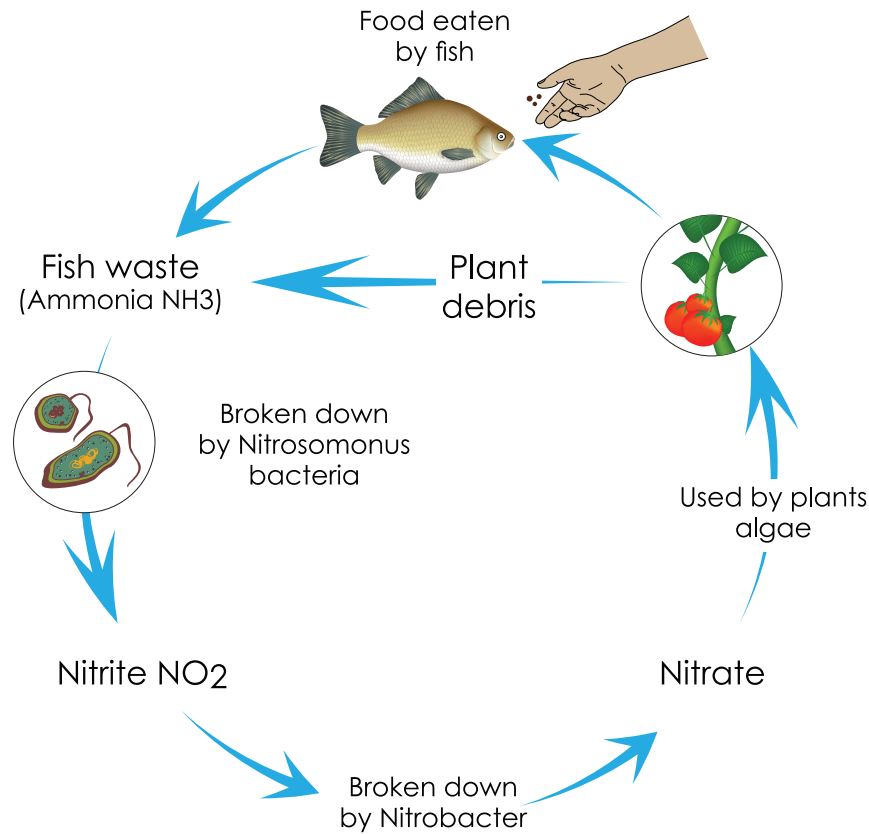


This final diagram is an adapted version of the previous diagrams explaining the nitrogen cycle and how the nitrification process takes place in **aquaponic systems**.



Test	Acceptable Levels
Ammonia (NH ₃ /NH ₄ ⁺)	1 (mg/l)
Nitrite (NO ₂ ⁻)	1 (mg/l)
Nitrate (NO ₃ ⁻)	5-120 mg/l

Fig 2.5 The Nitrogen Cycle seen in Aquaponics Systems

2) Nitrifying Bacteria and the Importance of Filtration

It is hopefully becoming clear that the **nitrifying bacteria** are vital for the overall functioning of an aquaponics unit. Chapter 4 (Unit Design) of this manual will fully describe how the biofiltration components (the parts where the major bacteria colony is hosted) for each aquaponic method work, and Chapter 5 (Growing Bacteria) will go into greater depth about the different bacteria groups that operate in an aquaponics unit. But, for now, we will briefly discuss some basic details about the nitrifying bacteria.

As explained above, it is the nitrifying bacteria that convert the fish waste, which is predominately in ammonia form, into nitrate for the plants. There are two major groups of nitrifying bacteria that are involved in this process: the **nitrosomas group** and **nitrobacter group**. They consume the ammonia in the following order:

The nitrification process:

- 1) **Nitrosomas bacteria** converts ammonia (NH_3) into nitrite (NO_2)
- 2) **Nitrobacter bacteria** then converts nitrite (NO_2) into nitrate (NO_3)

As you can see from the chemical symbols, the Nitrosomas group oxidize (meaning to add oxygen) the ammonia into nitrite (NO_2) and the Nitrobacter group further oxidize the nitrite (NO_2) into nitrate (NO_3).

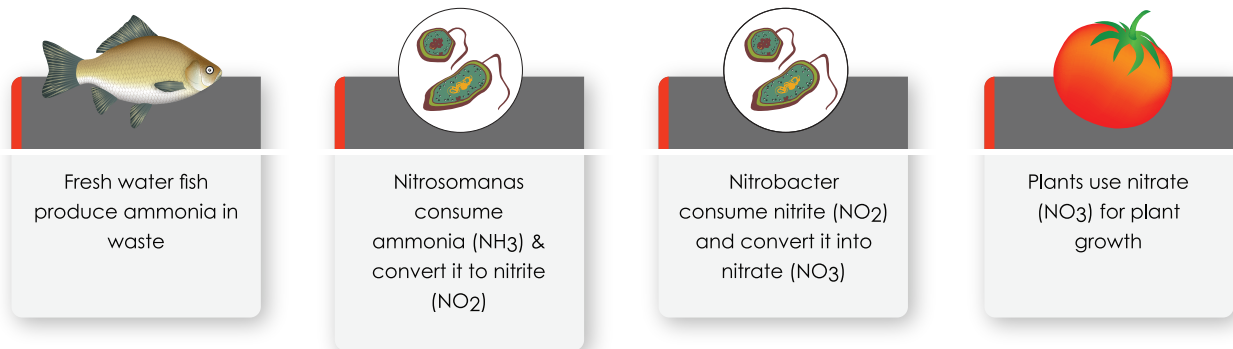


Fig 2.6 The Nitrification Process

In summary then, the eco-system within the aquaponics unit is totally reliant on the bacteria. If the bacteria are not present or if they are not functioning properly in the system, ammonia concentrations will rise in the water and kill the fish, as well as poison the plant roots within a definite period of time. It is vital to keep and manage a healthy bacteria colony in the system at all times in order that ammonia levels will stay close to Zero milligrams per litre (mg/L).

3) Maintaining a Healthy Bacteria Colony

Below are the major parameters that impact bacteria growth that we must keep in mind while maintaining a healthy bacteria colony:

a. Surface Area: Bacteria colonies will thrive on material with a high surface area such as inert grow media (gravel, volcanic tuff, expanded clay, bio balls etc) and they will also grow on plant roots, along fish tank walls and inside each grow pipe. Therefore all aquaponic units have some sort of bio-filtration component where material with a high surface area is contained (either bio-filter media or the actual plant roots). Chapter 4 explains the various types of bio-filter media, but for now it is sufficient to say that all aquaponic units are essentially made up of three physical components: fish tanks to house the fish, hydroponic containers to grow the vegetables and filtration (solids removal and biofiltration) to capture solid waste and house the nitrifying bacteria.



Fig 2.7 Media Bed Filled With Volcanic Tuff

Some units designed for a very low stocking density of fish rely solely on the plant root space to house the nitrifying bacteria required. This method will be discussed in more detail in chapter 4, yet the majority of this manual will focus on small-scale aquaponic units with medium-large stocking densities that require additional solid removal and biofilter containers.

b) Water pH: We will discuss this water quality parameter in more detail in the next chapter, but for now we'll simply say that pH is the amount of hydrogen ions in the water. The pH level of the water has a impact on the productivity (ability to convert ammonia) of the bacteria. The ranges for the two nitrifying groups below have been identified as ideal yet the literature on bacteria growth also suggests a much larger tolerance range (6-8.5) due to bacteria's ability to adapt to actual operating conditions.

Nitrosomanas SP: pH of 7.2-7.8

Nitrobacter SP: pH of 7.2-8.2

Thus, for aquaponics a more appropriate tolerance range to work with is **6-7**. Also, seeing as there is so much surface area on the biofiltration media and plant roots, even if bacteria were less productive it would have a minimal impact on the biofiltration requirements. This 6-7 range is also used to satisfy the optimal ranges for vegetables (see chapter 3 for more details on comprising water quality parameters)

C) Water Temperature: This is another very important parameter for the bacteria and for aquaponics in general. The ideal temperatures for bacteria growth and productivity are between 17-34 ° Celsius. Once the water temperature drops below this range (below 17°C) bacteria productivity begins to decrease. Below 10°C, productivity can be as low as 50% or lower. This will obviously have major impacts on unit management during the winter seasons which will be discussed in Chapter 8.



Fig 2.8 P.h & Temperature Digital Deter

D) Dissolved Oxygen: Nitrifying bacteria need good levels of Dissolved Oxygen (DO) in the water at all times in order to grow healthily and maintain high levels of productivity. Optimum levels of DO are between 4-8 milligrams per liter (mg/L). Nitrification will struggle if DO concentrations drop below 2.0 mg/l.



Fig 2.9 Aerated Bio Filter Containing Bio Balls

E) UV Light: Finally, it is important to note that nitrifying bacteria are photo-sensitive organisms, meaning that UV light from the sun is a threat. This is particularly the case during the initial formation of the bacteria colonies when a new system is set up (See Chapter 5 for how to start and aquaponics system). After the bacteria have colonized a surface (3-5 days), UV light poses no major problem. A simple way to remove this threat is to cover the fish tank and filtration components with UV protective material while making sure no water in the hydroponic component is exposed to the sun, until the bacteria colonies are fully formed.

Summary Table:

Nitrifying bacteria will grow on material with a high surface area that is protected using UV protective material under the following conditions:

	Temp (°C)	Ph	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	DO (mg/L)
Nitrifying bacteria	14-34	6-8.5	<3	<3	<400	4-8

4) Balancing the Aquaponics Eco-system Over Seasons

The final thing we need to discuss in this chapter are the concepts behind 'balancing' an aquaponics unit. This term 'balancing' is used to describe all the measures an aquaponic farmer takes to make sure that the eco-system of fish, plants and bacteria is at a stable equilibrium.

It is essential for the reader to know from the start, before we discuss any of the other topics in this manual, that aquaponics is primarily about **maintaining a balanced eco-system**. Simply speaking, this means that there is a balance between the weight of fish, the amount of plants growing in the unit and the size of the bio-filter used to convert the fish waste (meaning the amount of bacteria). There are fixed bio-filtration ratios & optimal plant & fish stocking densities for aquaponics (which will all be discussed in Chapter 8) that have been tried and tested exhaustively - it is very difficult to try and produce more than these optimal ratios without having disastrous consequences for the overall eco-system. This sub-section is a brief, but essential, introduction to balancing a system – please note that the bio-filtration and stocking density ratios will be covered in much greater depth later in chapter 8.

Fig 2.10 Not Balanced Unit

Consider the Following Examples:

Example 1: An aquaponic farmer decides to produce double the amount of fish in their unit **without** expanding the biofilter component of the unit to cater for the for extra fish waste. As the fish begin to grow, the waste produced from double the amount of fish is far too much for the bacteria growing in the bio-filter and on plant roots to convert into nitrate, so ammonia levels begin to rise. This leads to fish death as high levels of ammonia are highly toxic to a lot of species of fish. The high ammonia levels will also significantly reduce the bacteria's ability to convert ammonia and will eventually damage the plant roots (at very high concentrations, above 30-40mg/l) leading to poor plant growth, diseases and eventual death. **This, all because the eco-system was not properly balanced.**

