The Nitrogen Cycle

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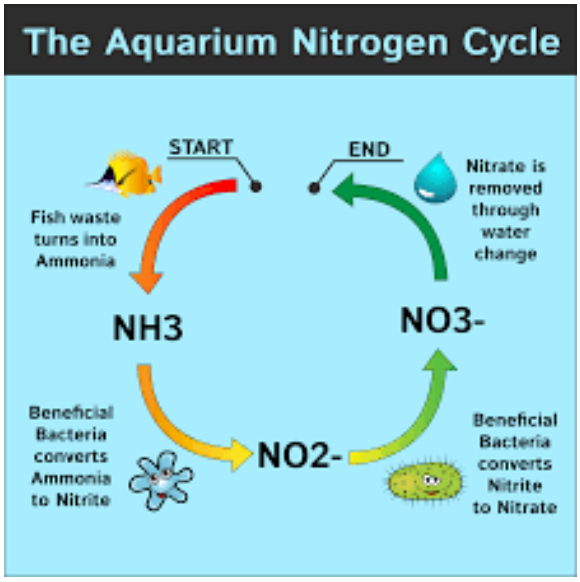
OVERVIEW

In an aquarium, waste such as fish poop, decaying plant matter, dead fish and rotting excess food breaks down and decomposes into ammonia (NH3). Ammonia is a toxic invisible substance. Beneficial bacteria (nitrosomas) in the tank convert the ammonia into nitrite (NO2). Nitrite is also toxic and invisible. More beneficial bacteria (Nitrobacter) convert the nitrite into nitrate (NO3). Nitrate is also an invisible substance, but it is fairly harmless except at high concentrations. Nitrate is partially consumed by live plants but mostly removed with water changes. In nature, water bodies are usually open systems and are constantly refreshed by flowing water and rainfall. Aquariums are closed systems and therefore nitrate removal and replenishment of minerals is achieved though water changes. The beneficial bacteria will grow to cope with the amount of ammonia being produced. Adding more fish means a greater amount of ammonia being produced and therefore more beneficial bacteria need to grow to cope with the added waste. Without these bacteria, the ammonia will continue to grow until your fish die of toxic poisoning. Even low levels of these chemicals will compromise the fish's' immune system and result in disease and illness. The biggest mistake people make is buying a new tank and filter, throwing in a bunch of fish straight away and then returning to the pet store a week later saying "I don't understand why all my fish died "the water looked fine". The fish produced a lot of ammonia and with no beneficial bacteria to consume it, the fish all died of toxic poisoning. Ammonia, nitrite and nitrate are invisible and therefore you need a test kit to determine the levels in a tank. Test kits are discussed later.

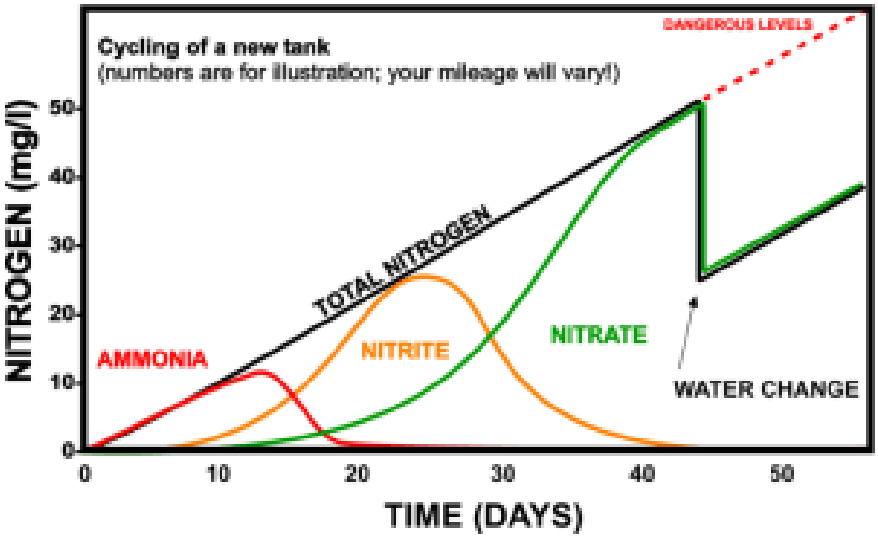


WHY YOU NEED A FILTER

Beneficial bacteria need a place to grow. They will grow on surfaces such as the tank walls, plants and in the gravel but the most important place for them to grow is inside a filter with a sponge. A filter accomplishes three things - it provides oxygen for the bacteria, prevents dead spots from forming in the tank where ammonia can build up, and provides a surface area in the form of sponge for the bacteria to grow on. Some filters even have biomedia inside such as Seachem Matrix. Biomedia is solid material with millions of micropores which makes it perfect for beneficial bacteria to colonise because the surface area is many times larger than the surface area of a sponge. Air-driven sponge filters are suitable for smaller tanks with small bioloads (amount of waste produced by the fish) and for fish which require slow flow whereas larger tanks with larger bioloads benefit from mechanical filters (both internal and hang on back which have impellors and plug into the wall) with biomedia to provide the surface area needed for the bacteria. Even if filters have biomedia inside, they still need sponge as well or filter floss to catch the dirt. The sponge or floss performs the mechanical filtration while the beneficial bacteria perform the biological filtration. The added advantage of biomedia, even in small tanks, is that you can rinse out or replace the sponge or floss to get rid of the dirt without disturbing any of the beneficial bacteria living in the biomedia. For people who do not have filters in their tanks, they have to perform large daily water changes to remove the ammonia to prevent the fish being poisoned. This is a lot of work and it is easier to get a filter and cycle it.

HOW THE BACTERIA GROW

When a new tank and filter is set up, there are no beneficial bacteria. Once there is an ammonia source in the tank, the beneficial bacteria will start to grow. These bacteria take a long time to grow (a couple of weeks) and will continue to grow until the colony is big enough to cope with the amount of ammonia being produced in the tank. Once there is an ammonia source, the nitrosomas bacteria start to grow. During this time, they consume some of the ammonia but the ammonia will still increase because there are not enough nitrosomas bacteria to consume all the ammonia being produced. As the bacteria grow, they will consume more and more of the ammonia until there are enough bacteria to be consuming all the ammonia as fast as it is being produced. This will keep the ammonia level at zero. However, these nitrosomas bacteria produced nitrite. Once there is a source of nitrite from the nitrosomas bacteria, the nitrobacter bacteria will start to grow. They will start to consume some of the nitrite but, in the same manner as the ammonia, the nitrite will continue to increase until there are enough nitrobacter bacteria to be consuming it as fast as it is being produced which results in the nitrite level being kept at zero. This means that the ammonia will increase before plateauing and finally decreasing to zero with the same thing happening to the nitrite. When this happens, the tank is CYCLED. The nitrobacter bacteria produce nitrate as their final product and unfortunately there are no bacteria to consume it. Nitrate will continue to increase and must be removed by water changes (with some being used by live plants). The more fish there are in a tank, the more ammonia is produced therefore the more bacteria you need, and the more nitrate is finally produced which means more frequent water changes are needed. In a healthy cycled tank, ammonia and nitrite should both be zero with nitrate being ideally less than 20ppm however most species will be fine at higher nitrate levels. I say “fine” not “happy”. The graph below shows how each chemical increases and then decreases its concentration as the bacteria grow. The time it takes for a tank to cycle depends on the number of fish. The correct way of cycling a tank is discussed later.



THE IMPORTANCE OF A DECHLORINATOR

Tap water contains chlorine and chloramine. These chemicals kill fish as well as all bacteria. This is why you put chlorine in the pool to kill all the bacteria that cause green cloudy water. This means that if you put straight tap water into your tank, you will not only kill your fish but also kill all the beneficial bacteria in your filter and start the cycle from scratch. This is one of the reasons biomedia is good because you can rinse the sponge under the tap without touching the biomedia and disturbing the bacteria. However if you only have an air-driven sponge filter, then you must always rinse it in old tank water during a water change to prevent it coming into contact with chlorine. There are many dechlorinators available but the best is Seachem Prime which also removes heavy metals along with the chlorine and chloramine. The dosage can also be doubled in the case of water with a high chlorine content. Some people may say that using reverse osmosis (RO) water is therefore better however this water has no minerals salts in it. Fish need these mineral salts to stay healthy so if RO water is used then mineral salts in the form of powder need to be added to the water first. Tap water is perfectly fine to use as long as the pH is kept around 7 (see below).

THE IMPORTANCE OF PH

The pH of water is a measure of how acidic or alkaline the water is. A pH of 7 is neutral. Less than 7 is acidic while greater than 7 is alkaline. Different fish prefer different conditions (bettas like 6.5 – 7). Depending on your water, you may need to use various methods (such as Daro ph up/down) to modify the water ph to bring it to the correct level. For example, my tap water has a pH of 9 so I fill up large containers with it and then add my dechlorinator and Daro pH down to bring the pH to 6.5 before adding it to my tanks. Soft water is more susceptible to swings in pH than hard water.

Advanced note: Ammonia has two forms, ammonia (NH3) and ammonium (NH4). Ammonia is highly toxic while ammonium is harmless. Together they form “total ammonia”. At a pH of less than 7, the total ammonia is made up of mostly ammonium (NH4) while at a pH of greater than 7 the total ammonia is made up mostly of ammonia (NH3). Therefore, the water of an uncycled tank of pH 6 will be a lot less toxic than the same water at pH 8. To throw a spanner in the works, beneficial bacteria stop growing below pH 6. They prefer a pH around 8 to grow quickly but will still grow at anything greater than 6. If you are struggling with cycling your tank, check your pH. I once had a goldfish tank that I was cycling and I could not figure out why it was taking so long. Turns out that due to the soft water, the pH kept dropping to around 4 and the bacteria couldn’t grow. After a permanent solution of adding a chunk of coral to the tank (not discussed here) the water self-buffered to around 7 and the tank was fully cycled in a few weeks.

Generally, these two aspects of cycling a tank do not need to be understood by your average person. All you need to know is keep your tank roughly at pH 7 and everything will be fine.

BOTTLED BACTERIA

Products have been created to speed up cycling. Some of these include Seachem Stability, Microbe Lift Nite Out II, Organic Aqua Filter Activator, Scape Bac Up, Dophin 14 in 1 Nitrifying Bacteria etc. Anything that talks about nitrifying bacteria is generally a good starting point.

TEST KITS

Since ph, ammonia, nitrite and nitrate are invisible, test kits were created. These kits tell you the mg/l or ppm of these substances in your water. An ammonia or nitrite reading of greater than 0 means your tank is not cycled and is therefore toxic for your fish. Anything greater than 0 is toxic but the higher the ammonia and nitrite concentrations the more toxic the water and the more quickly your fish will die. A nitrate reading of 20ppm or less is ideal for most fish but some are more sensitive and need lower nitrate levels while others are hardier and can withstand higher levels. Liquid test kits are generally more accurate than strips and my personal favourite is the NT Labs Mini Test kit which tests pH, ammonia and nitrite. Example of a cycled tank alongside with 0 ammonia, 0 nitrite and 20ppm nitrate.

SUMMARY

Beneficial bacteria convert fish waste and other decaying matter from ammonia to nitrite and finally to nitrate. Without these bacteria, the ammonia levels will rise and kill the fish. The more fish you have, the quicker the ammonia levels rise. These bacteria take time to grow and require a place to grow for which a sponge filter is great (with biomedia being even better). Tap water must be dechlorinated or the chlorine will kill the fish and the beneficial bacteria. This also means your filter media must be rinsed in old tank water not under the tap. The pH must be kept around 7 to ensure the bacteria grow as they will stall at a pH lower than 6. The ammonia and nitrite level will first increase and then decrease to 0 as the colony of beneficial bacteria grows. Once there are enough bacteria to be consuming all the ammonia and nitrite produced thus keeping it at 0, the tank is “cycled”. Nitrate (the final product) will continue to increase and is removed with water changes. An ideal nitrate level is less than 20ppm. An ammonia or nitrite level greater than 0 is toxic to the fish. Once a tank is cycled, more fish may be added in stages which allow the bacteria to catch up and cope with the added waste being produced. Adding a whole bunch of fish in one go will cause an ammonia spike. Bottled bacteria can be added to the water to seed the filter and speed up the cycling process. If you disturb the filter media whether that means removing some or rinsing it under the tap etc, you will need the missing extra bacteria to grow again which means your tank will mini-cycle until the bacteria have grown again to replace the ones that were lost. Bottled bacteria helps speed up the cycling process. If you move across a filter and the fish from a tank to a new tank, the tank will stay cycled as long as the fish population stays the same.

HOW TO CYCLE A TANK

There are two main ways of cycling a tank – fish in cycle and fishless cycle.

Fishless Cycle:

A fishless cycle is preferable and much easier. First step is to set up the tank and fill it with dechlorinated water. Then get the filter running. Make sure the filter is set up how you want it to be for the future regarding biomedia etc. If you have a heater, add it in and set it to 28C as this helps bacterial growth. Since there are no fish there is no ammonia source for the bacteria. This means that people who have "just let the tank run for 3 weeks without touching it" have achieved nothing. The bacteria need an ammonia food source and without fish this comes in the form of rotting food. Depending on the size of the tank, throw in some fish food (flakes work best) every few days and allow it to rot in the water and produce ammonia. Add your bottled bacteria every few days too to speed up the process. You can do water changes during this time but it is not necessary. Just let the tank run and make sure the ph stays above 7. You can slowly increase the amount of food you add as time goes by to make the colony of bacteria keep growing. There is no set length of time to cycle a tank like this but I would do a minimum of 4 weeks. Keep testing the tank during this time and wait until the ammonia and nitrite stay at 0. Remember that the bacteria grow to cope with the ammonia being produced. This means that when you add your fish, they may produce either more or less ammonia than the rotting food. If they produce less, then the tank is already cycled and there is enough bacteria to cope with their waste. If they produce more, the bacteria will need to grow some more to cope with the added waste. This is why you add fish in stages not all at once to allow the bacteria to catch up. Keep testing every few days after adding the fish to see whether the tank stays cycled or not. It is recommended that before you add the fish after cycling in this manner that you do a large water change as the water may be quite dirty at this point. Once you add your fish, adjust the heater back to the temperature that suits them (or remove it for coldwater fish) and stop adding fish food because they will produce the ammonia from now on. Make sure the pH is at a suitable level for them (usually 7). The only food you add is to feed them normally. From this point on a weekly water change of about 25% is recommended but that is just an estimate. The more fish you have the larger and more frequent the water changes need to be to remove the nitrate. For example my nitrates remain low in my tank since there are plants and few fish so I only do 25% every second week. Everyone will be different.

Fish in cycle:

A fish in cycle is more tedious because now you have livestock to think about. Set up the tank and fill it up with dechlorinated water of pH 7 (approx). Get the filter and heater running (heater is only used for tropical fish) and then add the fish. The fish will start producing waste which breaks down into ammonia. This will cause the bacteria to start growing. From now on, WATER CHANGES ARE VITAL!!! If you do not regularly change the water the ammonia will get too high and kill the fish. The amount of water and frequency of the changes depends on the number of fish in the uncycled tank. It is recommended that you start with one or two fish as the more fish you have the more ammonia will be produced. This means larger and more frequent water changes. As an estimate, a 1ft (15L) standard 30 x 23cm betta tank with a single betta and no other fish requires 50% water changes every second day to keep the ammonia and nitrite levels low enough to not poison the fish and takes about 6 – 8 weeks to cycle. A tank double the size would therefore only need perhaps a 50% change every 3rd day (for example). There is no exact answer to how often you need to change water but you need to keep the nitrite and ammonia low like less than 0.5ppm low. This is where test kits come in handy. You don't have to test every time but now and then to check the levels aren't getting out of hand is good. I usually recommend testing once a week during cycling. If your fish is/are not looking well, test the water and if the ammonia and nitrite levels are high then do a large (80% ish) water change. The more water you remove, the more you dilute the toxic substances. You will need to continue these changes for a few weeks until the ammonia and nitrite consistently read 0 and there is a nitrate reading. Once your tank is cycled you can add more fish but spread out over time to allow the tank to mini cycle each time and the bacteria to catch up. Adding bottled bacteria after each change and when adding new fish will help speed up the cycle.