Biological Filtration and the Nitrogen Cycle – An Introduction

Author: Noel Jhinku
Email: njhinku@hotmail.com
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So you've set up your new aquarium, all the equipment is running and everything looks great. Suddenly you recall something the pet store sales assistant told you, 'it's important to get your biological filter working', but you didn't bring one home with you! Where do you get one? What is it?! What the pet store assistant was talking about is the process of Biological Filtration. This process essentially refers to the purification of water by a number of beneficial strains of bacteria. More specifically, the purification involves the breakdown of toxic ammonia to less toxic compounds. This ammonia is produced by the breakdown of wastes that accumulate in an aquarium and if not controlled, you will have sick and dying fish.

In an aquarium with live animals and plants, there will always be wastes produced that will negatively affect the quality of the water. For example, you will most likely feed your fish a commercial dried fish food, your fish will eat most of this food along with any other tasty snacks it finds in the aquarium and then will excrete out whatever is not used as waste. Basically anything that goes in one end has to come out the other end! The food that is eaten will contain protein and one of the main components of protein is the element, nitrogen. While some of this nitrogen is used by the fish for growth and function, the unused nitrogen is mostly excreted in the form of nitrogenous wastes. This can be done a number of ways: firstly, these nitrogenous wastes are released when fish excrete organic matter in their urine and faeces; and secondly when fish breathe, nitrogenous wastes pass directly from their blood into the surrounding water through their gills. There are other sources of nitrogenous wastes in an aquarium as well, from plants that regularly lose old leaves, uneaten food and also fish and invertebrates that have died. All this waste eventually breaks down and releases ammonia. Ammonia is highly toxic to fish and other aquarium inhabitants and needs to be removed quickly. The problem is that there is very little you can directly do to remove ammonia from an aquarium apart from frequent water changes or additional products that cost you extra money. Let's face it; you would rather be sitting down enjoying your aquarium than doing a whole lot of water changes. Luckily for us and our fish friends, nature has provided a solution to this problem with nitrifying bacteria. A number of beneficial nitrifying bacteria known from the genera *Nitrosomonas*, *Nitrobacter* and *Nitrospira* and a few others are shown to have the ability to process toxic nitrogenous wastes such as ammonia and nitrite into a relatively less toxic compound nitrate. Nitrate is easily controlled by a number of ways mentioned below. You can think of these nitrifying bacteria as the engine that drives a biological filter.

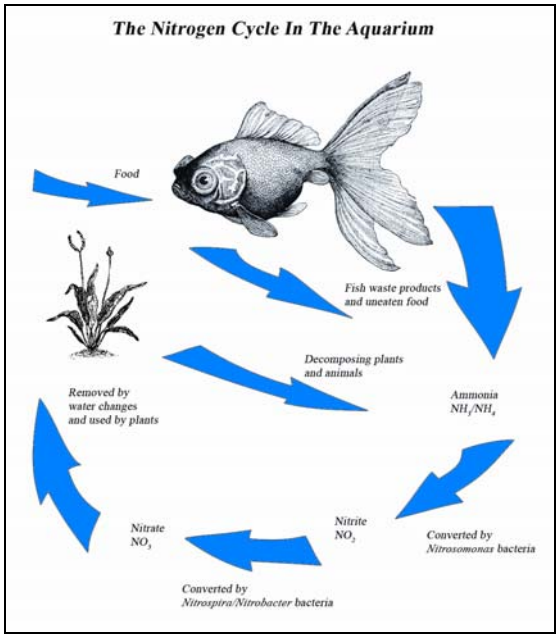

Figure 1. The ammonia produced by waste products is processed by *Nitrosomonas* bacteria into nitrite. *Nitrospira* and *Nitrobacter* bacteria further process nitrite into nitrate, which can be removed by regular water changes and used by plants.

So what does a biological filter look like and how do we set one up? Basically a biological filter can be found wherever a colony of beneficial nitrifying bacteria exists in an aquarium. These nitrifying bacteria can be found in higher numbers in mechanical filtrations systems such as canister filters, undergravel filters and other filters where there is more available oxygen because of higher

water flow and high surface areas on filter media for bacterial colonisation. These bacteria can also be found in lesser numbers on other surfaces such as gravel, the inside surfaces of an aquarium, or any submerged surface. Some of these bacteria can even be found floating freely in the water. The trick to setting up an effective biological filter is to establish large colonies of these nitrifying bacteria on the high surface areas available on filter media. The more beneficial bacteria your biological filter has, the more nitrogenous wastes they can process. This increased waste processing capacity means you can maximise the number of fish that you can keep. So if nitrifying bacteria form the engine that drives biological filtration, the filter media function as the wheels and body of biological filtration. If conditions in an aquarium are right, that is ammonia is present, these nitrifying bacteria will naturally establish themselves and thrive. One of the best ways to do this is to introduce a few hardy fish to kick start the process and to closely monitor ammonia and nitrite levels using a standard aquarium test kit. Keep in mind that new fish should always be added in small numbers spread out over a period of time to allow the bacterial numbers to adjust to the extra waste being produced. Other methods don't need fish at all but use other sources of ammonia such as fish food or commercial ammonia and bacterial preparations to kick start the process. It can take some time to establish sufficient beneficial bacterial numbers but it is well worth the wait because you will end up spending less time worrying about your aquarium and more time enjoying your fish. Your aquarium will also be a much healthier living environment! A certain set of processes need to occur for these bacteria to establish themselves and these processes involve the nitrogen cycle.

The nitrogen cycle is made up of a number of different processes and central to this cycle is the process of nitrification. Nitrification is what these nitrifying bacteria do to oxidise or convert the toxic nitrogenous wastes, ammonia (NH_3/NH_4) and nitrite (NO_2) to a much less toxic compound, nitrate (NO_3). You will notice that there are two forms of ammonia, a highly toxic unionised form (NH_3) and a relatively less toxic ionised form (NH_4) also called ammonium, the one you have will depend on the pH of your aquarium water. Once established in an aquarium, the nitrogen cycle works silently as part of your biological filter, to invisibly and very effectively help keep an aquarium healthy, in balance and 'cycled'. The nitrification part of the nitrogen cycle works like this: in a new aquarium, *Nitrosomonas* bacteria usually get established first as a response to increasing ammonia levels. These bacteria are naturally found both inside the gut, and on the surface of the fish, biologically active surfaces in your aquarium and even free floating in the water. *Nitrosomonas* basically do their thing by utilising ammonia and turning it into nitrite. This usually takes place over a period of approximately 10 days in a typical tropical setup however this can take longer in a cold water aquarium. During this stage, ammonia levels will be high as these so called ammonia oxidising bacteria (AOB) increase in numbers. Soon the established AOB start to reduce ammonia levels as they oxidise ammonia and release nitrites. *Nitrospira* or *Nitrobacter* bacteria is next to get established due to the increasing levels of nitrite produced as a by product of *Nitrosomonas* metabolism. *Nitrospira* and *Nitrobacter* do their thing by converting nitrite to nitrate. This conversion usually takes place over a period of approximately 20 days depending again on the conditions in your aquarium. During this stage, nitrite levels will be high as these nitrite oxidising bacteria (NOB) increase in numbers. As the nitrites start to get processed by the NOB, nitrates are released as a by product. In total, nitrifying bacteria will take around 1 to 1.5 months or even longer to fully become established to a point where ammonia and nitrite are being processed completely into nitrate.

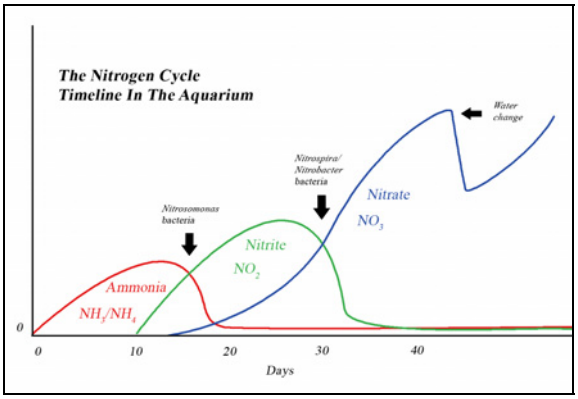

Figure 2. A rise in ammonia levels prompts the colonisation of *Nitrosomonas* bacteria and a rise in nitrite prompts the colonisation of *Nitrospira* or *Nitrobacter* bacteria. These nitrifying bacteria can take approximately 1 to 1.5 months to fully process ammonia and nitrite into nitrate in the aquarium.

The nitrate concentration will continue to rise in your aquarium as the nitrifying bacteria process wastes over time; however the high nitrate levels can be controlled easily through regular water changes, used as food by live plants and also processed further by anaerobic bacteria in other processes associated with the nitrogen cycle. While nitrate is much less toxic than ammonia and nitrite, fish will not tolerate high nitrate levels for sustained periods of time so it is always advisable to carry out regular water changes and to monitor nitrate levels.

It should be noted that while *Nitrosomonas* and *Nitrobacter* bacteria have historically been credited for 'cycling' an aquarium, bacteria from the genus *Nitrospira* are now shown to also play a significant role in the process of nitrification. The exact nature of the interplay between the different strains of nitrifying bacteria is still not completely known and is beyond the scope of this introduction. For you, as an aquarist, all that is needed is a general understanding of why biological filtration and the nitrogen cycle is important and how it works in your aquarium. Consider them as an important set of tools to help keep your aquarium healthy and looking great!