

Biofilter Start-Up

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What problem is being solved?

Before stocking the fish in any recirculating system, such as recirculating aquaculture system or aquaponics, the biofilter should be up and running, otherwise there is high risk of fish being poisoned by ammonia or nitrite accumulation. One should calculate 6 – 8 weeks of time from the start of the biofilter to be ready. Meaning that the population of nitrifying bacteria has established itself on the surfaces in the recirculating system, **Figure 1**.

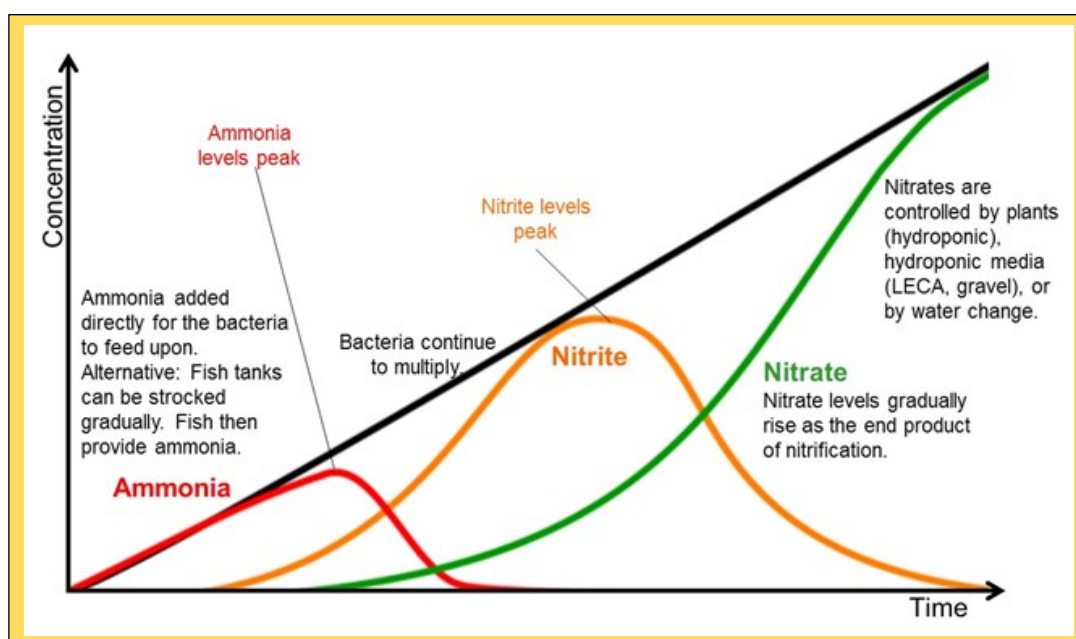


Figure 1: Development of the ammonia, nitrite, and nitrate levels during the biofilter start-up.

Procedure

You also need to consult Table 1.

1. Stop the water supply to the biofilter.
2. Set the water temperature to $\approx 25^{\circ}\text{C}$, bacteria like it warm!
3. Switch on aeration. As much as necessary, as little as possible. Keep turbulence as low as possible, position the diffusor head on the bottom of the tank.
4. The alkalinity of water should be approx. 150 mg/L . It should be maintained by adding sodium bicarbonate (NaHCO_3).

5. Add bacterial culture (if using). The temperature of the culture must be adjusted to the water temperature.

Instead of purchasing bacterial culture, one can use one of the following as a starter:

- sludge or media from another biofilter
 - In the nearby river or lake, scrape the slime from several large stones and mix it gently with water before pouring it over the biofilter. But **CAUTION:** Make sure the water is not contaminated, especially if you do not know what is happening upriver or if any parasites in the water could harm your fish or the system.
6. Feed bacteria in the biofilter by either adding ammonium nitrate (NH_4NO_3), any other fertilizer containing NH_4 or enough fish feed to reach the concentration of 10 mg/L NH_4 .

Calculation:

7. A) **When using ammonium nitrate (NH_4NO_3)**, to achieve a concentration of 10 mg/L NH_4 in a biofilter tank of volume of 200 L that has a starting concentration of 0 mg/L NH_4 you calculate the **required quantity of NH_4NO_3** as follows:

I. First, you must understand the relationship between NH_4 and NH_4NO_3 :

- NH_4NO_3 dissociates in water to give NH_4^+ and NO_3^-
- When NH_4NO_3 dissociates, 1 *mole* of NH_4NO_3 produces 1 *mole* of NH_4^+

II. Calculate the molar mass of NH_4NO_3 and NH_4 , where the molar mass can be calculated as follows:

- Molar masses required for the calculation:
 - H: 1.00784 g/mol
 - N: 14.0067 g/mol
- The molar mass of NH_4 is approximately 18 g/mol . As the molar mass of N is 14.0067 g/mol and H is 1.00784 g/mol , so $14.006 + 4 * 1.0078 = 18.04 \text{ g/mol}$.
- The molar mass of NH_4NO_3 is 80.043 g/mol

III. Calculate the total amount of NH_4 needed:

- The desired concentration of NH_4 is given as 10 mg/L
- The volume of the biofilter tank is 200 L .
- Therefore, the total amount of NH_4 needed in the tank is:

$$\text{Total NH}_4 = 10 \text{ mg/L} \times 200 \text{ L} = 2'000 \text{ mg}$$

- IV. To achieve $2'000 \text{ mg}$ in a biofilter tank that has a starting concentration of 0 mg/L NH_4 you calculate the **required quantity of NH_4NO_3** as follows:

$$NH_4NO_3 [g] = \frac{80.043 \frac{g}{mol} \times 2'000 mg}{18.04 \frac{g}{mol}} = 8'870 mg = \mathbf{8.87 g}$$

B) **When using fish feed**, the required quantity is calculated based on N content of the fish feed. Assuming 40 g NH₄ per kg feed, this depends on the protein content, the calculation for a biofilter tank of volume of 200 L and starting concentration of 0 mg/L NH₄ you calculate the **required fish feed** is as follows:

I. Calculate the total NH₄ needed, same as above:

- Desired NH₄ concentration = 10 mg/L
- Total NH₄ required for 200 L tank:

$$Total NH_4 = 10 mg/L \times 200 L = 2'000 mg$$

II. Calculate the fish feed required:

- Given 1 kg of fish feed produces 40 g that equals to 40'000 mg of NH₄,
- Fish feed required:

$$Fish\ feed\ [g]\ required = \frac{2'000 mg}{40'000 \frac{mg}{kg}} = 0.05 kg = \mathbf{50 g}$$

So, to achieve an NH₄ concentration of 10 mg/L in a 200 L biofilter tank, you would need 50 grams of fish feed. Additionally, to the source of NH₄, you also must add a carbon source.

- To add carbon, add 37 g molasses per m³ if using ammonium nitrate. This addition is not necessary if using fish feed because fish feed contains carbon, too.
- Determine the water values daily or at least every two days:
 - NH₄
 - NO₂
 - NO₃
 - Alkalinity (it should be > 125 mg/L)
 - pH (> 7)
 - Temperature
- If NH₄ falls below 3 mg/L, ammonium nitrate is added again up to 10 mg/L.
- If NH₄ falls again below 3 mg/L, NH₄ feeding is adjusted to the subsequent feed quantity. 40 g NH₄ per kg feed can be assumed.
- If NO₂ rises above 20 mg/L it must be diluted as it inhibits nitrification.
- The NH₄ concentration must be reduced to < 1 mg/L before stocking the fish into the system. If NO₂ is too high, this can be compensated with the addition of salt (NaCl) up to a concentration of 0.5 – 1 mg/L.
- Restart the water supply.

15. Fish can be stocked if all water quality parameters meet the requirements. The initial stocking of fish should be as low as possible.

Note: If you have plants in the system and cannot stop the water supply to the rest of the system for this or any other reason, you must calculate the required quantities based on the entire water volume, not just the volume of the biofilter.

		Start	after ca. 2 Weeks	after ca. 4 Weeks	after ca. 6 Weeks	before stocking fish
		Times are approximate (depending on various factors, e.g. temperature)				
pH	Target value	>7	>7	>7	>7	7 bis 7.5
	Nitrification	Depending on the water source, generally higher pH improves nitrification	pH should decrease slowly due to starting nitrification → Correct if necessary	pH should decrease further due to nitrification → Correct if necessary	pH should decrease further due to nitrification → Correct if necessary	pH should be held between 7.0 - 7.5.
	Monitoring	Check approx. every 3 days (better continuously)				
Ammonium NH ₄	Action	If too low, correct with a base, i.e. NaHCO ₃ (sodium hydrogen carbonate)				
	Target value	10 - 20 mg/L	10 - 20 mg/L	10 - 20 mg/L	10 - 20 mg/L	<1 mg/L
	Nitrification	Add ammonium with ammonium nitrate (NH ₄ NO ₃) so that the target value is reached.	Ammonium should decrease slowly due to starting nitrification → Keep in the range of 10 - 20 mg/L	Ammonium should continue to decrease due to nitrification → Keep high until the desired daily removal rate is reached	Ammonium should continue to decrease due to nitrification → Add only the required daily amount, which you calculate.	Do not starve the biofilter, but make sure that the value is <1 mg/L before stocking the fish.
Nitrite NO ₂	Monitoring	Check approx. every 3 days				
	Action	If necessary, increase NH ₄ fertilizer, calculate required quantity.				
	Target value	0 mg/L	Increasing	10 - 20 mg/L	10 - 20 mg/L	< 0.4 mg/L
Nitrate NO ₃	Nitrification	Nitrite should be zero at startup. For faster startup, nitrite can also be added at the beginning.	Nitrite should rise slowly.	Nitrite should slowly achieve its peak and also be degraded.	Nitrite should decrease by nitrification → Biofilter is ready when NO ₂ <0.4 mg/L with daily NH ₄ supply, calculated daily added amount.	Nitrite should be < 0.4 mg/L
	Monitoring	-	-	-	-	-
	Action	From week 2 measure approx. every 3 days				
Nitrate NO ₃	Target value	< 600 mg/L	< 600 mg/L	< 600 mg/L	< 600 mg/L	< 600 mg/L
	Nitrification	Nitrate concentration depends on water origin. Very low in drinking water. Increased values depend on fertilizer addition, e.g. with ammonium nitrate same quantity as ammonium.	Nitrate remains stable, only what is added by fertilizer is added → Too high nitrate values inhibit nitrification.	Nitrate should increase gradually also through nitrification → Too high nitrate values inhibit nitrification.	Nitrate should increase gradually through nitrification → Too high nitrate values inhibit nitrification.	Nitrate should increase gradually through nitrification → Too high nitrate values inhibit nitrification.
	Monitoring	-	-	-	-	-
Temperature	Action	From week 4 measure approx. every 3 days				
	Target value	If the values are too high → Flush out nitrate with fresh water				
	Nitrification	≈ 25 °C	≈ 25 °C	≈ 25 °C	≈ 25 °C	≈ 25 °C
Temperature	Nitrification	Temperature influences nitrification. Ideally, temperature should be in the range of the subsequent operating range.	Temperature influences nitrification. Ideally, temperature should be in the range of the subsequent operating range.	Temperature influences nitrification. Ideally, temperature should be in the range of the subsequent operating range.	Temperature influences nitrification. Ideally, temperature should be in the range of the subsequent operating range.	Temperature influences nitrification. Ideally, temperature should be in the range of the subsequent operating range.
	Monitoring	Check approx. every 3 days (better continuously)				
	Action	Heat or cool as required				

Table 1: Description of the timeline of development of water quality in the biofilter.