Biological Filters- Facts and Problems Part 1 –by Rene Jez from Tank Talk Volume 14 No. 4 1990

BIOLOGICAL FILTERS - FACTS AND PROBLEMS

By Rene Jez

Aquarium filters and filtration offer never ending discussion. Over the past two decades knowledge of the process widened to include biological treatment theory and steps to implement it. Advancement of theoretical research in the field of municipal waste water treatment has been forced upon Water and Sewerage Authorities by current stringent anti-polution laws. This in turn opens a flow of information to less important users. The fisheries, aquarium hobbyists and others profit from the spin-off from advanced research. Formerly empirical theories and formulae have been replaced by very accurate mathematical models.

Working for the Water and Sewerage Authority of the A.C.T., I have access to the technical library, which details recent research and achievement in microbiology, water treatment and associated fields. This allows me to apply conclusions and analogies to aquarium hobby problems. For an understanding one should be familiar with basic principles of the different aquarium filters (see **Tank Talk**, vol. 9, no. 2) and their function.

The task of this article is to present the laws of water treatment and some complexities of the process in a simplified way.

To start with, let us consider a freshly established tank with aged water and a moderate number of fish. With sparse feeding of the fish, the water remains in good condition, very close to drinking water (except for some bacteria causing problems to human health).

In time, and with continuing accumulation of fish wastes, the quality of the water starts to deteriorate, particularly with reference to nitrogen compounds. The steady increase of nitrates, biproducts of the nitrification cycle, leads to over-fertilisation of the tank water. A certain level of nitrate is tolerated by the fish and plants, but excessive quantities cause problems. Some hardy fish can withstand nitrates up to 5000 ppm but tropical fish from clean waters can hardly cope with a fraction of this amount.

World drinking-water standards specify limits of nitrate content from 40 to 100 ppm but for feeding infants, only about 25 ppm are permissible. However, some industrial countries are still using sources of water with 200 ppm or more.

A comparison of aquarium water with the condition of raw sewage is invalid because tank water is relatively clean. However, in its late stages, old aquarium water probably approaches in composition the final effluent from proper sewage treatment for release in inland waters, though not of course tha of untreated effluent that is often released directly into the se by some maritime Authorities. The cleaning and siphoning o tank gravel tells a different story, for the quantity of dirt i staggering. This concentrate is close to the condition of raw sewage. The dangers to the biological stability and environmental balance in long established aquaria are very high when the oxygen supply is starved. Any tank has its minimum biological oxygen demand (BOD).

What is BOD? It is the minimum quantity of oxygen in the water to satisfy oxygen consumers at any time and it is expressed in ppm or mg/litre of oxygen in solution. The microscopic bacteria and other organisms, as well as the fish, are the consumers of oxygen, which is essential for all life functions. The nitrification cycle, converting wastes into less harmful substrates, is driven by the tiny bacteria in their millions. Life for them is impossible without oxygen.

The dissolved oxygen (DO) in water covers these needs. The quantity of DO varies with conditions (temperature, atmospheric pressure, depth, water movement (aeration, etc.), with the phases of the daily life cycle, with species of fish and many other factors. Since the BOD must be met at all times, to avoid a total kill of life, we must provide DO high enough to cover all variations of BOD.

Very significant among the aquarium oxygen consumers are the nitrifying bacteria, which convert wastes to ammonia, nitrite and ultimately, to nitrate. Unfortunately these useful bacteria form those ugly brownish, slimy films, coating glass, plants and other available surfaces, but we have to tolerate them.

The main nitrifying bacteria are *Nitrosomonas*, utilising ammonia and changing it into nitrite. The *Nitrobacter* then oxidise nitrite to nitrate. The overall process is one of oxidation, producing energy and providing cell-building components to the bacteria. With more fish and heavier feeding, more waste is generated and the bacteria multiply. The coating thickens until even up to 1 mm thickness may result. Often the layer peels off when lower bacteria lose adhesion or sheer force of water shears off the base. Then the spot is colonised by new bacteria.

Such development indicates a high presence of nutrients in the water; it is called eutrophication or over-fertilisation and the only way to rectify the condition is by means of a series of massive water changes. One change only will not be effective as this will lead to starvation and consequent die-off of the bacteria, with production of further nutrients from their decomposition.

When thick layers of nitrifying bacteria develop nature starts to deal with the over-fertilisation itself, through a process of anaerobic denitrification, in the oxygen-starved inner parts. This process is the reversion of nitrate and nitrite molecules into free gaseous nitrogen, the liberated oxygen being consumed by combination with free hydrogen atoms to form water. While this is easy to state, it is usually difficult to achieve because the limits of the process are very narrow and the controls involved are critical.

Somtimes the aquarist can observe bubbles emerging from the bottom sand. These bubbles are either nitrogen, methane or hydrogen sulphide gasses and all are produced by the anaerobic process (lack of oxygen in the deeper layers of sand). Nitrogen is the desirable product but the other gasses indicate a rotting of organic matter within the sand.

New research discovered that *Nitrosomonas* and *Nitrobacter* can reverse their life habits and can function either in oxygen-rich or anaerobic environments. This is contrary to earlier thinking, where certain anaerobic bacteria were held to be responsible for the denitrification process.

How do we manage denitrification? The bacteria must live in an environment with low or preferably no oxygen. This forces them to steal it from available sources. Nitrate (NO_3) first offers reduction to nitrite (NO_2) and when nitrite loses oxygen, free nitrogen escapes. The molecular oxygen is utilised by the bacteria to build complicated cell structure and to cover energy needs. Other elements are required, particularly carbon.

In large scale municipal sewerage treatment plants, the denitrification stage is essential to stop well known brown algal blooms in the effluent-receiving rivers and dams, in Canberra's case, Lake Burley Griffin and the Murrumbidgee River.

Basically, denitrification involves a large airtight tank with processed effluents. The volume above the effluent is filled with methane gas or other carbon-rich media, without oxygen. The above-described reactions then occur. This can be done on a smaller scale but some difficulties must be expected. Firstly, however, let us explain a popular misconception of filters.

The name 'biological filter' is just a gimmick: all filters are always biological because bacteria will colonise any integrated gadget, filled with water. The effectiveness is determined by the area of filter, the larger the better. The latest 'trick' is the trickle-filter. The area of the filter media is extremely large. Water trickling through the infill is supersaturated with oxygen, so what we get is nitrification only. The filter filing is kept moist, constantly supplied with nutrient-rich water and aerated - absolutely ideal conditions for growth of nitrifying bacteria.

Water emerging from such filters, working under ideal conditions (sufficient size, optimum air-water mixture and adequate nutrients) is ammonia- and nitrite-free, but nitrates are constantly rising. Such filters do not reduce the need for water changes at all. To achieve reduction or total removal of nitrate without repeated water changes, a denitification filter is required and this will be considered in Part 2 of this series.

* *