**Hamburg Mattenfilter**

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Over the last few years, the use of the Hamburg Mattenfilter has spread widely in German speaking countries. Not in the least because of Olaf's site at [http://www.deters-ing.de/](http://www.deters-ing.de). In this article I will explain the working of this filter technique, directions for construction will be given, and I will show calculations which can be used.

**Use of aquarium filtration**

First and foremost, filters are used for cleaning dirty water and to ensure proper parameters for our aquaria. The type of pollution and the amount of it will determine which filtration system is used. Because of limited space available in a typical aquarium setting, only a few types of filtration may actually be considered. All aquarium filters can be split into two groups:

1. Strict mechanical filtration

2. Biological filtration

Just to be correct, it should be noted that the actual filters we use are usually a mix of both groups. A mechanical filter will be home to biological filtration and a biological filter will clear the water because of the removing of particles.
These groups can be divided into two more subcategories:

1. Internal filtration

2. External filtration

Over the past years, the aquarium world has accepted the conclusion that biological filtration is in fact superior to mechanical filtration. However, it must be noted that most of the filters currently in use are in fact more mechanical than biological units.

**What's the difference?**

A mechanical filter, with its powerful pump and dense filter medium, will remove particles from the water. These particles remain in the filter and this should be cleaned regularly to prevent clogging the medium. There is little or no biological filtration of the water because essential criteria for this are not met (more about this later). Especially the older models of the known canister filters belong to this category. I would therefore prefer to speak of mechanical filtration only, if frequent cleaning of the filter medium is necessary.
These filters contribute little to the establishment and stabilization of the biological environment in the tank, which is a disadvantage and I see it as a source of many problems in the aquarium.

A biological filter, on the other hand, is characterized by its relatively low throughput. It is true that these filters also remove particles from the water, but only those that are free floating in the water column which because of their low specific weight, can be caught and transported by the low suction of the filter. The effectiveness is based on bacterial activity in the mulm. But biological filters also perform the task of mechanical filter; they should be able to remove suspended particles from the water. Because of this limited suction of the biofilter, it is inevitable that part of the reduction should take place in the aquarium itself. These substances should be predigested, so to speak. Not that the biofilter is not capable of performing this task, it is just that these larger organic waste products (food leftovers, leaves) never get to the filter in the first place because of the low current involved.

**Nitrogen cycle**

A bit if theory is unavoidable, but I would like to keep it short. Biological filtration is based on bacterial activity. These bacteria change waste products into other substances during several processes. There is a type of bacterium for every step of the way. The required bacterial colonies will grow unaided and will - slowly - adapt to changing bioload in the aquarium environment. Which species actually grow differs from one tank to another. This chain of individual processes together is called the nitrogen cycle. Nitrates are produced at the end of the nitrogen cycle. There is insignificant further processing of nitrates in the aerobic (containing oxygen) biofilter and this nitrate should be removed by means of water changes.

Nitrogen oxidation is a so-called aerobic process, which means that these bacteria depend on the presence of oxygen. Primarily, the source materials for these bacteria are organic nitrogen compounds, urine and phosphate and ammonium. These originate, for example from fish food, plant material, dead snails and fish, fish waste and so on. In short, all biological waste products in the tank produce nitrogen compounds.

During this chemical change by several bacteria, ammonia (NH3) and/or ammonium (NH4) is released. This is oxidized into the dangerous nitrite (NO2) and after another step this produces the relatively harmless nitrate (NO3). Between these individual steps there are other substances in between. Another product is CO2. Under anaerobic conditions, further reduction of nitrates is possible, resulting in nitrogen gas. The circumstances required for this process are generally highly undesirable in an aquarium and seldom occur.

So for the time being nitrate is the end product of the nitrogen cycle. This is measured in mg/l. Values between 10 and 50 mg/l are common in our tanks. These are values that usually aren't catastrophic but could be too much for certain species of plants and fish. (German law accepts a maximum value of 50 mg/l. Values higher than this could lead to damage with sensitive small children under certain circumstances, USA jurisdictions tend to accept 40 mg/l). It should be our goal to keep nitrate under 20 mg/l. This should ensure that nitrates will not be the cause of problems.

**Seldom and usually undesirable: denitrification**

When oxygen values get low, certain bacterial species will switch from using oxygen to using nitrates. This leads to nitrate reduction. Nitrate would be reduced to nitrite again. This is a dangerous material for fish in any substantial quantity.
This is done on purpose in large water processing plants, but it can be done because the water can be allowed to release its gasses prior to further treatment in the next stage. A bacterial reduction of nitrates can be done for your aquarium, using specific filtration equipment. This process needs water that is depleted of oxygen, which is only possible at the cost of very low throughput. This in turn means that it is not possible to use a nitrate filter as an "afterburner" in a conventional aerobic filter. After the occurrence of nitrates it is Game Over! Time for water changes.

**The filter medium**

The most important part of the filter is the medium. This is where the bacteria should do their work. That is why we need to provide them with a material they can colonize and which is in a permanent flow of the water that needs filtering. Large numbers of bacteria are required, which means that we need a large surface area in the filter medium. This can be achieved by selecting a material that has many holes and capillary pores. These will increase the total surface area for a given volume of filter material.
The size of these holes and pores should not be too small, because the bacteria would otherwise block them or even wouldn't fit in at all. These bacteria range in size from about 10 µ (1 micrometer = 10^-6 m) down to 200 nm (1 nanometer = 10^-9 m). Just to compare: if 1 mm were 1 m, then 10 µ would be 1 cm and 200 nm = 0.2 mm.
When holes and pores are so small that bacteria do not fit in anymore, only the outer surface remains to be colonized by them, even if the substances these bacteria require still fit in because they are essentially micro molecules.
The extra price for these smallest capillaries and enormous inner surface is money down the drain. According to some critics, this is the case with some filter media being sold in this country. The suggested enormous surface area is therefore nothing but a marketing trick, and evidence is still lacking in support of these claims.

**What to do with high nitrates?**

Before going into this, it should be made clear which values should be labeled "high". It is possible that a value of NO3 = 5 mg/l is too low for plants like Eichhornia azurea or Chinersia. For other plants, like Cryptocoryne rosanervigae, this would be about right.
The NO3 level is relatively unimportant, as long as it doesn't go into extremes. Values higher than 75 mg/l could damage eggs and fry because of influencing internal oxygen processes. I mean, a value of 15 mg/l on average can be seen as an acceptable amount of NO3. If the nitrate value is too high, it should be determined if this is a permanent situation or just a temporary rise. After a particularly heavy feeding for example, or a dead fish in the tank, levels could rise for a while. More dangerous because it may go unnoticed, is a situation where suddenly all snails in the substrate die, for example after a water change with water that has too much copper in it. In any case of a temporary rise in nitrates, a partial water change is a good thing to do, while at the same time protecting your bacterial flora. So don't siphon out all of the mulm at once. It is exactly in this mulm where your bacteria are who convert the nitrogen surplus. If it is a more permanent situation, then the filter itself probably isn't functioning as it should. This could be caused by a number of reasons.

**The meaning of flow rate**

As discussed above, the nitrogen cycle is a bacterial process. Bacteria change one chemical substance into another. An important prerequisite for this is sufficient time for them to actually do it. It should be clear from this that the time needed for the water to pass through the filter medium is of critical importance. Ideally, the water would stay in the filter long enough for all processes to complete.
But there is another very important factor: the velocity at which the water passes these bacteria. In water clarification plants, it is assumed that bacteria will hold their substrate up to a velocity of 30 cm/minute, or at least be allowed to perform their tasks unhindered. If this velocity increases to higher levels, so does the tendency of the bacteria to go look for a less stormy place. They will release from their substrate and settle elsewhere in the aquarium. It is true that most sessile bacteria live in a protective layer of slime, but its protection will not endure high water flow.
This is exactly the point where mechanical filters differ from biological ones. A biological filter cannot perform its task quickly because of this reason. It is simply impossible. In my experience lies the correct velocity between 5 and 10 cm/minute. These values should not be seen as holy gospel. It is not a disaster if calculations should produce a value of 3 cm/minute or 15 cm/minute. There are other factors that could influence the calculated values somewhat. It means that the values between 5 and 10 cm/minute are a nice target, lower being better. This value has shown to be an excellent level in practice. To be correct it should be mentioned that the actual water flow at bacterial level is somewhat higher because of the small capillaries involved. This is the same for power filters, however. This is why the 5-10 cm/minute level should be an acceptable one.

**Sizing a Mattenfilter**

There is a direct relation between water flow, pump capacity and filter surface. A direct result of this is the time it takes to make a single pass through the filter. This time is also related to the thickness of the filter medium. Increasing thickness means more time required. With the Mattenfilter, it can safely be assumed that the actual oxidation takes place in the first one or two centimeters.

With filtration there is a direct relationship between velocity of water flow (surface area of filter mat) and pump capacity per hour. When sizing a pump and/or a filter mat, the pump is defined first. Twice the tank capacity per hour is a good average. It doesn't matter whether it is calculated with or without substrate thickness. I always use the nominal volume. For a 200 liter aquarium, the pump capacity should be around 400 ltr/h. Calculation is done with maximum pump capacity because there is little or no head involved.
Now that we have a pump capacity available, a desired velocity will result in the surface that is needed for the Mattenfilter. This is around 1000 cm2. But because a 200ltr aquarium has a side surface of 40x50cm=2000 cm2, this means that the actual water flow will be around 3 cm/minute. So a pump one size bigger should be selected for the job, even if this means that the water will flow at a faster rate than two tanks per hour. This is how you determine the correct combination of pump capacity and size of the filter mat.

The other method uses the available surface for filtration. Usually one of the sides of the aquarium is used and this means a fixed surface. Using the desired water flow through the medium then produces the required pump capacity. This will result in a certain number of tank volumes per hour filtered.

**Calculations**

Here are some formula's to do your own calculations:
A = surface filter mat
V = flow rate
Q = amount of water filtered
n = number of tanks filtered per hour

Flow rate in the filter:

This one is used to calculate the throughput velocity in the filter.
The factor thousand relates to the fact that 1 liter = 1000 cm3. This should be taken into account to remain constant in the formula.

By formulating it as follows:

the result is the required pump capacity, relating to the available filter surface and the desired flow rate. Divide by 1000, to go from cm^3 to liters. Multiply by 60 to get from ltr/minute to ltr/h.

The dwell time is then calculated by dividing the thickness of the mat by the throughput:


The required surface for the filter is a result of:

This formula enables you to calculate the size of the required mat with a given filter capacity and a desired flow rate.

Tanks per hour: 1-2 times the content of the aquarium should go through the filter. This value has proven to be a desirable one. When the flow goes below 1 tank per hour in an aerobic filter, a rise in ammonium is possible because bacterial reduction of waste is no longer 100%.

Flow rate: 5-10 cm/minute has shown to be an optimum throughput. It doesn't matter much if the actual value is 2 or 18 cm/minute. There are other parameters anyway that were not taken into account, causing a higher flow rate through the pores of the filter medium in reality. This is exactly the reason to keep the flow rate at a low level.

**Construction of a Mattenfilter**

Having done the calculations for a tank, it should be clear that a larger filter surface is needed than available in conventional filters. A Hamburg Mattenfilter is made of a foam mat, inserted vertically in the tank, about 2 cm from the side wall. This distance can easily be realized by putting a piece of tubing between the foam and the glass, or any other suitable blocking.
Because of this distance, a water reservoir is created behind the mat. If the mat sits too close to the glass, the only water that would actually move, would be the water around the intake of the pump, and much too fast also. It is desirable to use the entire surface of the mat, with the exception of the water below substrate level. This can be left out.



Drawing 1 shows a construction of a Mattenfilter using a simple powerhead. The circle at the bottom is a piece of tubing, used to maintain a distance from the side glass. The distance is about 2 cm. It should not go below 1 cm, to ensure proper water flow through the entire filter. In this case, the pump is connected to the back wall using suction cups. Some PVC tubing is used to pump the water from behind the mat and back into the tank again, just below the surface. The surface agitation can be regulated of course. The required hardware for this setup should be available in any serious aquarium shop. I particularly like products from the "Hobby" company. The hole in the foam can easily be made with a knife.



Drawing 2 shows a setup powered by an air pump. The air lift sits behind the mat. The exit tube sits in a carved out slit at the top of the mat and sticks out 5 cm to ensure that small fish will not crawl through. Some species seem to like this. These animals almost seem hypnotized by the current and are drawn into it.
It is very well possible to hide the heater and the thermometer behind the filter. Other hardware, for measuring pH or redox for example, may be installed here, also.



Here a frontal view of the filter. Both varieties are shown.

Usually, the new foam is blue. This bright blue changes into a more calm brown/green with time. If this effect does not occur, it is safe to assume that the bacteria have not colonized the foam yet. These bacteria need a few weeks for that. Mats with a coarse structure seem to take a bit longer for the first bacterial colonization. After that there seems to be no difference with finer grade mats.
These mats can easily be planted with Java Moss. Just stick a bit of moss between the foam and the glass. The moss will grow well when left undisturbed. The pump will be covered completely in time. It is also possible that some algae will grow on the mat. These do not harm the functioning of the mat.
Direct maintenance of the filter, as with canister filters, is not required. This would do more damage than any good. Large particles can be siphoned away carefully when doing a water change. After a while, a layer of mulm will build behind the mat. This mulm should not be disturbed, because it consists largely of highly desirable bacteria. If cared for properly, a Mattenfilter should last many years. Only when the mat shows some serious signs of aging, recognizable by a huge difference in water level between the tank and the water behind the foam, can the foam be removed and washed. But reaching that stage should take some years.



Drawing of growth on a Mattenfilter.

**Areas of use / performance limits**

Type of aquarium and size:

The Mattenfilter can be used for fresh water tanks. It can be used for the smallest fry tanks up to aquaria containing over 1000 liters (~264 US gallons). The deciding factors remain 1-2 tank volumes per hour and 5-10 cm/minute flow rate. With large mats special care should be taken to ensure stability of the foam. The total pump capacity can be made up by multiple pumps and the return flow of the water can be setup to avoid dead zones in the aquarium.

Bio load:

When the bio load gets too high, a Mattenfilter won't be able to handle the situation and both NH4 and NO3 will be detectable. This is only known from tanks with an extreme bio load. On the other hand, a Mattenfilter needs a certain minimum load of organic compounds i.e. fish food and waste. If this is too low, the filter mulm mass will be reduced and the bacteria are too widely spaced, and a lot of water will pass through unfiltered. This too could lead to problems.
Because of a lack of time, some of my killi tanks (25 liters each) are running empty, and algae growth can be seen. In well stocked tanks with a proper feeding regime, this should be rare.
In my opinion, a stable aquatic environment depends on the available mulm. More mulm means more stability. Mulm is a result of some organic load. This means that a certain bio load is needed to build up and maintain this mulm. This is a deciding point in successful aquarium keeping. In an established filter there is such mulm, and that is the actual point of a Hamburg Mattenfilter.
I think a certain amount of mulm in the aquarium on the substrate and among the plants should be there and be tolerated. In normal tanks this is usually the case. The reason being that coarse particles, like plant material and surplus food, first have to be predigested to be able to get to the filter in the first place. This predigestion is a result of the presence of bacteria and other micro-organisms, snails and bottom dwelling fish too. If this predigestion is absent, the best bio filter in the world is not going to work. It is therefore not some unique quality of the Mattenfilter.

**Alternative construction**

Many people who show interest in the Mattenfilter, are concerned by the idea of losing so much space in the aquarium. From my experience I can only say this is space well spent. If the aquarium is setup in a reasonable fashion, concerning fish load and feeding for example, the Mattenfilter will contribute to a biological stable environment. This should be worth something.

**Space saver mat:**



My smallest tanks are no bigger than 5 liters. These are photo tanks. I have used a construction there whereby the channels for transporting the water are carved out of the back of the foam, rather than leaving 2 cm between mat and glass.

**External Mattenfilter:**



Other aquarists have moved the Mattenfilter out of the tank, into a second tank, i.e. a sump. If the balance between the size of the combined tanks, the flow rate and amount of water filtered is preserved, there really is no argument against this sort of setup. With some DIY it could even be possible to hide a sump setup underneath the tank.

**Mats in a row:**

A popular item for discussion, but guaranteed not to work, is a setup of several smaller mats behind each other in a row. It is true that this provides the correct surface, but the flow rate would be too high. It won't work.
Another reason is the fact which I mentioned before that the biological reduction actually takes place in the first few centimeters of the medium. Any more than that won't do much. It's no use, the mat should have the appropriate flow surface.

**Curved mat:**



It is also possible to squeeze the mat into a curved position in a tank's corner, as a quarter or half circle setup. The mat is held in position by vertical glass strips. These 3 cm wide strips are siliconed to the glass walls in such a way that they hold the mat tight. The radius should be calculated to have the required surface. The actual curve should not be too small, because the inside of the mat is compressed somewhat and will slow down the water flow a little. How far you can go depends on the actual type of foam used and its thickness.

**History**

The Mattenfilter itself is quite old. As far as I know, it was already in use with German breeders in the sixties. Most of them were in the area of Hamburg, where local breeders had spread the word around.
A presently well known aquarist then entered the aquaristic scene. Based on his scientific study and interest in deeper biochemical relations in the aquarium, he quickly recognized the working and efficiency of this filtration method. Over the years he has promoted this at many seminars, but opinions remained mixed. Some people got it. Others still trusted the high tech solutions. Concepts like Bio and Eco weren't exactly hot items in those days. And years went by...
One day, I came into contact with this particular aquarist. Being a student at the time, I was chronically short on money. The discovery of this filtration method was a gift for me. It was cheap and simple, "optimal" so to speak. I built these filters without having to install expensive canister filters and was able to increase the number of my tanks. This filtration method convinced me more and more. Others weren't convinced, however. They still relied on technical solutions and tried all sorts of magical media and constructions to outsmart Mother Nature. A lot of effort should obviously bring a lot of results. Many still see it that way today...
Years went by and someone gave me a diploma. Part of my study involved a closer look at sewage treatment plants. More accurate might be 'smelly bits'. Apart from lectures we also visited some plants. More and more concepts and terminology came up that were somehow familiar from aquaristics, and from my aquaristic friend who developed measuring equipment for these treatment plants as a chemist for a living. Slowly the whole thing came full circle.

The Mattenfilter hadn't spread far in the aquarium world by that time. Enters the next important meaningful person. At the time he was head of the local aquarium club, and presently the president of the VDA: Jochen Matthies (VDA: Der Verband Deutscher Vereine für Aquarien- und Terrarienkunde, the organization of German aquarium and terrarium clubs). He decided in his direct manner that yours truly was going to build a website. The VDA had to keep up with modern times and connect to the internet. That was 1997. I set out to create the desired pages. Some might even remember these first steps on the net. This building and writing became more and more fun for me to do and as a result of all this surfing and the aquaristic half, I wanted a homepage of my own. A site that would not just show pictures of tanks with a list of inhabitants, but would have some practical use for readers. What would be better than describing the Mattenfilter? An engineer sees things differently from chemists or biologists. I have therefore done some technical "research" and keeping in mind the biochemical aspects, this resulted in the texts and formulas we know today.

This means that the descriptions here are a direct result of two points of view, the biological and the technical points of view. From then on the Mattenfilter established itself and managed to crawl its way out of breeding rooms in the living room aquaria.

Some aquarists like to DIY and try to change the Mattenfilter and reduce its size. Usually as a result from the idea that it looks bad and takes up too much space. Myself, I cannot really quite follow this. A mat can be integrated into the tank visually and the advantages of an internal Mattenfilter are clear. No more tubes, fry food and leaf collections at the filter intake.
But all this is allowed and possible, as long as the main principle of accurate water flow throughout the mat is recognized. It doesn't matter whether the mat is constructed vertically or horizontally, whether it is dark or light, whether the pump is behind the mat or in front of it. Exactly this makes the Mattenfilter so brilliant. No matter how you mess around with it, you always return to this principle.