Basics of Biofiltration

Ammonia is the main byproduct of protein metabolism excreted by most aquatic animals, and, unless it is removed efficiently and continuously, it will make life in an aquarium unbearable. Heterotrophic bacteria convert other nitrogenous waste to ammonia. Biofiltration is an effective approach to the removal of ammonia, nitrite, and nitrate from the marine or freshwater aquarium by percolating the water through a filter or reactor containing appropriate bacteria on a carrier or support.

Three genera of bacteria, omnipresent in the environment, can usually establish themselves in the aquarium and metabolize the inorganic nitrogen compounds that would otherwise accumulate there: Nitrosomonas, Nitrobacter, and Thiobacillus. Nitrosomonas convert aquarium ammonia to nitrite, which Nitrobacter convert to nitrate, which Thiobacillus and other denitrifying genera anaerobically convert to nitrogen gas.

Nitrosomonas are short gram-negative rods of about 0.8 by 1.5 . They are obligate chemolithotrophs, strictly aerobic, that convert ammonia (as the ammonium ion) to nitrite. Nitrobacter are also short gram-negative rods, about 0.7 by 1.5 , strictly aerobic, obligate chemolithotrophs, that convert nitrite to nitrate. Both can function between pH 6.5 to 8.5, although the optimum is about pH 7.5 to 8.0. Thiobacillus are short gram-negative rods, about 0.5 by 2 , strictly autotrophic and facultatively anaerobic. They require reduced sulfur compounds as an energy source, converting them to sulfate, using nitrate as an electron acceptor to form nitrogen gas. Carbon dioxide is their only source of carbon. In the presence of oxygen, they utilize ammonia. They can function anywhere between pH 2 to 10, but the optimum is between pH 6.6 to 7.2. There are several genera of anaerobic bacteria that utilize organic compounds (methanol, sugar, other non-nitrogenous organics) and nitrate, converting the nitrate to nitrogen.

While these bacteria can exist as free swimming agents, they do much better on a support matrix. To promote proliferation, it is important to maximize the available surface area. Both Nitrobacter and Nitrosomonas require oxygen. For that reason, aeration and circulation are essential, and wet-dry systems are usually more efficient. The pH optimum is not consistent with the pH of most marine or freshwater tanks, but this is not of serious consequence. Both genera are intolerant of free ammonia and this can be the main cause of difficulties in getting a tank to cycle. Animals or ammonia should be introduced gradually to avoid sudden sharp increases in ammonia concentration. Even a well established tank can have its biological filter severely damaged by excessive ammonia. Concentrations in excess of 25 mg/L will have adverse consequences on the filter bed. Effective use of Thiobacillus and organic utilizing genera requires anaerobic conditions (no oxygen). This can be achieved simply with a special substrate like denitrate™ or with the more complex use of a special air-tight filter chamber. Since the aquarium water is generally rich in oxygen, water flow through anaerobic filters must be sufficiently slow to allow efficient oxygen depletion. Thiobacillus must also have a continuous supply of reduced sulfur compounds such as thiosulfate, bisulfite, Prime®, or Safe™. Organic utilizing genera require an organic source. Methanol is used in some system, but this can be quite hazardous. Most aquariums have more than adequate organic matter available to feed these bacteria. Certain organic supplements, such as Reef Plus™ and polygluconate based Reef Calcium™, will enhance the activity of these bacteria. If a sealed filter chamber is used, it should have a means of venting any accumulated nitrogen gas.

An alternative method of removing nitrates is the promotion of vigorous algae growth, either by harvesting algae in the aquarium itself or in a separate algae filter. This usually requires vitamin and trace element supplements as well as intense lighting.

Several products are available on the market for biofilter support. Most were not specifically designed for that purpose, but are adapted from other applications to provide surface area. The feature they all have in common is that they only provide external surface area, which is relatively inefficient, and requires considerable space. Seachem offers some innovative solutions: denitrate™ and Matrix™ are supports for bacterial proliferation that provide predominantly internal surface area. denitrate™ is supplied as particles ideally sized for canister filters, and Matrix™, as well as Pond Matrix™, is sized for canister or trickle filters. They allow for the concentration of an intense bacterial population in a relatively small space. The ratio of surface to physical space as compared to other biosupports is better than 50 to 1. Each 500 mL of denitrate™ or Matrix provides a minimum of 2 square meters of internal biologically available surface. This is equivalent to the surface provided by the gravel bed of a 10 gallon tank or by 5 liters of Dupla Bioballs®.

Both denitrate™ and Matrix™ are full of macropores that are ideally dimensioned for the proliferation of nitrifying bacteria. The pore structure of both de*nitrate™ and Matrix™ permits both aerobic and anaerobic proliferation. The pores are in the 3–30 range, ideal for bacterial entry and proliferation, but too small to permit the entry of most debris and detritus. Thus, the pores remain open and the interior remains clean. Dead bacterial fragments wash out easily.