unless there are fewer plants than needed to absorb (uptake) all the nitrates generated by the fish and bacteria processes I just described.

This brings us to the solid fish waste. The good news is that nature provides. In this case nature provides us with another type of bacteria known as heterotrophic bacteria. Heterotrophic bacteria live in the water and attach themselves to any dead organic matter like uneaten fish food, dead plant roots or solid fish waste. Through a process called mineralization, the heterotrophic bacteria convert these leftovers into their component parts, which then become nutrients for the plants. Heterotrophic bacteria also produce their own waste, which is more ammonia; and it is converted by the autotrophic bacteria mentioned above into nitrates for the plants. In addition, heterotrophic bacteria help keep the water in the fish tank clean and clear. Heterotrophic bacteria also require and consume the dissolved oxygen (DO) in the water in order to live and do their work. So, heterotrophic bacteria take organic suspended solids in the water and convert them to dissolved solids that can be utilized by the plants while the heterotrophic bacteria consume dissolved oxygen (DO).

It is important to note that the above processes each require and use DO found in the water (as do the fish and plants) and deplete it from the water as they go about their business. This DO must be replaced on a continuous basis or the process will not work properly. I will discuss the importance of ample DO in your system in a later part.

The plants, which are planted in the grow beds, receive the nutrient rich water containing all these wonderful ingredients including DO, uptake them along with some water and use them to grow. The remaining water now has reduced amounts of nutrients, and it is returned to the fish tank for use by the fish. So, the fish are fed by the AP farmer, and their waste feeds the bacteria. The bacteria convert their food (fish waste) into bacteria waste that feeds the plants. The plants uptake the nutrient rich food provided by the bacteria. The water is cleaned in the process and returned to the fish. These symbiotic relationships are on-going as this is a recirculating aquaculture system that has both fish and plants as well as natures gift of beneficial bacteria working away, and it is known as Aquaponics.

Congratulations! You've just completed Aquaponics 101 Part 1.

Now it's time to test your knowledge. Take the Part 1 Quiz below:

1. What is Aquaponics?
2. How long does it take most edible fish species to Grow Out?
3. In what climate can you set up an AP System with minimal cover?
4. What is the Growing Season for Aquaponics fruits and veggies when the AP System is in a controlled Greenhouse?
5. How much less water is used in Aquaponics farming compared to tillage farming?
6. Besides fish and plants, what is the general name of the third living organism in an AP System?
7. What are the names of the two types of this third living organism?
8. Where do each of the two types of this third living organism live in system?
9. How many kinds of waste do fish give out?
10. What are the names of these kinds of waste?
11. Besides holding your plants, what second important role do Media-filled Grow Beds play in an AP System?
12. What is the name of the bacteria that converts ammonia into Nitrites?
13. The fish can tolerate ______ times more Nitrates than Nitrites and ammonia.
14. Besides fish food, what needs to be replaced on a continuous basis for the system to work properly?

Aquaponics 101
Part 2

"I'm so pleased you decided to continue with your Aquaponics 101 tutorials. After each part there will be a Quiz Board so you can test your knowledge.

"If you missed the Quiz Board, you can go back to Part 1. If you're ready to move on, just start by reading and studying the information that follows.

"Part 2 is all about System Design."

OLIVER

Aquaponics 101 Part 2: The System Design

This is the second in a series of Tutorials on Aquaponics 101 that are going to teach you most of what you need to know about Aquaponics (AP). So, if you're curious about the most amazing food growing technology on the planet today, keep reading.

In Part 1, "The Bio-Chemical Process", I talked about what Aquaponics is and why it is important to Preppers (those preparing for what is about to come down the pike).

To quickly review, Aquaponics combines the raising of fish and using the fish waste as plant nutrients so you can grow vegetables. This is done year-round and can provide food fish and veggies for your family.

The bio-chemical process includes the breakdown of fish waste into plant nutrients, the uptake of these nutrients by the plants being grown in separate grow beds and the cleaning of the water to be returned to the fish tank and reused in an endless loop. This is all done in a continuous flow recirculating aquaculture system called Aquaponics.

I'm now going to focus on a particular AP system type and its design, but I'll also be referring to other designs. As mentioned in Part 1, the fish tank and grow beds are separate entities. This precludes growing the majority of your vegetables directly in the fish tank. However, some green leafy plants like lettuce can be grown on rafts floating in the fish tank as long as the particular fish being raised don't eat the plant roots. However, this is generally not done and tilapia love plant roots.

As I also mentioned in Part 1, there is a need for a bio-filter, which is a part of the system; and it is filled with a media that contains lots of surface area on which the bacteria live. Most AP farmers (I'm talking about home and school farmers here) choose to combine their grow beds and their bio-filters into a single unit. This simplifies the design and construction of their AP system in addition to saving cost and space. It is this combined system I will be focusing on here.

This is our favorite media. It's made from an expanded clay material that is pH neutral. (We'll talk more about pH later in this tutorial)

Hydroton is easy to work with because it is buoyant. When you need to get roots out of your siphon, this becomes a real advantage. So is the fact that it has lots of surface area.

The combined grow bed/bio-filter containers (from here on referred to as grow beds) need to have enough volume to contain ample material with enough surface area to support the number of fish (by total weight) in the fish tank. They also must provide enough planting area to support the optimum amount of plants needed to uptake the nutrients without depleting the system of these nutrients, thereby causing poor plant growth. Seems complicated; but, fortunately, many have gone before us and have worked this all out. We can build on their shoulders.

Grow beds are generally filled with media, either expanded clay or smooth river stones (gravel), in order to give the needed surface area on which the bacteria thrive, while simultaneously holding the plants in place. The grow bed is filled with the media to a level near the top of the grow bed container, and the fish tank water is pumped into the grow bed filling it to a maximum level that is one inch below the top of the grow bed media. This one inch barrier is to prevent the top of the grow bed media from becoming and staying wet, thereby preventing algae growth on the top of the media. This barrier also helps prevent the bottom leaves of plants in the grow bed from becoming wet and moldy.

The optimum grow bed container depth is about twelve inches. This will allow for at least eleven inches of media and ten inches of fish tank water to be placed in it, which is enough to provide for bacteria growth as well as providing ample depth for anything you wish to grow. It will also allow for some accumulation of fish solids in the bottom of the grow bed and give them time to break down before they over accumulate. Grow bed containers deeper than 12 inches are more costly to fill with media, heavier and transfer more water back to the fish tank (more on this later).

Generally, deeper beds are unnecessary, unless you're using gravel as a grow bed media. Then, the extra depth can be beneficial (more on this later, also). Grow bed containers less than twelve inches deep cause your planting area to grow bed volume ratio to be less than ideal, thus creating more planting area than the bio-filter volume can support (depending on what type of plants you have in the grow bed) and an accumulation of fish waste in the shallow beds. This twelve inch number is not cast in stone; but if you build a system using it, it will work. If you use other depths, especially less, then you are on your own. This is the basic design of all our Food Forever™ Growing Systems we build and sell.

The size of the grow bed can be whatever you wish; but understand that if you go over 30 inches in width, you will have difficulty reaching across it. For wider grow beds you will need to have plenty of walk around room to get to two opposite sides. Forty eight inches is probably the maximum width you should be considering. The length is not as important as the depth and width. It is best to have at least two grow beds in your system rather than just one. This will allow you to shut down one bed to clean out any plant roots between plantings while still having your other grow bed working to keep the water clean and safe for the fish.

There are two different configurations of media-filled grow beds, flood and drain (also called ebb and flow) and continuously flooded. Flood and drain are the best, regardless of the types of plants you are planting, because it provides the best distribution of incoming nutrient rich water throughout the bed as well as adding aeration to the wetted media and plant roots where the bacteria live. This also adds dissolved oxygen (DO) to the water being flooded back into the bed and then returned to the fish tanks.

You will need a way to flow the water into the grow bed. The water entry point into the grow bed depends, in part, on the shape of your grow bed and how you plan on using it. With a flood and drain grow bed, the point of entry of your water is not critical; but it should have an unrestricted opening so as not to clog with fish waste solids. Do not attempt to spray your water into the grow bed, for the spray holes will clog up in short order (experience speaking here).

Here is a great Bell Siphon that I designed and built for our Food Forever™ Growing Systems; and it works like a charm.

One of the best features it offers is it's wide mouth, which is 4" in diameter. This wide mouth allows you to reach right into the siphon and clean out any roots that may have taken up residence. It is also easy to insert and remove the Stand Pipe.

One of the best ways to drain your grow bed is with a Bell Siphon. This is a device with no moving parts that, when the grow bed is filled with water, starts to syphon out all of the water in the grow bed down to a preset level before "breaking siphon". At that point, the siphon action stops; and the grow bed starts to refill. The design of this syphon is critical in order to get it to do its job in a timely manner. I'm not going into the design and construction of Bell Siphons here. This information can be found elsewhere on the web, as there are several different designs available. The siphons must be sized properly in order to remove the water from the grow bed in a fraction of the fill time it takes to fill the bed and still function properly. Grow beds using a Bell Siphon have water continuously being flooded into them at a slower rate than the syphon drains the water out, so you get a flood and drain cycling action. It is important to have a continuous vertical drop (down hill all the way) of at least 6 inches (the more the better) below the siphon so the water is drawn out of the grow bed.

The more often you flood and drain your grow beds, the more dissolved oxygen will be added to the water returning to your fish tank. You should count on cycling your grow beds at least four times per hour. Not only does the design of the syphon influence the cycle timing, the rate at which you flow water into your grow bed, does as well. This cycle timing is one of the most critical parts of the design of an AP system. Needless to say, you will need enough pumping power to exchange most of the water in your grow beds four times an hour.

Keep in mind that once the grow bed media is in the grow bed, it will displace at least 50% (expanded clay) of the volume of the grow bed (more for gravel) leaving half or less of the original grow bed volume for water. This should be taken into account when sizing your water pump. The good news is, you may be able to use a smaller pump requiring less electrical power as long as other pump sizing requirements are met (more on this in a later part).

Within the AP community, you will find differing opinions on the numbers I'm about to give you; but I believe them to be the most accurate based upon what I have learned from those with years of experience in building and testing different combinations of system sizes and ratios, as well as from my own experience in verifying these numbers. You can build an AP system any size you desire, for it is the ratios of the various component sizes that really mater. So, lets start with the ratio of the fish tank size in gallons to the grow bed container size in gallons. There should be about a one to one ratio between the fish tank and grow bed container size. This is assuming that you are using media filled grow beds.

Media filled grow beds are ones that use a growing media such as expanded clay or gravel to fill the beds. It has been found that the amount of grow bed volume needed to support a system is more related to the pounds of fish in the tanks and how much they are fed than the amount of water in the system. If you are using expanded clay as a grow bed media, a good rule of thumb for the size of grow beds is 6 gallons of grow bed (minimum) container size for every pound of fish you plan to have in your system at maximum fish grow-out size. If you plan on a ratio of six gallons of water per pound of fish in the fish tank, then this works out to about one gallon of fish tank capacity to one gallon of grow bed container capacity when using expanded clay as a grow bed media.

Many AP farmers are pushing these numbers in their systems and will argue for what they are doing. I am trying to give you what I believe are optimum parameters here for a system that will have the highest probability of working and allow you the greatest possibility of success as a first time AP farmer. Some live close to the edge and seem to get away with it, others are not so lucky.

As to the difference between flood and drain grow beds and continuous flow grow beds, it is well known that some plants won't grow well or at all in constant flow grow beds; for their roots need more oxygen than do other plants. Flood and drain supplies this needed oxygen while constant flow does not. Logically then, the bacteria living in the grow beds would do much better with more oxygen. We used to only flood and drain for half of our grow beds and did continuous flow for the rest.

That was when our DO (dissolved oxygen) in the water was low. Now we flood and drain all of our media filled grow beds; and, along with the other changes, we have much better DO. It is just simple physics and logic that the water flowing through a constant flow grow bed is not going to get as good of an even distribution of nutrients and oxygen as a flood and drain grow bed, which does a nearly complete grow bed purge with each cycle.

Shown here is a Dissolved Oxygen (DO) meter. Go to our Instruments page for everything you'll need to know about this handy (and from my perspective) much needed DO measuring device.

DO Meters take the guesswork out of determining what's going on in that very important part of the Bio-Chemical Process; and well oxygenated fish are happy fish.

As to the grow bed depth, it is a number that has been tested by those who have been working with flood and drain aquaponics grow beds for many years. It has to do with the surface area of the particular media with which you are working.

One big debate is the removal of fish waste solids. Those who use deep (12" or more) grow beds generally find that they do not have a problem with over accumulation of these solids for a considerable amount of time. Those with shallower grow beds tend to complain about the accumulation of fish waste solids. I hedge my bets on this by weekly adding heterotrophic bacteria, and I will write about this product in a later part.

After several years of running deep media grow beds, and yearly cleaning out just plant roots, I have found the solid fish waste problem not to be a big one. Around our fifth year, we ran into some undissolved fish waste solids when planting and decided that completely cleaning the beds, meaning removing the Hydroton, washing it and the bed. Doing this about every year or two would be a good idea. This is a low maintenance recommendation for your deep media beds. I believe the deep media beds only need this minimal maintenance due to the depth of the grow beds allowing time for the solids to break down and the abundance of dissolved oxygen as well as the weekly adding of the Heterotrophic bacteria. If you follow this maintenance advice, when digging into the grow beds while they are flooded, you will find solids in the water in the process of breaking down, but you will not find them accumulating in the bottom.

There is a lot of research available that shows the importance of DO levels needed for both plant and fish growth, and the science of nitrification clearly indicates its necessity. The flood and drain process also has been shown to increase oxygenation of the water in the grow bed, which gets returned to the fish tank.

The deeper the grow beds, the more surface area there is for both the nitrification process to take place as well as oxygenation of the wetted surface area of the substrate media in the grow bed. The oxygen only goes a few molecules deep into the water surface, so the more surface area, the more oxygen is dissolved and eventually returned to the fish tank.

I need to impress the importance of high levels of DO in the system, for it is the prime ingredient that is required in every aspect of the process. Anything that one can do in the system design and operation to increase the DO will benefit the whole system. Unfortunately, this is usually mostly ignored, I believe, because of the cost of DO meters. We are now offering a high quality and affordable DO Meter on our web site (AquaponicsUSA.com).

Congratulations! You've just completed Aquaponics 101, Part 2.
Now it's time to test your knowledge. Take the Part 2 Quiz here:

1. Why can't you grow your AP lettuce in a fish tank full of tilapia?
2. The most simplified AP System combines the ____________ and the ____________ into a single unit.
3. Since you're not using soil in an AP System, what do you place in your grow beds?
4. There are two main reasons you want the water in your grow bed to be 1 inch below the top of the media. What are they?
5. What is the optimum grow bed container depth?
6. What's the disadvantage of using shallower than optimum media grow bed depth?
7. Why is it best to have at least 2 deep media beds instead of just one in your AP system.
8. What are the two types of media in media filled grow beds?
9. Of the two types of media filled grow beds, which one is superior and why?
10. Why should you not attempt to spray the recirculating water into your grow beds?
11. What is one of the best ways to drain a flood and drain grow bed.
12. The more often you flood and drain your grow beds, the more_______ will be added to the water returning to your fish tank.
13. If you're using media filled grow beds, you need to have a _____ ratio between the fish tank size and the grow bed size.
14. A complete cleaning of deep media grow beds, meaning emptying them and cleaning the media and the bed should take place about every ___ years.

Aquaponics 101
Part 3

Part 3 is a Continuation of Part 2

You're moving along nicely. How are you doing on those Quizzes? This Part is actually a continuation of Part 2, System Design. There are many factors you have to take into consideration regarding your System Design because all of the components are interconnected. If one piece goes out of whack, your system fails.

OLIVER

Aquaponics 101 Part 3: The System Design Continued
This is Part 3 in a series of tutorials that are going to teach you most of what you need to know about Aquaponics.

Some will argue that the standard ratio of grow bed size to fish tank size is two gallons of grow bed container capacity to one gallon of fish tank capacity instead of the one to one ratio I mentioned in Part 2. Again, the number for expanded clay is 1:1 and for gravel about 1.3:1 gallons of grow bed container capacity to fish tank capacity. The reason for this one to one ratio limitation is that the water in the fish tank goes up and down during the grow bed's flood and drain process, and too much variation in water height can stress the fish. You can use the 2:1 number only if you flood and drain some of your grow beds but not all; or if you add a sump tank to catch the water that would otherwise be returned directly to your fish tank. The increase in the ratio for gravel is that it usually displaces more water than does the expanded clay and, therefore, you need a larger grow bed in order to have room for the same amount of water.

The simplest AP system design has a low to the ground fish tank that is 24 to 30 inches high and grow beds that are up on tables high enough so that the water pumped up from the fish tank to the grow beds can gravity flow back into the fish tank from the bottom of the grow bed siphon and have it function. I prefer 24 inch high fish tanks so the grow beds don't need to be so high and, therefore, you don't need a step up to comfortably reach across them. This allows for at least six inches of extra siphon draw down below the grow bed thereby reducing the grow bed's drain time (more on this later).

The grow beds' siphons activate on their own timeline; but at some point, with multiple grow beds, the siphons arrive at nearly the same schedule. Like two or more metronomes, occasionally they all sync up and drain at the same time filling the fish tank to capacity and then they simultaneously pump water into and fill all the grow beds. With a two to one grow bed to fish tank ratio, the extra water required to fill the grow beds leaves the fish tank with a dangerously low amount of water (if none at all), which will stress the fish.

With a one to one grow bed to fish tank volume ratio, the water level in the fish tank won't go so low as to stress the fish. So, one to one is the number you want to aim at in your AP system design.

Some will argue that one way to avoid this water level in the fish tank problem created by increasing grow bed volume is to add a sump tank (mentioned above) that catches the drained water from the grow beds. The water is then pumped back to the fish tank from the sump tank after it's water reaches a certain level by way of activating a float switch connected to a submersible pump in the sump tank. This allows the sump tank to absorb the intermittent water flowing into it and helps keep the fish tank from experiencing major swings in water level during grow bed siphoning.

This is one of our 120 Gallon Fish Tanks. It's being shown with an 11 sq. ft. Grow Bed that's growing lots of basil. This 11 sq. ft. Grow Bed has about 70 gallons of capacity so two of these fit perfectly (give or take 20 gallons) with one of these fish tanks. When the flood and drain happens and the two beds do not flood at the same time (which is most of the time), the water level drops about 4 inches, which is insignificant for the fish.

On the few occasions when the two grow beds flood at the same time, the water will drop only about 8 inches; and the fish barely notice it.

We call this our EZ-Reach Grow Bed because the AP Farmer can reach across its 35 inch wide front to plant and harvest. This grow bed is a real space saver as it can be butted up against walls.

For a short fish tank that sits on the ground, this requires an extra pump (in addition to the one in the fish tank) and a float valve switch (mentioned above) in the sump tank, which adds extra parts, cost and potential points of failure. Turning a pump motor on and off repeatedly shortens its life, and, if either the pump motor or float valve switch were to fail (and eventually one or the other will fail), you will have water all over the place, a fish tank void of water and dead fish. In my opinion, this is not a good design. You might as well increase the size of your fish tank and keep the same number of fish, thereby saving yourself the cost of the sump tank, pump and float switch, along with its complexity and poor reliability.

Another system design raises the fish tank or has a tall fish tank, like a tall IBC tank with its top cut off, which overflows the fish tank water through a pipe into a sump tank that is positioned at a lower level. The water is pumped from the sump tank through a Tee directly into the fish tank. The pump is sized to have a good flow to the fish tank so the solids are lifted from the fish tank bottom on the return path to the sump tank. By continuously circulating a generous flow of water from the sump through the fish tank, the fish waste solids are lifted up through the overflow pipe, which starts near the fish tank bottom and exits the fish tank near the top.

The other side of the pump Tee goes to the grow beds through control valves where the water flow is individually adjusted to each grow bed for proper siphon action. The water returns from the grow beds to the sump tank, which is large enough to absorb the flood and drain action of the water coming from the grow beds while leaving the fish tank water at a constant height.

This design was created by Murray Hallam of Australian aquaponics fame and is known as a CHOP II, which stands for Constant Height One Pump, Version II. It is an elegant design because it adds only minor complexity and cost to building your system while using a single continuously running pump, and it works well.

It is very important that a float valve bringing in outside water be added to the sump tank in order to assure that there is enough water in the system because evaporation will reduce the water level in the fish tank to a level where it won't overflow, thereby keeping the fish tank water from being circulated.

This is a high quality efficient magnetic drive submersible pump.

We offer five different sizes of these great little pumps. They require from 16 to 92 Watts of electricity depending on the size you use.

As I explain below, the advantage of using one of these is they macerate your solid fish waste, which goes through this submersible pump before it goes into your grow beds.

You can see suction cups at the bottom of the pump; and they really do a good job of keeping the pump stuck to the bottom of your fish tank.

The solids I have watched live and on my fish cam are wrapped in a clear sheath, which appears to be the slime component of the worm-like solid. By first sending the solids through a pump before they go to the media filled grow bed, they get macerated; thereby breaking them into smaller components, which allows for the heterotrophic bacteria to do a faster job of mineralization. To leave them in the sheathed form may allow them to accumulate in the grow beds, and if the water is being pumped into the top of the media filled grow beds that is where the solids accumulate. The flies love it, but it is not a pretty sight.

The simplest of systems have a submersible pump in a low fish tank that pumps ample water under pressure to the grow beds. The water can be controlled by valves at the grow beds in order to regulate their fill rate while providing some additional water under pressure to be jetted back into the fish tank in a high velocity stream for added aeration. This extra pump pressure allows for purging of the lines to the grow beds by fully opening the grow bed control valves individually for a short period of time on a weekly basis. This needs to be done periodically because the fish waste solids are heavier than water and the slow flow up to the grow beds doesn't allow for all of the solids to make it into them. This slow upward flow causes some accumulation of solids in the plumbing, which the purging alleviates.

The most common type of auto-siphon is the bell siphon. Siphons return the water to the fish tank or sump tank from the grow beds by gravity. This is accomplished by using a line connected from the bottom of the bell siphon to the fish tank above the water level. The grow beds are high enough without being too high, and the fish tank is low enough to allow for a good flow return from the siphons.

Grow beds can be made of wood with plastic liners, but fitting them with the needed bulkhead fittings that don't leak may prove to be a challenge. However, it can be done successfully. The bulkhead fittings in the grow bed bottoms are necessary and are part of the bell siphon.

Another type of siphon is the loop siphon. It consists of a pipe that picks up the water from the inside bottom of the grow bed through some sort of strainer and brings it up and out (or out and up) of the grow-bed through a bulkhead in the grow bed wall. The top of the loop is set at the upper most desired waterline level in the grow bed when it is flooded. From the loop's top, it makes a U turn downward and the water flows out the down pipe into the fish tank or sump tank. The siphoning action occurs when the grow bed is flooded and the water level starts to exceed the height of the top of the loop, and the siphon break occurs when the air enters the strainers inside the grow bed bottom after most of the water is siphoned out. We have found a properly designed loop siphon is superior to a bell siphon in its range of water flow, its ability to cycle rapidly and its leaving more grow bed space for planting.

Bell siphons and loop siphons are functionally the same.

This pretty much describes the system designs (minus the aeration) we build and sell here at Aquaponics USA and are currently using, which are elegant in their simplicity and very cost effective. Again, to be clear, I have borrowed significantly from the tried and tested work of others.

Hydroponic reservoirs make good grow beds (at least the twelve inch deep ones do). These seventy gallon, eleven square foot (one square meter +) inside reservoirs are what we use in our FGS-20 systems, and they are very sturdy. These reservoirs need bottom support when used as elevated grow bed containers because they are made to sit on the floor. We also use rectangular white reservoirs as grow beds and they have a nice form factor of 33 inches across and also need bottom support.

Animal stock tanks make good fish tanks. They are about two feet tall and, depending on the brand, are very well made from USDA approved polyethylene with UV inhibitors. You don't want to have a black fish tank because it limits the light in the tank making it hard to see the fish. Many fish species do better with more light.

As for submersible pumps, we recommend and sell magnetic drive (mag-drive) pumps because the motor is in its own sealed compartment and should never leak any oil out into the fish tank water, which would be really bad for the fish. Good ones are relatively inexpensive and have a one year warranty. The pump should be capable of turning over the total gallons in the fish tank about every thirty minutes at six feet of head pressure minimum. Be careful of advertised flow rates at zero head pressure, because that doesn't tell you what you need to know for your system (more on this below).

In sizing your pump, make sure you have enough flow to fill all of your grow beds at least four times an hour. For example, let's say you have a 120 gallon fish tank and two 70 gallon hydroponic reservoirs as grow bed containers for a total of 140 gallons of grow bed capacity. The water in the grow bed will only be filled up to the 60 gallon mark, for a total of 120 gallons for two grow beds. The grow bed media will displace at least half of that so now we are looking at about 60 gallons of water total in the two grow beds. Not all of the water will drain, so let's say about a total of 50 gallons drains out before syphon break. We replace that four times an hour so we need 4 X 50 = 200 gallons per hour just to fill the grow beds. We need another 20% to jet back into the fish tank for additional aeration, which is 40 gallons per hour. The total water is 200 + 40 = 240 gallons per hour at 6 feet head pressure. This works out to be twice the fish tank volume every hour.

The rule is to always over size your pump in case you wish to add other components to your system later that require water under pressure, like vertical grow towers or an elevated small brooding tank, both of which can gravity flow/overflow back into your main fish tank. Pumps come in discrete sizes, so we use a 1000 GPH at 6 feet of head pressure pump.

The extra water pump capacity is used to rapidly move the fish tank water through the plumbing to the grow beds in order to clean out (purge) the plumbing. As explained earlier, this is necessary as the normal flow from the fish tank to the grow beds is very slow and the fish waste solids tend to accumulate in the plumbing. Line purging is accomplished by fully opening the control valve in the line to the grow bed and allowing the full force of the pump to rapidly move the water through the line for a period of about 30 seconds, at least once a week. The water coming out during that time will be very brown. When it clears, then reduce the flow to the proper amount for your flood and drain cycle timing.

We offer five sizes of these quality air pumps; and, depending on their size, they pump from 571 to 1,744 gallons of air per hour. They have aluminum alloy housings and a water resistant cylinder and piston.

Hook a few 4" cylindrical air stones to your pump and you're providing your fish with a lot of much needed dissolved oxygen in your AP System.

We use diaphragm type air pumps that require the diaphragms to be replaced after about one year of continuous use, but they are very inexpensive and easily changed. Air pumps are notoriously inefficient. They produce lots of heat and move little air, but they are absolutely essential for your AP system. You will need a pump rated at about 7 GPH of air for each gallon of fish tank capacity. With a range from 5 GPH to 8 GHP of aeration per gallon of fish tank water (a 60% increase), we saw a better than a 20% increase in DO (dissolved oxygen).

The best way we have found to put air into the tank is through cylindrical air stones. Even though they have relatively large air bubbles, they don't clog up as much as the finer bubble diffusers.

Our dissolved oxygen levels regularly measure between 6 and 7 ppm depending on water temperature. A study made with tilapia and varying amounts of dissolved oxygen (DO) in the water showed a doubling of growth rate from a DO of below 3 ppm to a DO above 6 ppm.

Air pumps need to be run 24/7, to do otherwise is to kill fish. After all, how long would you last without air?

You should never have any metal in your system or plumbing, including the fish tank, metal grow bed containers without liners, valves, especially copper, zinc or brass because they will leach toxic metal into the water and kill your fish. Just stay completely away from any metal coming into contact with your system water with the exception of iron, titanium or stainless steel.

This and the previous part describe one type of Aquaponics system with some variation; but, by no means covers all of them. I've also given some information about the design of the systems we call our Food Forever™ Growing systems. For those of you who will be building your own systems, we are sharing these details about how to build them yourself because we really believe food shortages are coming; and we want to help as many people as possible get prepared. So now you can buy the parts from various vendors and build your own custom system. As long as you follow the above suggestions, you will have a system that has the potential to work well and produce food because it is properly designed.

As stated earlier, we are using a low profile fish tank so we can keep the grow beds low enough to reach across or into them without having to have a step-up.

The fish tanks we use are 4 foot diameter, 2 foot high 120 gallon (or larger) stock tanks.

Fish Tank Titanium Heating System Kits

Ranging from 150 Watts to 800 Watts with Price Points from $99 to $179

Controller **Heating Element & Shroud**

These Titanium heater kits come with a 1000 Watt Digital Controller to keep constant tabs on water temperature, while the heating element maintains temperatures at a user-defined set point between 68° and 92° F. We offer different sizes of these heaters including a 150, 300, 500 and 800 Watt size.

There is what I consider misinformation regarding the size of an Aquaponics system and its biological stability. I challenge the idea that an aquaponics system has to be a minimum number of gallons to maintain biological stability. It has more to do with the fish to water ratios, regardless of the size. This assumes a constant system temperature.

The system's temperature stability is another matter. It has to do with the volume of water to the surface area of the fish tank plus the surface area of the top of the water in the fish tank. Add to that the surface area of the grow beds (all 6 sides) and the water contained therein. Then consider the amount of insulation, if any, surrounding these components as well as the varying air temperature where your system is located and you have the thermal stability.

In addition, you will be pumping air through your fish tank in order to increase your dissolved oxygen levels. This process cools the water due to transfer of liquid water to vaporized water as the air bubbles rise through the water in the fish tank. The same thing is happening in the grow beds as you pump in and siphon out water. Air is also pumped in and out during this process as well, causing evaporation and cooling. This is known as latent heat of vaporization, or cooling as water is evaporated.

The temperature stability affects the biological stability. So, the larger system may have a better overall stability due to the larger thermal mass to surface area ratio.

Congratulations! You've just completed Aquaponics 101, Part 3.

Now it's time to test your knowledge. Take the Part 3 Quiz here:

1. What is the reason for my 1:1 ratio limitation regarding grow bed container capacity to fish tank capacity.
2. Why does the 1:1 ratio change to 1.3:1 when you're using gravel media in your grow beds instead of Hydroton?
3. What's the preferred height of the fish tank from the ground?
4. Why are shorter fish tanks in this height range preferred?
5. What function does the water pump serve in relation to the fish waste solids?
6. How do you purge the lines to the grow beds?
7. Why do you need to purge the lines to the grow beds and how often should you do this?
8. The auto siphon uses __________ flow to return the water from the grow beds to the fish tank or sump tank.
9. What is the name of the second type of siphon other than the Bell Siphon?
10. What are the advantages of this second type of siphon?
11. A water pump should be capable of turning over the total gallons of water in the fish tank every ____ minutes at a minimum of ____ feet of head pressure.
12. In sizing your pump, you need to make sure you have enough flow to fill all of your grow beds at least _____ times an hour.
13. Tilapia grow twice as fast when the DO is above ____ ppm as verses below ____ ppm.
14. True or False (Circle one), thermal stability depends on only one element in your AP System.

Aquaponics 101
Part 4

"Congratulations, you've made it to Part 4 of Aquaponics 101. Assuming you've gone through Parts 1-3, you now have the know how to build an efficient, reliable AP System.

The next step is called System Start Up, Operation and Maintenance. This info comes in two Parts, Part 4 & Part 5."

OLIVER

Aquaponics 101 Part Four: System Start Up, Operation & Maintenance:
This is the fourth in a series of Tutorials that are going to teach you much of what you need to know about Aquaponics.

In Part 1, “The Bio-Chemical Process”, I wrote about what Aquaponics is and why it is important to Preppers (those preparing for what is about to come down the pike). Aquaponics allows you to grow food for yourself and your family year- round as long as your AP system is in the proper environment. I also gave a description of the bio-chemical processes involved that make Aquaponics work.

In Parts 2 and 3, “System Design”, I wrote about the components of a basic system. To quickly review, I wrote about the need for a bio-filter and that it is usually combined with the grow bed to form a single AP component called the grow bed, which is the most important part of an AP system. I told you about the grow bed media, the grow bed shape, and that you need about one gallon of grow bed-bio filter volume for every gallon of fish tank volume and the reason for this ratio. I discussed the need to flood and drain your grow beds four times an hour and how to properly size your water and air pumps.

I'm now going to focus on how to Start Up, Operate and Maintain your system, but first we need to talk about water. To your AP system, water is life. The water in your system contains elements that provide life to the various organisms living in your system. These organisms include the fish, bacteria and the plants. The one element in your water that is essential to all of these organisms is oxygen in the form of dissolved oxygen (DO). As mentioned earlier, an AP system with ample DO will perform much better than one that is lacking in this life giving element.

At all times, you should strive to keep your DO levels above 6 ppm (parts per million or milligrams per liter). The only way to know the value of DO in your system is to measure it, and the best way to do that is to have a DO meter. The design guidelines I have given you in the previous parts will assure that you achieve this goal, so the actual purchase of a DO meter is desirable but not crucial.

Most backyard Aquaponics hobbyists don't pay much attention to DO levels because in the past the DO meter was rather expensive. They are investing minimal money into their systems, and the price of a DO meter is not in their AP budget. I understand this; but for me, as a researcher, I felt that I needed to swallow hard and pony up the cost once I was convinced of the importance of DO levels in the system. Not knowing what my DO levels were and what I could do to affect them was more than I could stand. We now carry available a high quality Milwaukee Instruments Dissolved Oxygen Meter at an affordable price.

As I wrote in Part 1, fish need oxygen to live. The bacteria also need oxygen to live and to convert the fish wastes into usable nitrates. The plants need oxygen to grow. Above are three photos of plants growing in our Greenhouse. Although the corn grew beautifully, we don't recommend growing it in a Greenhouse unless the roof is extra tall because once our corn hit the roof, it couldn't produce it's fruit. The only stalk that did produce a delicious ear of corn was the one that was able to grow out of our sky vent to it's full size at which point it fruited.

Some of the plant oxygen comes from the DO in the water, which brings us back to the water. The water also has a pH, which stands for the Power of Hydrogen. The word, "Power" here is a mathematical function where each level is ten times the previous. So, pH is a logarithmic scale, base 10, or power of ten. Each number is ten times the next lower number and one tenth the next higher number. So, a change of one number on the pH scale is a change of ten times. The lower on the pH scale, the more acidic the water and the higher on the pH scale the more basic. Bases can be thought of as the chemical opposite of acids. A strong base will raise the pH of water toward 14. Seven on the pH scale is neutral.

Notice I said basic (base), not alkaline. Some would argue that they are the same; but in dealing with pH and water quality, there is a difference. Alkalinity is a measure of the alkaline buffers found in the water. These alkaline buffers are dissolved minerals, like calcium, that keep the water's pH at a higher than neutral 7 pH. Any attempt to lower the pH of water by adding in an acid (pH down) will be countered by these alkaline buffers and not allow the water's pH to change and go to a lower number. You might see a sudden change after adding in an acid, but it won't last and will soon rebound back to its higher pH value as it is absorbed by the alkaline buffers. You can keep adding acid to your water until you have saturated the alkaline buffers, but understand that acid + alkaline convert to salt + water. What this says is that what you will end up with is a more neutral pH and salty water.

When the fish add their waste to the water, the bacteria release hydrogen from the ammonia in the waste. This hydrogen is one of the building blocks for acid, and you will see a decrease in pH. The alkaline buffers will attempt to raise the pH; but with the continued release of hydrogen, the water's pH will achieve a tug-of-war balance that is lower than the pH of the water with buffers before the bacteria started doing their job. As the fish grow out, and you feed them more food, they will produce more waste causing the bacteria to grow thereby producing more nitrites and nitrates.

In the process, more hydrogen is released from the fish waste ammonia. This will continue to pull the pH to a lower, more acidic number.

This will also increase your total dissolved solids (TDS) in the form of salt, mentioned above. Where your pH level starts partly determines where it ends up. You will be continually adding water to the system to replace evaporation and plant uptake. This will slowly increase your dissolved solids, including alkaline buffers if they are in your water, because they do not evaporate with the water.

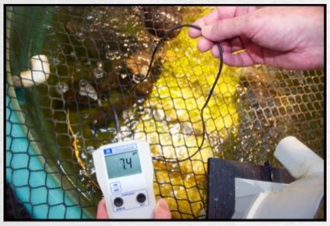
A Float Valve will assure you that the water in your Fish Tank remains at the proper level. Your water will never get too low to stress or worse, kill your fish. With proper installation, it will automatically fill your tank as needed.

Every time-saving device you can add to your AP System is a real help. This inexpensive gadget is great.

Because the water continuously evaporates, it leaves behind minerals. The solid fish waste is also mineralized so the mineral content of the water continues to increase over time as measured by a Total Dissolved Solids (TDS) meter. A high level of dissolved solids is generally not a problem, but this depends on the species of fish you raise. I am not going into this further here because there are just too many fish species to talk about them all. I don't want to pretend to be a fish expert, nor do you have to be one. But, you do need to learn as much as you can about raising the species of fish you choose to populate your AP system.

We have found that a pH of 7.3 from our tap water is an acceptable number. It is very important that the water you use in your fish tank be free of chlorine and chloramines. Municipal water will always contain one or both of these. The best way to remove chlorine is to use a carbon filter designed to do just that. You can also just put the water in a separate bucket or open tank for a day or so, thereby allowing the chlorine to off-gas (evaporate) out of the water before transferring it to the fish tank. Because adding water is a repetitive chore for an AP farmer, this separate tank method becomes a hassle after a while. Adding a catalytic carbon filter and a float valve in your fish tank, connected to your tap water, is a way to reduce your work load and not chance letting your fish tank water get too low.

You will need a water testing kit, and I recommend the API Freshwater Master Test Kit. This is the number one preferred test kit by Aquaponics farmers. It will measure pH high and low, Ammonia, Nitrites and Nitrates. You can use the testing kit to make pH measurements, which will give you a ballpark range that is adequate. But the best way to measure your pH is with a reliable pH meter, one that is easy to calibrate and use. Monitoring your pH with a pH meter is very simple and requires less than a few minutes to make an accurate pH measurement. I know, I'm always finding ways for you to spend money on your system. So, tell me about a hobby where this is not the case. However, Aquaponics is more than a hobby, it is about growing your own food for you and your family; and you want to get it right because your life and the lives of your loved ones may depend on it.



A pH Meter is a must have if you want to keep your fish alive and well. We've discovered that pH can fluctuate over time for a variety of reasons so it needs to be measured frequently.

The unit comes complete with probe, nine-volt battery, and 20-mL sachet of calibration solution. It's easy to calibrate and use.

The meter probe only takes a minute or two to adjust to the fish tank water temperature and give an accurate reading. This allows me to see the slightest change in pH and gives me a warning if something is out of the ordinary. You should never let your pH meter probe dry out. Letting it dry out will cost you another probe, for they cease to function once they have become dry. I calibrate the probe using calibration solution and adjust it to a pH of 7.0 on a weekly basis.

I do not recommend adding pH down down chemicals to your fish tank water, and the pH up should contain only Potassium Hydroxide (potash). Many off-the-shelf pH up solutions contain elements that are not friendly to either plants or humans. Remember, this is an AP system, not an aquarium. I don't care how much fish raising experience you have. What I have seen is that those coming from an aquarium background bring with them knowledge that they believe is beneficial, but it is often detrimental to their AP systems. The same is true for those coming from a hydroponics background. This is not aquaculture or hydroponics. It is Aquaponics; and it has its own set of rules and requirements which are all about balance between fish, the beneficial bacteria and the plants.

You can also use Calcium Hydroxide (Lime) as a pH-up. It is important to mix it with lots of water prior to adding to your system and even then, go slow–very slow. Make certain that whatever you use is pure and doesn't have any other chemicals added, as it can kill your fish.

Another source of pH problems is gravel grow beds. You need to make sure that the gravel you place in your grow beds is both sterile and pH neutral. This is just another reason to use Hydroton. Hydroton is expanded clay balls that have been popped in an oven, much like popcorn. It is pH neutral, sterile and very easy to work with. I recommend the 8-16 mm mix size. It is sold in 50 liter and smaller bags. You can find it at any hydroponics store or on line for a better price, but ordering it on-line will add shipping and may prove to be more expensive. We offer Hydroton with shipping from our supplier's nearest-to-you warehouse, thereby reducing the shipping price. Once it is shipped to you, any shipping overcharge will be refunded. Buying larger quantities will reduce the shipping charges. Hydroton is a one-time purchase as you can use it over and over.

Some Aquaponics do-it-yourselfers go down to the local river, gravel pit or Home Depot and get gravel, put it in their grow beds and they don't have a problem. But from reading the fora, many end up with a serious pH problem from doing this.

It will be necessary to keep your water temperature in a range that is healthy for your fish as well as your plants. For example, some species of Tilapia require the water to be around eighty degrees F. While other species of Tilapia can live in much colder water. Vegetable roots generally like the water to be in the sixty Fº range. You can see the water temperature conflict.

Trout may seem like a good fish to raise because they do well in colder water; but they tend to take a long time to grow out and are sensitive to poor water quality. For a first time AP farmer, I would not recommend raising Trout. You might want to consider Carp if you don't plan on eating your fish, although some people eat Carp. Look into the fish species that is best for your climate and legal for your area.

Once your system is assembled and the grow beds are filled with media, the water is in place, the pH is balanced, the pumps are tested and the grow bed flood and drain timing is adjusted, you can now cycle your system. Cycling your system simply means that you want to turn on the water and air pumps and leave them on so you can grow some bacteria. By the way, once you have your system up and running, you never, ever, want to turn it off, not even for the night. You might want to consider some kind of a power back-up in case of a power failure.

First, you must get bacteria into your water; and here is where we get into an area of debate amongst those who have been into Aquaponics for some time. There are differing opinions as to how to accomplish this task. There are commercial products like API Quick Start pictured above that claim to contain living bacteria; and we have used this and provide it with our systems. However, I make no claim of its viability. Another source of this starter bacteria is your (or a friend's) aquarium water. You can take some of it and place it in your AP fish tank along with your water. However, in doing this, you will run the risk of bringing with it pathogens, which is not a good thing to do. The same is true for pond water. Upon receiving your fish, they will be in water that contain bacteria. So, that may suffice if you do not use fish-less cycling (below); in which case you will need some starter bacteria.

Bacteria multiply once they are fed. Here, again, we get into some tall grass of opinion. You must supply the bacteria with ammonia in order for them to multiply. This fish-less cycling process will take at least two weeks before the system is considered "cycled" and ready for fish and veggies. One way to do this is to purchase chemically pure ammonia (keep it refrigerated) and very slowly (and carefully) add a diluted amount each day while measuring your system water chemistry. Do NOT use any animal urine, and especially not human urine, for these prolific sources of ammonia contain toxins, including prescription drugs (and perhaps non-prescription drugs) that you do not want in your AP system. Remember, we hope you are planning on growing organic fish and veggies in your system, so keep it pure and your fish alive. This whole process is known as "fish-less cycling".

In starting our first system, we added some of the bottled bacteria I mentioned above. We then added some diluted pure ammonia. Later we added too much ammonia and killed off the bacteria that convert nitrites into nitrates. We knew this because we had very high levels of nitrites and zero nitrates. So, we exchanged some water and added more bottled bacteria and everything started to work.

Congratulations! You've just completed Aquaponics 101, Part 4.

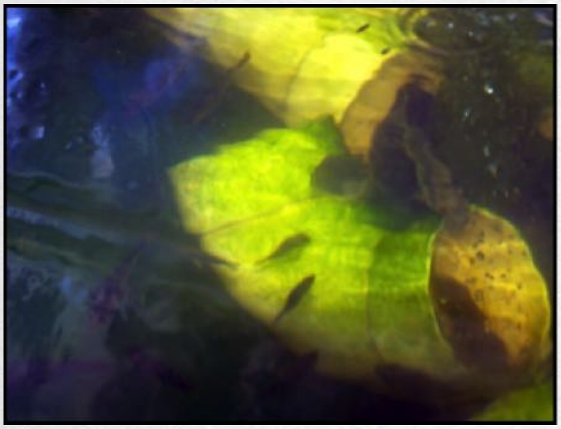
Now it's time to test your knowledge. Take the Part 4 Quiz here:

1. What element besides DO in your AP System provides life to the organisms in your system?
2. The best way to measure the DO in your system is to use a ______________.
3. What does the "p" stand for in the symbol "pH"?
4. What does the "H" stand for in the symbol "pH"?
5. When pH is neutral, it is at what number?
6. If you add acid to your water, your pH goes (up or down).
7. What is the function of a Float Valve in an AP fish tank?
8. What is the purpose of an API Freshwater Master Test Kit?
9. What items does the Fresh Water Test Kit measure?
10. To measure pH, it is best to use a ____________.
11. Where do you place your pH probe when it's not in use?
12. If you use a commercial pH-up solution, it is safe it contains only _______________.
13. Calcium Hydroxide (Lime) can also be used as a _______________ solution as long as you use it sparingly.
14. Why does gravel from a riverbed or supplier sometimes cause a problem in your AP System?
15. What does Cycling Your System mean?

Aquaponics 101
Part 5

"You only have 3 more Parts to go before you're ready to build and operate your AP System so hang in here. Make sure you're taking the Quizzes as you go along. They really help to solidify your knowledge. This Part 5 is a Continuation of Part 4, System Start Up, Operation and Maintenance."

OLIVER



Here's a group of fingerlings that are about the size of the fingerlings you receive when you order fish from our website.

These fish ship overnight and are guaranteed to arrive alive.

You can choose from five different species; and they are all GMO and Hormone free.

Aquaponics 101 Part 5: System Start Up, Operation & Maintenance Continued
I believe the best way to cycle your system is to place your baby fish, be they fry or fingerlings, into the fish tank and begin feeding them small amounts of food. When adding in new purchased fish to your system, you will always be adding in some water from their previous location. This water will contain the bacteria that you need for your AP system. It is a good idea to add some bottled bacteria as well, like API Quick Start that we discussed in Part 4. Slowly increase the amount of food given to your fish while making daily water chemistry measurements. If the ammonia or nitrites get too high (1.0 ppm), reduce your fish food feeding amounts or stop feeding your fish until they settle back down to about 0.5 ppm or less. This is just an indication that your fish feeding increases are getting ahead of your bacteria growth.

After about two weeks, you should be able to feed your fish as much as they will eat and not have an ammonia spike. At that time, you can reduce your water measurement to a frequency of once every few days instead of daily. However, you should never go more than a week without making a measurement. It is important not to over feed your fish because the excess food will have to be broken down over time by heterotrophic bacteria. In the mean time, your fish water will become cloudy. During this two week cycling process, you should see your nitrates begin to climb. Not to worry, for as I stated earlier, fish can handle higher levels of nitrates than they can ammonia or nitrites by about one hundred to one, depending on the fish species.

Once you see nitrates in your system water, you can start your seedlings in a seedling tray. If the ammonia and nitrite levels are below 0.5 ppm or less, you can then use some of the nutrient rich (nitrate) water from the fish tank to spray the seedlings once they have sprouted. This will help condition them for the transfer into the grow beds where they will receive the full dose of the water chemistry in the system. By the time they get transferred into the grow beds, your nitrates should be high enough (10 ppm or higher) to start to support them as long as you stick to leafy greens. As a note, never transfer plants into your grow beds from a soil environment. Soil contains pathogens that can be detrimental to your fish. Always start from seeds.

Go on line and purchase some API Stress Zyme. Stress Zyme contains heterotrophic bacteria; and as I mentioned in Part 1, it will process any left over fish food and fish solid waste. It will also help keep your fish tank water clear. Just follow the instructions on the bottle.

We use about four ounces a week of API Stress Zyme total in our three 120 gallons fish tanks. It works as advertised. Our fish tank water is relatively clear, and there are no fish waste solids over accumulating in the grow beds after several years. There will always be some fish solids in your grow beds because it takes time for them to break down. With the addition of the Stress Zyme, we have not seen any continued build up of solids; and we have cleaned our grow beds several times to remove the excess roots mentioned below.

For your first planting, it is best to plant only leafy green vegetables like lettuce, spinach or basil; as they do not require high levels of nitrates. Leafy green vegetables will grow quite well on 40 ppm of nitrates. Do not plant tomatoes or other flowering plants the first time out because when they start to flower, they will suck up all of the nitrates from your system. The other plants, along with the flowering ones, will respond by putting their efforts into growing roots in search of nitrates, which are not there. You will end up with grow beds full of roots and not much happening above (experience speaking here). Wait until your system is considered mature, which is about one year, and your fish have grown out to plant your flowering plants. Even then, go slowly with just one flowering plant per grow bed. Test your water weekly and take special notice of the water measurements when they start to flower. You will need nitrates at or above 80 ppm to support flowering plants, and it will drop considerably when they flower.

As always, make regular water chemistry measurements. If you notice your ammonia or nitrite levels rising too high, reduce or completely stop feeding your fish until they are at safe levels. If they get to very unsafe levels then do a water exchange, which means dumping a lot of your existing water and bringing in fresh water, which will bring them back to safe levels. These safe and unsafe numbers depend on the species of fish you are raising. Again, get to know your fish species' requirements.

At this point you have enough basic information on how an AP system works, the components necessary to put a working system together and how to start up, operate and maintain your system. What I have given you here is just a thumbnail sketch of the complexities of operating an AP system.

If you are serious about becoming an AP farmer, then I suggest that you join an AP forum such as DIY Aquaponics. This particular forum is for Aquaponics do-it-yourselfers located mainly in the USA. There are, however, members from all over the world on board. You will find knowledgeable people here as well as beginners. There are several other fora located in Australia where Aquaponics has been around for some time. I have learned much from the Aussies about Aquaponics. They use metric units in describing their systems and talk about local fish which are not available here in the USA. Still, much information is to be had from down under where they've been dealing with extended drought conditions because the physics is the same regardless if their fish swim upside down. I just don't know how they make water run uphill, though.

Becoming an AP farmer can be an emotional experience. For some this will be quite the journey into this area of feeling. For others, it will be a little intense. To see your first plants grow out and especially to see, over time, your fish become edible size and then have to make the decision as to whether or not to have them for dinner, is what I am talking about when it comes to emotion. Perhaps the roughest part of becoming an AP Farmer is to see one or more of your fish die, especially once they have become fully grown. I mention this here only to let you know that it is part of the life of an AP Farmer and ask that you not become discouraged over these little setbacks, for life goes on, the system continues to produce and you will receive the benefit of having grown your own food for you and your family.

I hope you have found this tutorial valuable so far. For now, please consider what you have read and the possibility of becoming an AP farmer. These parts, up to this point, have given you what you need to start your first system. Read on for more information.

Congratulations! You've just completed Aquaponics 101, Part 5.

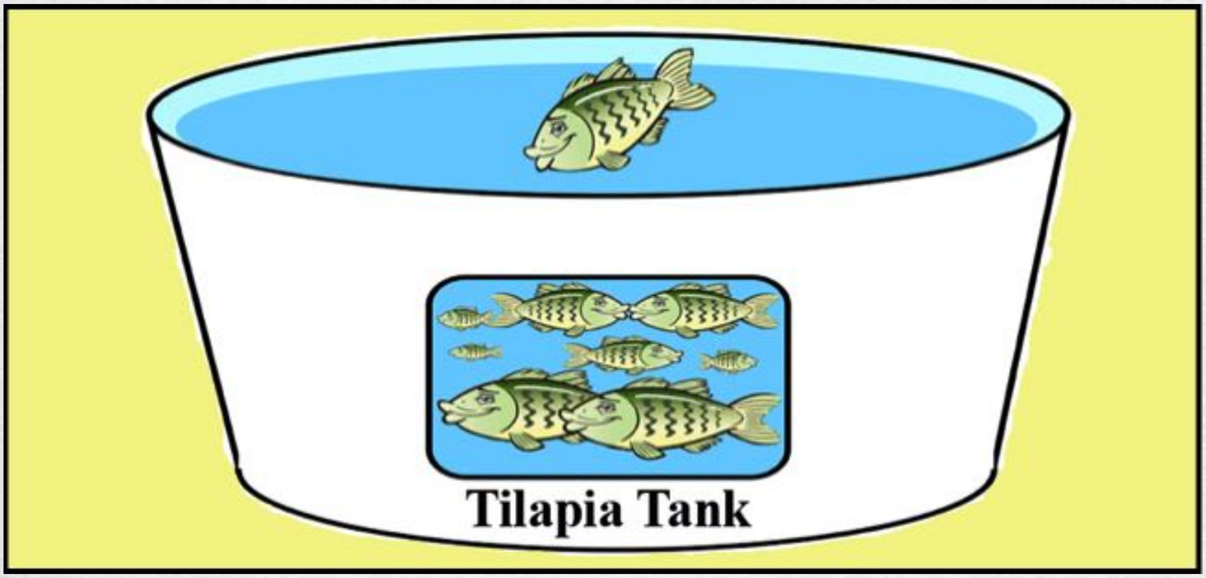
Now it's time to test your knowledge. Take the Part 5 Quiz here:

1. What is the best way to Cycle your System?
2. When you add new purchased fish into your AP System, you're also adding water from their previous location, which contains __________.
3. As you slowly increase the amount of fish food, you also need to make daily ____________ ___________ measurements.
4. If the ammonia or nitrites get too high (1.0 ppm) what action do you need to take?
5. You should never go more than _____ ______ without making water chemistry measurements.
6. During this initial two week cycling process, in measuring water chemistry you should see your ___________ levels increase.
7. Fish can handle ______ times more nitrates than ammonia or nitrites.
8. What do you need to see in your system water chemistry measurements before you start to sprout your seedlings in a seedling tray?
9. How high does your Nitrate levels need to be before you plant leafy greens in your grow beds?
10. You should never transplant plants from ____________ into your AP System.
11. What kinds of vegetables should you plant in your first planting?
12. Once your AP System is cycled and growing plants, what do you need to do if you see an ammonia or nitrite spike?
13. If your water chemistry goes to a very unsafe level of ammonia and/or nitrites, what action should you take?

Aquaponics 101
Part 6

"You're really doing great! Before you know it, you'll be running your own AP System and growing food in your own backyard or school setting. In fact, if you're a Teacher, feel free to use this Tutorial with your students complete with the Quizzes. Just give us credit. Now let's discuss the Ratio of Fish to Water."

OLIVER



Aquaponics 101 Part 6: the Ratio of Fish to Water

This is the sixth in a series of Tutorials that are going to teach you much of what you need to know about Aquaponics. So, if you're curious about the most amazing food growing technology on the planet today, continue this series of educational Tutorials on Aquaponics 101 and please, become interactive by making comments or asking questions through our email address at urbanfarmer@aquaponicsusa.com.

In Part 1, "The Bio-Chemical Process", I wrote about what Aquaponics is and why it is important to Preppers (those preparing for what is about to come down the pike). An AP system will allow you to grow food for you and your family year round as long as its in the proper environment. I also gave a description of the bio-chemical processes involved that make Aquaponics work.

In Parts 2 and 3, "The System Design", I wrote about the components of a basic system. To quickly review, I wrote about the need for a bio-filter and that it is usually combined with the grow bed to form a single AP component called the grow bed, which is the most important part of an AP system. I told you about the grow bed media, the grow bed shape, and that you need about one gallon of grow bed/bio filter volume for every gallon of fish tank volume and the reason for this ratio. I discussed the need to flood and drain your grow beds four times an hour and how to properly size your water and air pumps.

In Parts 4 and 5, "System Startup, Operation and Maintenance" I talked about an AP system water and all the important aspects of the water like the DO (dissolved oxygen), nitrites, nitrates, pH and alkalinity. I talked about how to measure the water using a freshwater test kit, TDS meter, a DO meter and a pH meter to determine that it's safe for the fish and the plants. I also explained how to get an AP system started and how to cycle your system.

I'm now going to focus on the Ratio of Fish to Water, which determines how many fish you can grow in your AP system. In this segment, I'm only going to discuss the most popular fish, Tilapia, among AP farmers in the US because that's the species with which I've had experience.


I'm going to tell you about an important item that needs to be addressed, the Ratio of Fish to Water. There are a number of fish to water ratios being given out by AP enthusiasts. So, let me start by giving you my preferred ratio of 6 gallons of system water for every pound of Tilapia as a maximum density of fish to water. As a beginning AP farmer, I recommend you stay at or above 6 gallons of water per pound of fish. But this is not the most important number in determining how many fish you can raise in a given system.

Please, let me explain.

These are the numbers we presently have in our system including our greenhouse, our enclosed growroom and our enclosed fish room. Our system has a total of five 120 gallon fish tanks in that fish room. Our Greenhouse has two, 11 square foot deep (12″) media grow beds, with a vertical duct growing system pictured above. Then there's a horizontal duct growing system in the growroom.

Except for the two deep media beds, this is not a normal backyard or school system. We are running what we call a Micro Food Forever™ Farm, which is our Proof of Concept for our larger Food Forever™ Farms. If you want to learn more about our Food Forever™ Farms, go to BioponicEarth.com. Nevertheless, we are holding almost the same ratio of fish to water as we used when we had only five deep media beds and three 120 gallon fish tanks in our Greenhouse alone.

We recirculate the water between the five fish tanks so they act like a 600 gallon fish tank in their biological stability; and the greenhouse and the growroom share the same water. What we found as the fish grew out and are now averaging about 2 pounds each, is that the 55 square feet of 12 inch deep media grow beds adequately converted the fish waste (including solids – without accumulation), into plant nutrients. We add heterotrophic bacteria weekly to help with the solid waste mineralization and for water clarity.

Our current system actually has a total of about 500 gallons of water in it and about 100 pounds of Tilapia for a gallons of water to pounds of fish ratio of about 5:1.

With an increased amount of bio-filtration (more grow beds), it may be possible to decrease the water to fish ratio to a lower gallons of water per pound of fish. With a decrease of bio-filter volume then this ratio must be increased. This is based on feeding the fish as much as they will regularly eat and as often as is practical with no food left in the tank.

Another way to increase the fish density is to decrease the amount of food given to the fish. This will slow their growth, which may be desirable once they are fully grown. In any event, the real ratio here has to do with the amount of food digested and the size of the bio-filters needed to process the waste. As can be seen, the pounds of fish the system can support is more a function of the amount of bio-filter volume available than it is to fish tank size. This assumes proper design and selection of other system components.

We have found that the best way to regulate and insure that the fish are fed portioned amounts of food and on schedule is to have an automatic fish feeder. The feeders we use have a three event per day timer and can be set to dispense preset quantities of food and are available on this web site. By setting the timer to dispense food three times every day, which is about every four hours, we know that the food they receive is the same every day. This allows us to adjust the amount of food given the fish as needed and it also allows us to leave for a few days without worry that they won't be fed. As the fish grow out, we can increase the amount on individual feedings, thereby giving the fish more food. We highly recommend using an automatic fish feeder.

I wouldn't want to be raising Tilapia without one of these automatic fish feeders. Once we did an Expo with live fish and plants. A woman came into the Booth and said to my partner, Grace. "I bet you take care of the plants and Oliver takes care of the fish." We looked at each other and said: "No one takes care of the fish." Then we said, "No. The fish feeders take care of the fish!" Tilapia are easy to raise when they feed on auto-pilot. It's eat, swim, mate, repeat.

As the sun crosses the equator, we change the quantity of food in the feedings. In the spring and summer, the days are longer supporting more food, as verses less food in the fall and winter. This allows for more food and, therefore, waste in the system. Couple this with warmer water temperature, and we have a faster fish growth rate as well as more nutrients available for the plants. The warmer water also contains less dissolved oxygen (DO), which is problematic. The warmer water can also be less conducive to plant growth.

Another way to increase fish density is to remove the fish waste solids from the system. This would un-tax the system from the need of some of the DO (dissolved oxygen) in the water and would reduce the amount of system ammonia; but it would also reduce some of the resulting nitrates. In addition, this would remove some valuable plant nutrients that are a result of the mineralization process of fish solid waste. So, we leave in the fish solids, add heterotrophic bacteria weekly (see Aquaponics 101 Part Four: System Start Up) and provide ample aeration.

Through the process of solid waste mineralization, the nutrients and minerals found in the fish food makes their way into the plants. So, what you feed your fish is what you feed your plants.

The key to this all working is adequate DO (dissolved oxygen, see Aquaponics 101 Part Four: System Start Up) in the water. As we measure it weekly, we have changed our system design over time to improve this important factor. Because the fish waste conversion to plant nutrients requires ample DO, we have a DO meter; and in using it regularly, along with other water chemistry measurements, we learned about the system dynamics as it matured.

As our fish grew out and we increased the amount of food we gave them, the DO in the water decreased over time, which affected the nitrification process. DO is also a function of water temperature and this must be accounted for in making DO measurements. We then increased the aeration in the fish tanks. The DO then increased to a good level for the mineralization of the fish waste solids and the nitrification of the ammonia in the system.

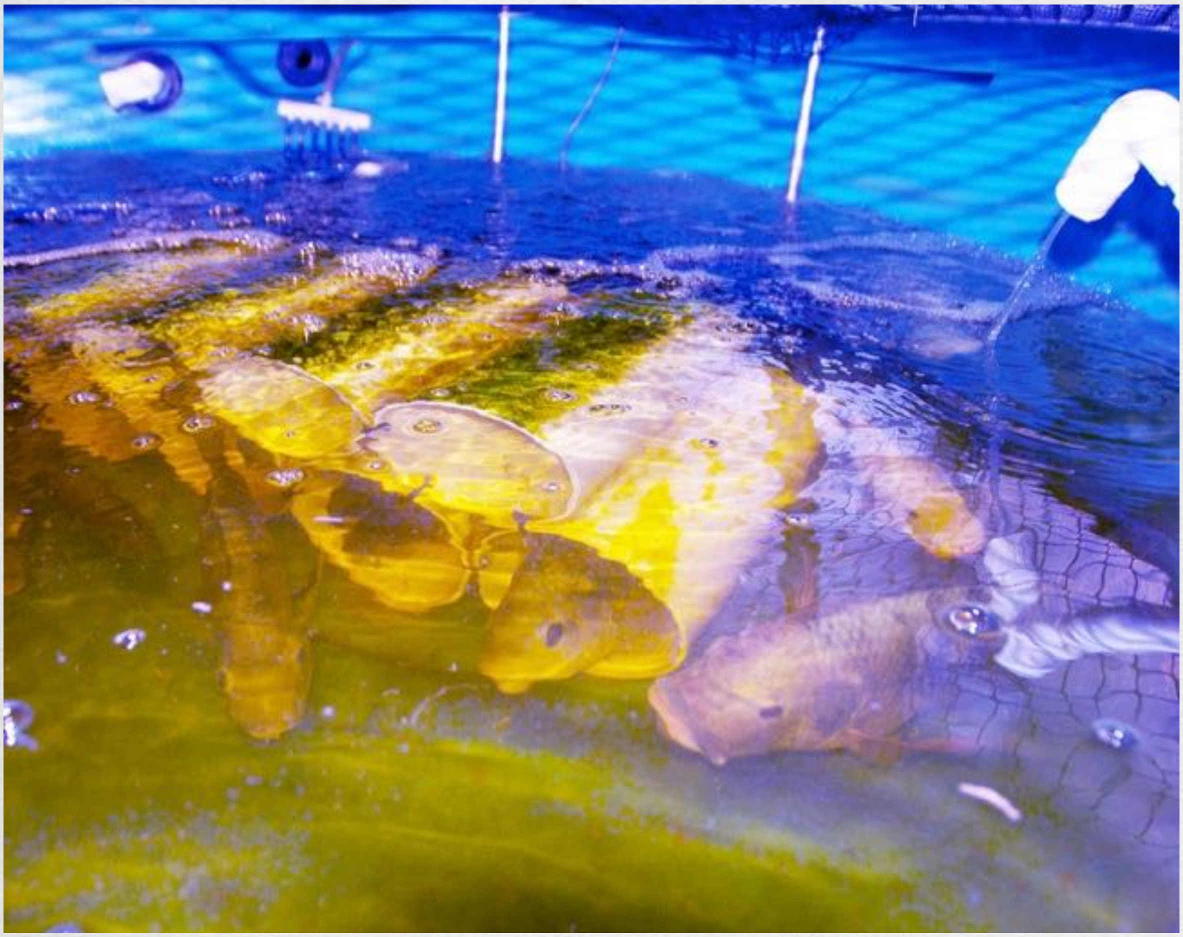
Once the ratio of fish pounds to water gallons reached about one pound of fish for every four gallons of water we noticed the pH of the water dropping below the optimum of 7.3. As the fish continued to grow, the pH found its way down to as low as 6.0 ppm.

With the pH dropping below 7.0, the bacteria stopped properly functioning and the ammonia levels started to climb. Water exchanges were an immediate fix but not a long term solution. Adding in more bacteria and Potassium Hydroxide, pH Up, to the system brought the pH back up to 7.3 ppm and the ammonia levels soon went down to safe levels.

After about three plantings and many grown out flowering plants, the potassium had been mostly depleted from the system. The flowering plants stopped producing, leaves turned yellow and the cucumbers went from green to white. We now add Chelated Iron along with the potassium to keep our plant leaves and green veggies colorful and healthy. In some of the fish tank photos like the one below, you'll see that our water has a yellow tinge to it. That means we recently added the Chelated Iron, which turns the water yellow for a time.

An eleven square foot, deep-media (12″) 70 gallon grow bed holds about 36 gallons of actual expanded clay volume and 30 gallons of water. This includes about one inch of expanded clay above the highest water line to prevent algae growing on top of the expanded clay and mold growth on the leafy green plants bottom leaves. This gives about 60 gallons of wetted grow bed media being used as a bio-filter.

A two, 11 square foot deep-media grow bed system can support about 20 pounds of fish maximum with ample fish tank (120 gallons) and grow bed aeration, and works out to about 6 gallons of bio-filter/grow bed volume per pound of fish. Again, this one pound per six gallon of bio-filter number is a maximum and is only for a mature system, one that is at least one year old. Keep it safe and stay below one fish pound per six gallons of useable bio-filter.

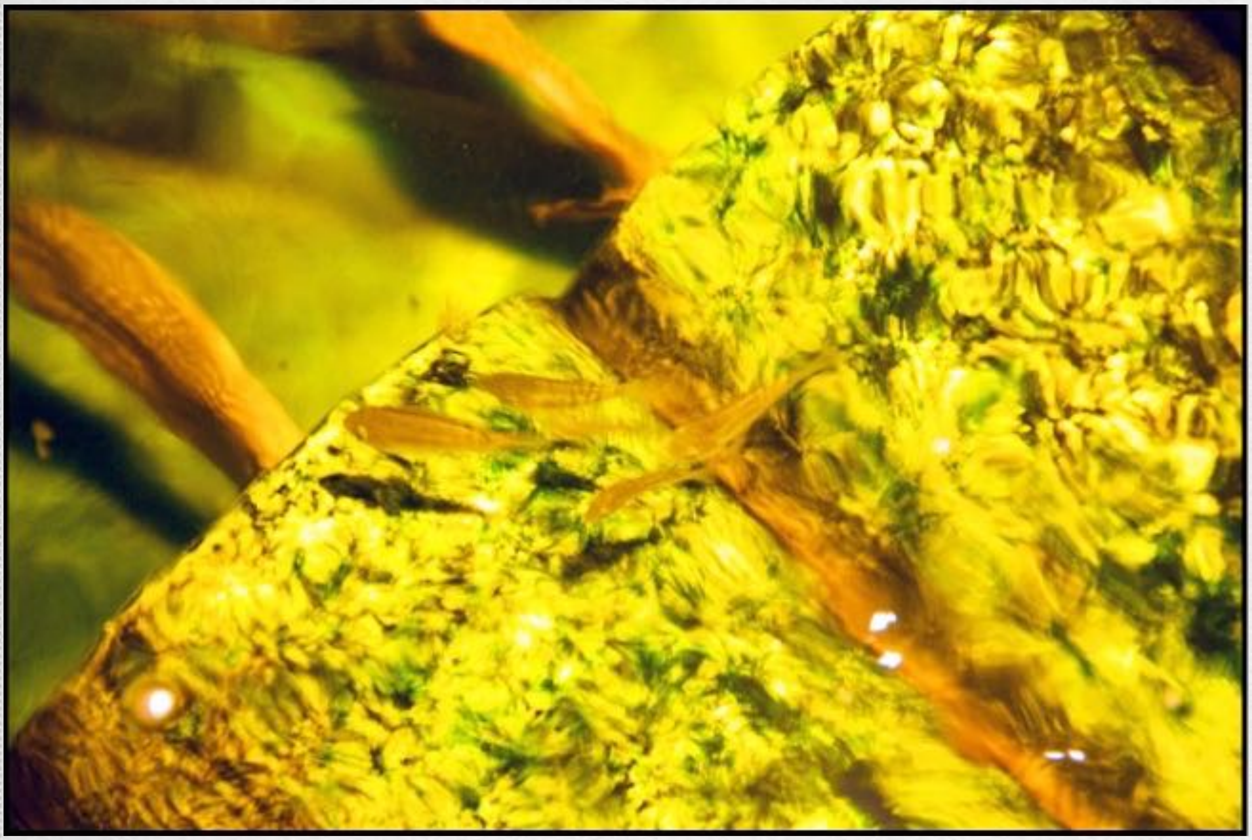


It is important that the grow beds all be of the flood and drain (ebb and flow) design. This allows for the bacteria on the surface of the Hydroton and vegetable roots to be aerated between the drain and flood cycles. Even with added grow bed aeration, which adds additional DO to the water, added aeration by way of air diffusers in the bottom of the grow bed does not reach all of the bacteria or vegetable roots as well as does draining and re-flooding.

As the fish grow out, they often do so at different rates, and you need to plan ahead for the maximum size they will be before harvesting. If you do not plan on harvesting your fish and choose to keep them in the tank for their life, then you need to plan on the maximum poundage of each fish when fully grown. Breeding your fish for sustainability is another option you may want to consider.

It is important to note the difference between maximum fish poundage and yearly pound production. Tilapia (as with most fish species) tend to grow faster in warmer water with longer daylight hours, natural or artificial. It is possible with certain Tilapia species to grow to market size (1.25 pounds) within 6 months. This would give you two crops of fish per year in a single tank thereby doubling the maximum poundage numbers to get annual yield poundage.

This brings up the concept of system design again. A system is designed for either maximum fish growth or maximum vegetable growth, but not both. Keeping your fish water warm and removing fish solids is a method of maximizing fish growth and are some of the techniques used in aquaculture, as is adding pure oxygen to the water. However, warm water is often not conducive for good vegetable growth. These and other factors determine what it is that you will accomplish in your system.



This foursome of fingerlings are swimming over the top of two of the large pvc tubes we use as Tilapia Condos for breeding and just hanging out.

You can see two adult Tilapia tales sticking out from the Condos to help you get a perspective on the difference in size between them.

As always, monitoring your water quality regularly, adjusting the amount of feed given the fish and adjusting your pH to maintain that quality is important.

Our breeder fish are always adding fry to the fish tanks, and as they grow out we will be pushing our system density. Every time fry are introduced into our system, the fish density in the system is being pushed, and we have had to keep an ever closer eye on the system chemistry. You need to find the balance between the fish you harvest to eat and the new fish coming into the system. If you don't eat enough, or any of your fish, the juveniles (who are carnivores) help you balance your system by eating the fry. If you separate the fry out from the rest then they will have a much better chance of survival, and at some point your fish numbers become just too great and your system becomes too unstable to continue to increase the density any further.

To summarize, increasing your fish density will allow you to produce more nitrates and other nutrients for your plants. As the fish density increases the system becomes less stable and requires more timely attention. This is true for a system of any size. As we found out, adding high pH water as a part of evaporation replacement worked well to keep the system pH in the proper range but as the fish density increased through time, the system started having new problems in the area of water chemistry. This required a greater and more timely attention and compensation in order to keep the system healthy. So, a six to ten gallon per pound ratio is a fairly safe and laid back place to be in a home or school aquaponics system. If you want to get the most from the least, then you can increase your fish poundage to water ratio. If you do that, then you will need to stay on top and ahead of your system, for it will go places it has not gone before.

Congratulations! You've just completed Aquaponics 101, Part 6.

Now it's time to test your knowledge. Take the Part 6 Quiz here:

1. What is my recommended of water to fish ratio?

2. If you increase the area of bio-filtration (grow beds), it may be possible to decrease or increase (Circle one) the number of gallons of water per pound of fish in the fish tank.

3. What is a way to safely increase fish density?

4. The real fish to water ratio has to do with the amount of fish food digested and the size of the bio-filters needed to process the waste. True or False (Circle one).

5. What is the easiest and most efficient way to feed your fish?

6. What is a 3rd way to increase fish density?

7. When the pH drops below 7.0, the _________ stop functioning properly and the ammonia levels climb.

8. What do you need to add to your AP System to keep your plants green instead of yellowing or going pale?

9. What's the minimum age of a system that's considered to be mature?

10. You always need to plan ahead in your system design regarding the total fully grown poundage of _______ in your system.

11. An AP System is designed for either maximum ________ production or maximum ________ production, but not both.

12. How do the fingerlings and juveniles in your AP System help you keep your system in balance?

13. As the _______ density increases, the system becomes less stable and requires more time and attention.

Aquaponics 101
Part 7

"This is the last Part of this 7 Part Tutorial on Aquaponics 101, Improving Water Quality. Get ready to purchase or build one of the most advanced ways to grow food on the planet today using an AP System. Have fun becoming an AP Farmer; and thank you for participating. Remeber to Download your Completion Certificate!

OLIVER

Aquaponics 101 Part 7: Improving Water Quality

This is the seventh in a series of Tutorials that are going to teach you much of what you need to know about Aquaponics. So, if you're curious about the most amazing food growing technology on the planet today, complete this Tutorial series of educational posts on Aquaponics 101.

In Part 1, "The Bio-Chemical Process", I wrote about what Aquaponics is and why it is important to Preppers (those preparing for what is about to come down the pike). An AP system will allow you to grow food for you and your family year- round as long as your AP system is in the proper environment. I also gave a description of the biological processes involved that make Aquaponics work.

In Parts 2 and 3, "System Design", I wrote about the components of a basic system. To quickly review, I wrote about the need for a bio-filter and that it is usually combined with the grow bed to form a single AP component called the grow bed, which is the most important part of an Aquaponics system. I told you about the grow bed media, the grow bed shape, and that you need about one gallon of grow bed/bio filter volume for every gallon of fish tank volume and the reason for this ratio. I discussed the need to flood and drain your grow beds four times an hour and how to properly size your water and air pumps.

In Parts 4 and 5, "System Startup, Operation and Maintenance" I talked about an Aquaponics system's water and all the important aspects of the water like the DO (dissolved oxygen), nitrites, nitrates, pH and alkalinity. I talked about how to measure the water using a freshwater test kit, TDS meter, a DO meter and a pH meter to determine that it's safe for the fish and the plants. I also explained how to get an Aquaponics system started and how to "cycle" your system.

In Part 6, Ratio of Fish to Water, I talked about how many fish you can place in your system based on a specific and safe ratio; and I said that as a beginning Aquaponics farmer, I recommend you stay at or above 6 gallons of water per pound of fish. Then, I proceeded to give you all the reasons why this is my recommendation.

The photo on the left is of one of our Food Forever™ Growing Systems that we installed in a classroom at Manzo Elementary School in Tucson, AZ. Later, it was placed outside in this Greenhouse. From the looks of their water, we're thinking they're not using Stress Zyme, a product we recommend in Part 5.

This is an FGS-40 System, which has 44 sq. ft. of growing area spread out among four 11 ft² Grow Beds with a 320 Gallon fish tank.

One of the Manzo Aquaponics Instructors is leaning over the Fish Tank holding a really small fish net. You can follow the progress of the Manzo and the Davis Elementary School Food Forever™ Growing Systems on their facebook page.

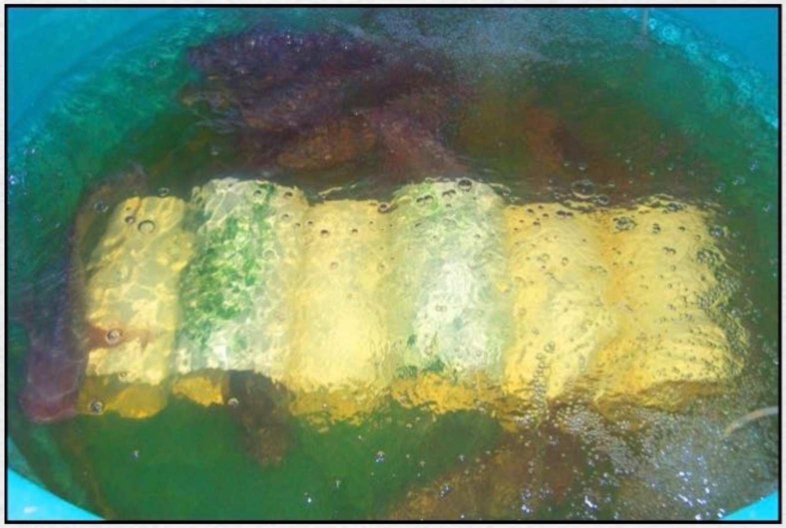
Now I'm going to discuss Improving Water Quality. Since everything depends on everything else in an AP system, we need to do a little more review. In the previous Aquaponics 101 tutorials, I have put forth an Aquaponics System design. This included a simple set-up of a single fish tank and one or more deep media filled grow beds. This design retains all fish waste in the system and, thereby, allows for (and requires) the mineralization of the fish waste solids in the grow beds, which also serve as bio-filters. Some of the advantages of such a design are low maintenance and operational cost, as well as a minimum number of components required to build the system.

In order for this system to function properly, it must meet certain design criteria. It must have ample bio-filter volume in order to process the delivered fish waste. It must have ample water flow in order to deliver those wastes. It must have ample water aeration in order for the bacteria to process the fish waste. It must have ample grow bed space to grow the plants needed to uptake the produced nutrients. And, it must have ample fish tank volume to hold the fish, which are the engine of the system.

For a simple backyard or school AP system, this is all that is required, as long as it is limited to low fish density, which means having about one pound of fish for every six gallons or more of bio-filter/grow bed. This number can be pushed to one pound of fish for every three gallons of bio-filter; but that borders on the edge of instability. Even if the chemistry measures in the safe range, the lowering of pH due to the nitrification process will always require constant (weekly) adjustment by adding a pH-up solution. As I've shared before, this solution can be either Potassium Hydroxide (potash) or Calcium Hydroxide (lime).

As mentioned above, the system must have ample aeration. This is necessary in order to create a Dissolved Oxygen (DO) content of 6.0 or higher. It will also help to de-gas the water. More on this below. This DO level can be difficult to achieve by just aerating the fish tank, especially if the water temperature is above 78 Fº, because the higher water temperature drives out the Oxygen. Additional aeration can be added to the grow beds; but it adds only a small amount of DO to the system water.

This is because the depth of the water in the grow beds is minimal, and the air bubbles don't spend much time in the water. Also, due to the shape of the grow beds, it is difficult to fully aerate them without multiple aeration devices spread throughout their bottoms. Again, this does add some DO to the water but at an equipment and energy cost.



Adding additional system components to help improve the water quality is a common practice among commercial aquaculture and AP growers. In the picture above, you can easily tell, even though we have a lot of aeration going in this tank, that our water is quite clear because we have added what we call our WET (Water Enhancement Technology) tank to our system, which I'll explain later. The Tilapia on the left who is out of the bubbles is clearly seeable.

In order to understand these added components, we must first understand what need is being addressed by adding them to the system. Water contains dissolved gasses. In addition to some oxygen in the water, it may contain excesses of Nitrogen, Hydrogen, Methane, CO_2, and Hydrogen Sulfide. Some of these gasses are from the process of fish waste being broken down by the bacteria in the system. Hydrogen, for example, is released into the water when autotrophic bacteria break apart Ammonia (NH_3) into Nitrogen and Hydrogen. They add Oxygen to the Nitrogen to produce Nitrite (NO_2) in its first iteration process and later add more Oxygen to produce Nitrate (NO_3), which is less toxic to the fish than either Ammonia or Nitrite and beneficial to the plants. The released Hydrogen is then combined with the Carbon DiOxide (CO_2) in the water to produce Carbonic Acid (H_2CO_3), which is what causes the water's pH to lower. Carbonic acid is also formed anytime Carbon DiOxide is dissolved in water ($CO_2+H_2O\text{->} H_2CO_3$). The alkaline buffers that may be present in the water initially will keep the pH high, but they will eventually be overwhelmed by the shear amount of Carbonic Acid being produced as the fish density increases when the fish grow out and are fed more food.

Part of the solution to these troublesome gasses in the water is to de-gasify them in a degassing tank. This is usually a rather shallow tank, which the water flows through as air is being pumped in by way of aerators in the tank's bottom. This degassing operation also adds some aeration to the water.

This is what we call our Engine Room because the fish are the engine of an AP System.

As I explained before, this is not a typical backyard or school system. Our system is demonstrating our commercial sized Food Forever™ Farm Systems in miniature. We do have one 11 sq. ft. Deep Media Grow Bed seen in the back of this room but was later removed.

Our Aquaponics USA website is all about small backyard home and school systems while our BioponicEarth.com website is all about building large-scale systems for commercial growing and for sustainable development in under developed countries.

Notice again how clear the water is because we have added our WET Tower (to be explained below) and our Solids Separation BioConversion System, which is proprietary.

We have now added two extra components to the system, a mineralizing tank and a degassing tank. And, if we plan on using a deep water culture (DWC) Raft, NFT (Nutrient Film Technique) or Aeroponics (the spraying of nutrient rich water onto the plant roots) instead of deep media grow beds to grow our veggies, then we will need to add another component to the system, the bio-filter. It is interesting to see how little attention is paid to the bio-filter in some of the commercial system designs I've looked at on the internet. The bio-filter contains media with lots of surface area so the Autotrophic bacteria have a place to live and do their thing of converting the Ammonia to Nitrates. The bio-filter is a container of some sort where the mineralized (or filtered) and degassed water passes through the media; and, if properly designed, aeration devices are added to help with the process and to de-gas the Hydrogen.

So, why go to all of this trouble and expense in adding these components? Well, if you are building a low density backyard system, then they are not necessary. But if your system is a larger higher density one, and you want to get serious about growing large amounts of food (vegetables and fish), then improving your water quality not only makes sense, it is a requirement.

In a media filled grow bed, the addition of the solid fish waste can be problematic. Even though I have advocated for this being done in order to simplify a small low density home or school system, the grow bed is not the ideal place to mineralize the solid waste. It coats the grow bed media making it less usable for the autotrophic bacteria, which need the media's surface for attachment. It can also coat the vegetable roots preventing them from proper uptake of nutrients. As the amount of solid waste increases, this then becomes a problem.

Many of the Aquaponics growing techniques have been borrowed from Hydroponics, which has been around for a long time.

The picture on the left is a trough growing system, similar to both DWC and NFT. It is a Shallow Water Trough (SWT) system. We have a similar system in our Growroom we call Horizontal Duffy Ducts.

If you are growing lettuce or other leafy greens, they can be grown in a DWC raft system. Growing them in media, such as expanded clay, takes more time to both transplant and harvest. In a commercial operation, this added time cuts deep into what little profit margin there may be. By using a raft or other deep water culture (DWC) system, the transplanting and harvesting time is greatly reduced.

In order to use what is called a NFT (Nutrient Film Technique) System or a Raft growing system, the water must be relatively clean, which means free of solid fish waste that might interfere with the plants' uptake by coating their roots. This coating would retard their growth requiring more time and thereby adding cost to the yield. Clean water is especially necessary in Aeroponics, as the sprayers can otherwise become clogged with solid fish waste.

So, how do we accomplish this water quality improvement without adding a lot of system complexity and cost? One way is to combine as many of these operations into as few components as possible. Think vertical. By using a relatively tall tank (which we refer to as a water tower), say six feet or taller, we can take all of the water from the fish tank pump (it must have enough head and flow to reach six feet or more) and pump it into the bottom of this vertical water tower and remove it near it's top. By adding aeration devices in the bottom of the tower, the air takes time to cover the distance to the tower's top, which is vented. On our test tower pictured below, there is an eight inch cap on its very top with a vent hole. We cut a larger hole in this cap and inserted a bulkhead so we could extend the height to prevent water overflow as well as provide a high vent and a place to insert the airline running to the aerators in the bottom of the tower.

About eighteen inches from the tower's top, we added a bulkhead outlet (as far as we could reach into the tower from the top with the cap removed) where the water is allowed to flow from it into the grow beds. This outlet is well above the height of the grow beds and good flow has been achieved. Each grow bed has its own control valve to adjust the flow into it. About one foot above the grow bed outlet and about six to ten inches from the tower's top is another outlet (this, along with the bottom inlet, were built into the original tank) where the excess water being pumped in and not flowing into the grow beds is allowed to overflow back into the fish tank(s).

The slow upward movement of the water allows the heavier than water fish waste solids to precipitate. The air from the air stones placed in the tower's bottom keep the solids suspended.

Here it is our WET Tower. It's been in operation for about four years where it started in our growroom that originally had four 11 ft² Deep Media Grow Beds.

In February of 2014, we moved it into our Engine Room pictured on page 29. It's sitting in the near right corner of the room out of the shot.

This is one of the reasons our water is clear enough to grow in the Vertical Lettuce Growing System you saw on page 24.

The other reason is our proprietary Solids Separation BioConversion System, which we also installed into our Engine Room and which is also purposefully out of the shot.

When we moved our WET Tower from one room to the other, we discovered it had been working perfectly as there was no accumulated fish waste in it.

The project appears to be successful. The air under pressure entering the bottom of the tower and rising degases the water. The smell from the top of the tower is an indication of this process. Distributed over forty four square feet of grow bed, the smell was not noticeable, but the smell coming from the hole in the top of the tower gives an enhanced experience.

The Dissolved Oxygen in the water coming from the overflow back to the fish tanks is at 97% saturation as measured on our trusty Milwaukee DO meter. That is a measured 8.3 ppm (mg/L) out of a possible 8.5 ppm. The DO coming from the grow bed return to the fish tank is 6.5 ppm or greater. The combined DO level as measured in the fish tank is 7.5 ppm. This is quite an improvement from our previous fish tank DO.

The water going to the grow beds is much cleaner than it was prior to incorporating this technology. The fish tanks are becoming even clearer than before.

We have stopped our weekly adding of Heterotrophic bacteria and the water continues to remain clear. This is an indication that the Heterotrophic bacteria is self sustaining. We believe this is due to the high level of dissolved oxygen and our continuous monitoring and adjustment of the pH to keep it very near 7.2.

Over two years of operation and everything still is performing great. We drained the tower in order to move it into a new room we built to separate the fish tanks, filters and tower from the plant growing area as we build out our micro-farm system. We expected a lot of sludge to come out of the bottom of the tower as we drained into the field next door. To our surprise only clean water came out of the tower bottom from the beginning to the completion of the draining process.

This was a welcome discovery and an indication that the mineralization process was working over the two plus years we incorporated the tower into our indoor growing system.

If you're interested in building a Food Forever™ Farm, just email us and we'll send you an NDA to sign. At that point we can share the other components in our cutting edge water cleaning technology in a document we call "How A Food Forever™ Farm Works".

A Really Big Congratulations! You've just completed the final Tutorial of Aquaponics 101, Part 7.

Now it's time to test your knowledge. Take the Part 7 Quiz here:

1. The _______ are the engine of an AP System.
2. The higher water temperature the more it drives out the _______ from your AP System?
3. What are the common dissolved gases contained in water?
4. Which of these gases is released into the water when autotrophic bacteria break apart Ammonia (NH_3)?
5. The released _________ is combined with Carbon DiOxide (CO_2) in the water to produce Carbonic Acid (H_2CO_3), which causes the water's _______ to lower.
6. What is one of the solutions to dealing with gasses in the water?
7. When is improving water quality beyond adding Heterotrophic bacteria a requirement in an AP System?
8. How many extra components did we add to our AP System when we built our Micro Food Forever™ Farm?
9. What is the name of the Tower we designed?
10. What did we add to the bottom of the Tower that makes it work?
11. The Dissolved Oxygen in the water coming from the overflow of our Tower back to the fish tanks is at _______% saturation as measured on our trusty Milwaukee DO meter.
12. The DO coming from our grow bed return to the fish tank is ______ ppm or greater.
13. What is allowing us to grow vertical walls of lettuce in our Micro Farm Greenhouse?

You Did It! Your Aquaponics 101 Tutorial is complete. Now you can Download your Completion Certificate and again, Congratulations!

It's been great having you in my Class,

Oliver

Aquaponics 101 Conclusion

"Congratulations! You did it!
You've completed Aquaponics 101; and you're ready to buy or build your own AP System, which will become your own food fish, fruit and veggie lab.
But before firing up your own system,
Download (below) your
CERTIFICATE OF COMPLETION
You earned it. Put it in a frame and show it off."
OLIVER


Things have changed here since you started your Aquaponics 101 Tutorial. I have so many Students, I had to bring 2 Fish Tanks into the Classroom.
I have my hands full. I'm also doing Private Phone Consultations for anyone building Home & School Systems. Just go to our Consulting Page.
Oliver Duffy
AUSA
Aquaponics 101
WATER
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Privileges to be an AP Farmer bestowed.

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Oliver Duffy
Aquaponics USA
Date____________________