ON THE SURFACE

When it comes to biofiltration, the effective surface area is what counts.

By Timothy A. Hovanec

For many hobbyists, the biological filter with the largest amount of surface area is obviously the best. In reality, a fair comparison of biological filters should be based on their effective surface area.

Effective surface area is that which is actually available for colonization by nitrifying bacteria. As we shall see, the effective surface area can be much smaller than the actual surface area of the filter. And indeed, having more surface area does not automatically mean you will have more nitrifying bacteria.

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Aquarists tend to assume that nitrifying bacteria increase in direct proportion to the amount of ammonia produced in the aquarium. However, it is not known for certain whether continuing to add ammonia means the population of nitrifying bacteria also continually increases, or if the numbers level off and those bacteria simply work more efficiently.

"More efficient" is defined as the same number of bacteria oxidizing more ammonia in the same amount of time. Thus, a very important piece of data that is critically important to our discussion is missing, demonstrating that there is still much to be learned about the ecology of nitrifying bacteria. However, what is known is that the nitrifying bacteria (or their efficiency) will not continue to increase unless there is a concurrent increase in ammonia production - the source of their energy.

When comparing the surface area of biological filters, it is important to consider factors which can limit the effectiveness of a biological filter and possibly reduce the value of larger surface areas. Oxygen, for example, is of prime importance.

The rate at which a colony of nitrifying bacteria can oxidize ammonia is determined by the amount of oxygen that is available. Therefore, when there is less oxygen, more surface area is needed to support the larger numbers of bacteria required to do the same work as smaller biofilters in which the bacteria have more oxygen available to them. This is the case, for instance, when comparing undergravel filters to wet/dry filters.

Undergravel filters have been the standard biological filter for many years. They have a great amount of surface area, but are inefficient compared to, say, wet/dry filters, which perform the same work with less surface area because their media is exposed to the atmosphere. Air has a much greater amount of oxygen than that available in aquarium water. In this way, fewer (or more efficient) bacteria and less surface area is needed to accomplish the same amount of work.

Two other factors limiting the effective surface area of biofilters are clogging and competition among types of bacteria.

Only the upper inch or so of gravel on an undergravel filter contains nitrifying bacteria. This is due, in part, to the reduction in oxygen as the water passes through the gravel. Thus, when calculating the effective surface of an undergravel filter, only the top portion of the gravel layer really counts.

The same is true for the biological filtration media in canister filters. When clean, the media receives a lot of oxygen via the aquarium water, but as the canister clogs and the flow rate is reduced, less oxygen passes by the nitrifying bacteria. And as more organics are trapped in the canister, they also consume oxygen. This double negative significantly reduces the effective surface area of the biofilter media.

Two other factors limiting the effective surface area of biofilters are clogging and competition among types of bacteria. If the biofilter doubles as a mechanical filter it will clog even faster.

As the media becomes increasingly clogged, less and less area is available for the nitrifying bacteria because much of the media is no longer exposed to the aquarium water. These areas of the media become dead spots. Of course, when the media is cleaned, such as during a siphon-cleaning of an undergravel filter, the nitrifying bacteria can re-colonize it. But this leads to cyclic nitrifying populations - they first increase when the area is clean, but then decrease as the area clogs. This can manifest into periods of high ammonia concentrations in the aquarium, which is why it is important to keep the biological filter area clear of organic matter. Media that is prone to clogging has a less effective biological filtration surface area.

Another reason for reducing organic material is competition from heterotrophic bacteria for the space occupied by the nitrifying bacteria. Heterotrophic bacteria are responsible for the breakdown (mineralization) of organic material into simpler compounds and elements. These bacteria grow on and around particles of debris such as solid fish waste, uneaten fish foods, dead plant material and so on. If this material is present on the biofilter media, the heterotrophs will grow on it.

Problems arise because the heterotrophs grow much faster than nitrifying bacteria - they can actually grow over and smother the nitrifier colonies. In a 24-hour period, a single nitrifying bacterium will double, forming two bacteria. In that same period, a single heterotrophic bacterium can reproduce to a population of 2,361,183,241,434,820,000,000 bacteria - that's over 2 sextrillion! Further, the heterotrophs are aerobic like the nitrifiers. Thus, they are consuming oxygen that otherwise would be available to the nitrifiers. Lastly, the principal endproduct is ammonia.

It is obvious that everything should be done to discourage the growth of heterotrophic bacteria, especially on the biofilter media. This can be accomplished by removing the organic material they require. At the same time, if the biological filter media is also the mechanical filtration media, the nitrifying bacteria are going to be reduced when the filter is cleaned or eliminated when it is thrown away (this is the reason the mechanical filter should be completely separate from the biological filter). For our discussion on effective biofiltration area, this means that a biofilter which is constantly clogging and needing cleaning is not a stable environment for the nitrifiers and its useful area is not as large as it seems.

An obvious, yet often ignored consideration in determining effective biological filtration surface area is that the media must be wet. Some types of wet/dry filters suffer from the tendency of the water to wick down the sides of the sump, bypassing the filtration media. Poorly designed drip trays and rotating spray bars also reduce the amount of media in contact with the water. The media is there, but it is not getting wet and, therefore, no nitrifying bacteria can grow on it.

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The determination of effective biological filtration area must also consider aquarium water chemistry. For instance, the assimilation and reproduction rate of the bacteria is directly tied to the water temperature.

The colder the water, the slower the bacteria work. Under such conditions, more surface area may not automatically mean less ammonia, because the bacteria can only grow so fast. In the event of low temperatures, it will take months for the nitrifying bacteria to reach a population level that can remove significant amounts of ammonia.

Another factor limiting the efficiency of the nitrifying bacteria is pH. At low pH values the rate at which the bacteria oxidize ammonia is much reduced. This may be due to the fact that the ammonia is in the ionized form (ammonium) and the bacteria utilize the un-ionized form (ammonia) and the balance of the two shifts as the pH falls. Or, it could be that the acidic environment is physiologically unhealthy for the bacteria. In either case, the ammonia concentration increases but unless water conditions change, surface area is not as much a concern.

How do temperature and pH relate to a calculation of effective surface area? If the biological filter media is under water, the bacteria must cope with the ambient water temperature and pH. But if the media is not completely submerged (i.e., in the atmosphere, such as a wet/dry rotating or trickle filter), the localized conditions on the media are different because the room air will effect the water temperature and pH. Therefore, the media will be more conducive to the nitrifying bacteria and they can work more efficiently. Once again, the effective surface area is much different than the actual media surface area.

What should be clear from this discussion is that not all biological filters are equal and they cannot be evaluated by looking only at total surface area. To fairly compare different types of biological filters, one must consider both their biological filtration efficiency and their surface area. Furthermore, some biofilters will require more maintenance than others.

Undergravel filters, for example, can work but they must be serviced more often than other biological filters in order to support the same fish load. When considering your next biological filter, think about the points addressed here and choose a filter that matches the time you are willing to devote to maintenance and service.

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