

## Fish Pond Filtration

**Fish ponds present unique filtration requirements that are easily solved once you understand the basics.**

*By Stephen M. Meyer*

Gardeners spend their winter months poring through seed catalogs in anticipation of spring. This is part of the fun of gardening. For pondkeepers, winter is also a time for planning. Pond filtration is too important and costly an endeavor to be approached in a haphazard manner. If you are thinking about building a pond or improving an existing pond, now is the time to plan and prepare for that day in spring when you will actually begin your project.

I receive many letters through Aquarium Fish Intl. that ultimately boil down to questions of pond filtration. Most ornamental fish ponds — just like conventional home aquariums — are 100-percent recirculating systems: the same water remains in the pond all the time unless some special effort is made to change it. The levels of biological pollutants in the water rise quickly unless the pond is in ecological balance or a supplementary filtration system is used to slow the rate of decline in water quality.

When setting up a home aquarium, you can easily purchase simple, effective mechanical, chemical and biological filtration systems that do a good job of maintaining water quality. Even the first-time hobbyist recognizes the need for some aquarium filtration, and store shelves are loaded with an amazing variety of filters and accessories.

In contrast, filtration is almost always an after thought for the budding pond enthusiast. The pond is built, fish and plants are dumped in and the pond is done. Things are usually fine for a while — longer than with standard aquariums because there is much more water involved. Eventually, however, water quality-related problems usually do arise.

Part of the trouble is that many first-time pondkeepers are initially hooked by the idea of having their own miniature version of a "natural pond." The notion of creating an ecologically balanced system of fish, plants and insects is indeed attractive, and there are many fine examples where it actually does work. All too often, however, natural pond enthusiasts quickly violate the rules of ecological balance by stocking their ponds with quantities of fish out of all proportion to a properly balanced ratio. Or, a pond that was initially in balance with many small, young fish is pushed out of balance within a few years as the fish grow rapidly to maturity. For example, it might seem reasonable to stock a small pond with several one-year-old koi. A typical year-old koi could weigh 1.4 ounces or so. This same fish could weigh more than 14 ounces by the time it is three years old. Therefore, even if the number of fish in the pond remains the same, the total fish load in the pond will increase 10-fold within several years.

When a pondkeeper inquires about filters, he or she learns that the assortment of commercial mechanical, chemical and biological filter systems readily available to aquarists has no counterpart in the world of ponds. While there are numerous so-called "complete" pond filtration systems available for purchase, they vary significantly in their practical value, effectiveness and price. To wisely choose among them, you need to know a considerable amount about filtration principles and techniques. Some pondkeepers, frustrated by the lack of commercially available filtration systems to choose from, realize that they might be better off attempting to design and build their own pond filter. It is certainly less expensive and almost always more effective when tailored to a particular pond.

This article looks at the fundamentals of pond filtration, with an emphasis on practical design and operation. More than 20 years of research and experience by fisheries scientists, aquaculturalists and waste water treatment specialists has produced a substantial body of findings that is directly relevant to the filtration of ornamental ponds. There are many possible filter designs that adhere to these principles. I really don't believe that there is any single optimum filter system design — although some may be better than others in terms of operation and maintenance. Consequently, this article steers clear of proposing a particular design.

You may be wondering why you even need a pond filter. As I have already noted, most ornamental ponds are 100-percent recirculating systems. Except for rainfall or water changes by the pondkeeper, no new water is added to the pond. Under these circumstances, water quality declines fairly quickly, and the pondkeeper must contend with consequent problems of fish health and pond aesthetics. A properly designed filtration system can significantly slow the decline of water quality, although no filter can maintain the pristine conditions of an open aquatic system, such as a spring-fed pond.

There are three basic types of pond pollutants: nitrogenous wastes, suspended and settled solids and dissolved organic carbon. The most serious water quality problem for the pondkeeper, by far, is control of nitrogenous wastes — in

particular, ammonia. Unfortunately, you cannot have fish in your pond without also having ammonia constantly being added to the water. Fish continuously excrete ammonia through their gills, and additional ammonia is released into the pond water by the decay of fish feces and uneaten food. Moreover, almost any organic matter — solid or dissolved — likely to fall into your pond can be partially mineralized into ammonia.

Ammonia appears to hinder oxygen uptake in the fish's blood. Lethal concentrations can build up rapidly in heavily stocked ponds. Continuous lower concentrations of ammonia cause chronic physical stress that ultimately reduces a fish's ability to fight disease. Gill filaments become irritated and begin to swell. This cuts off the oxygen supply to the membrane cells, which then become infected with bacteria. Kidney damage has also been observed under these conditions. Low concentration, ammonia-related stress also reduces food consumption and growth, inhibits reproduction and causes premature death.

Bacterial consumption of ammonia produces toxic levels of another nitrogen compound, nitrite. Nitrite, like ammonia, interferes with the ability of the fish's blood to transport oxygen. Other bacteria convert nitrite to nitrate, which is much less toxic to fish. Contrary to popular belief, the nitrate levels commonly found in ornamental ponds do not affect goldfish and koi in any measurable way. Toxic effects do not show up until levels reach several hundred parts per million (ppm).

Any materials that do not dissolve into the water are considered to be solids, which can vary from microscopic particulates, such as tree pollen, to large objects, such as leaf and tree fragments. Suspended solids are undissolved materials that stay afloat in the water (though not necessarily on the surface), circulating around the pond. In an ornamental pond, suspended solids may be composed of fine mineral particles that flow into the pond via rain, wind, ground runoff and so on, detritus (a composite of finely ground-up organic and inorganic material originating from plants and animals) and plankton, the microscopic plants and animals that dwell in the pond.

The greater the quantity of suspended solids in the water, the higher the turbidity. One of the most common causes of high turbidity in ponds is planktonic algae, which turns the water pea soup green. From an aesthetic standpoint, not only does turbidity reduce transparency through the water, but it also makes the pond look dirty. In addition, some forms of suspended solids can also irritate fish gills, causing stress and making the fish more susceptible to disease. Fancy goldfish seem to be especially sensitive to turbid waters, whereas koi and pool comets (a variety of goldfish) appear to be totally unaffected.

Settled solids drift to the sides and bottom of the pond. Unless disturbed, they tend to sit where they land. Koi keepers know, however, that these fish constantly stir up settled matter, adding to the turbidity of the water. Admittedly, the distinction between suspended and settled solids is somewhat artificial, because under very quiet conditions and with enough time, many suspended solids will settle out. Then again, many settled solids can be resuspended by stirring up the water. In either case, even though these solids ultimately leave suspension, they affect the aesthetic and biological qualities of the pond.

Suspended and settled solids are composed largely of organic matter, and thus are susceptible to decay. Bacteria in the water will convert (mineralize) some of this matter into ammonia, which then adds to the overall nitrogenous waste burden in the pond.

Another water quality concern is dissolved organic carbon (DOC). DOC consists of carbon-based compounds (excluding carbon dioxide and carbonates) that are the metabolic by-products of pond life. Carbohydrates, proteins, amino acids, fats, phenolic compounds and pheromones (hormones that affect the behavior of other fish) are just a few examples. Concentrations of DOC may be as low as 1 ppm in clean rivers and lakes, whereas polluted waterways may have levels up to 100 ppm.

The bacterial decomposition (mineralization) of some forms of DOC will add directly to the ammonia load in the pond. DOC can affect fish health by supporting populations of disease-causing (pathogenic) bacteria and parasites. It can also have a direct biological affect on fish when pheromones are present, inhibiting growth and lowering disease resistance. What is important in this latter case is the origin and composition of the DOC, not necessarily the total DOC concentration. On the one hand, in ponds with very light fish loads, the primary source of DOC will be the metabolic products of plants and planktonic algae. Cellulose-decomposing bacteria will dominate the water's bacterial population, and only very low concentrations of fish growth and immune system-inhibiting DOC will be in the water. On the other hand, in heavily loaded ponds, the fish are the main source of DOC, and the composition of the DOC is quite different from lightly loaded ponds. This DOC will support rich populations of "protein-eating" bacteria and fungi, some of which can cause disease in fish. The much greater concentration of fish-originated DOC will directly suppress fish growth and immunity, making the animals more susceptible to bacterial and parasitic infections. DOC pollution is of greatest concern when the primary source of DOC is the fish load.

The implications of all this are clear: your pond must have some mechanism for controlling the relative concentrations of solids, DOC and nitrogenous wastes if your fish are going to live and thrive. Some ponds can handle these pollutants without any supplementary filtration, whereas other ponds require substantial assistance.

The question then becomes whether or not you need a pond filter. The answer will depend on the kind of pond you plan to manage and how you manage it. Let me draw a useful distinction between a garden pond and a fish pond. A garden pond is an attempt to recreate an ecologically balanced system among plants and fish. The key here is that the amount and variety of plants are high, while the quantity of fish is very low. I have seen many gorgeous examples of garden ponds. They vary in size, but all have the same common situation — the plants are the primary attraction and the fish are almost secondary.

A typical garden pond might be kidney bean shaped — 8 feet long, 5 feet wide and 2 feet deep — and hold about 550 gallons. Plantings would include several waterlilies, a variety of submerged plants, such as Anacharis, Cabomba and Myriophyllum, floating plants, such as water lettuce or water hyacinth, and assorted bog plants, such as iris and horsetail that rise out of the water. Fish in the pond would be limited to perhaps a pair or two of goldfish or several small koi.

This garden pond depends on ecological balance instead of filtration to maintain water quality. The fish load is intentionally kept very low so that the pollutants they produce can be handled by the bacteria, plants and microscopic flora and fauna that populate the pond. Most of the solids settle out of the water — resulting in low turbidity — and a considerable amount is broken down by bacteria in the pond. Of course, an occasional hand skimming of leaves and other debris helps maintain low solids levels. Concentrations of the DOC we are most concerned about remain low because 1) the fish load is low, 2) mineralization removes some DOC and 3) partial water changes remove some DOC. Lastly, the level of nitrogenous wastes produced in the pond remains low (because the fish load is low) and is rendered harmless by the activity of nitrifying bacteria living on the pond walls and plants. The nitrate produced by nitrification is consumed by the plants. No supplementary filtration is required.

In order to maintain this balance, no additional fish are added. As the fish grow, the fish load is kept constant by judicious culling. If spawning occurs, the new arrivals are quickly removed so as not to upset the balance.

In contrast, a fish pond is dedicated to the breeding and showing of fish. Its primary purpose is to raise fish for display, as is the case with most ornamental koi ponds. Here, the fish dominate the plants, and often there are no plants at all. Fish loads are quite high — far in excess of what you would ever find in nature.

There is simply no way to achieve an ecological balance in such cases, and therefore substantial supplementary filtration is needed. The solids, DOC and nitrogenous wastes are produced in quantities far in excess of what the population of bacteria in the pond can handle. Moreover, most of the solids and DOC are of fish origin, increasing the importance of removing them. They will just accumulate over time until the fish begin to get sick and die — tragically bringing the pond back into balance.

Because pond conditions vary so widely — much more so than conventional home aquariums — pond filtration needs vary as well. Some ponds may only have a problem with the accumulation of solids and turbidity, whereas others may only need a means of removing nitrogenous wastes. More than anything else, the fish load will determine how you should assemble your pond filtration system. Below, we will discuss the component parts of supplementary filtration for fish ponds, examining various alternatives for removing solids and DOC. In part two, we will consider methods for controlling nitrogenous wastes.

Reducing solids requires some type of mechanical filtration that physically removes solids from the pond water. There are two basic approaches worth considering: gravitational settling and physical screening.

Gravitational settling is a process by which solids denser than water eventually drift to the sides and bottom of the pond under the force of gravity. Pond turbidity frequently increases in the aftermath of a heavy rain storm as materials are washed into the water and previously settled materials are stirred up. Subsequent settling activity usually leads to substantial clearing in a few days. Essentially, any pond is a settling basin. But rather than allowing this matter to settle anywhere in the pond, it is better to either direct settling to occur in a specific part of the pond or to have settling occur in a special basin outside the pond to facilitate removal.

In the first instance, a special depression — a sump — is built into the pond floor. Over time, settleable solids drift down into this area, where a bottom drain, a siphon or a pump is used to remove this material. Although a sump is simple, it has two problems: 1) a sump cannot be added after the pond is built and 2) koi and goldfish love to muck around in

sumps, stirring up debris.

A preferable alternative is to add a settling basin outside the pond. The settling basin is a transitory waterway through which pond water is pumped. It is big enough so that solids settle out before the water returns to the pond. The advantages of a settling basin are that it can be added to a pond system at any time, it is not accessible to the fish and draining and flushing are simple.

How big should the settling basin be? All else being equal, the time required for a given particle to settle out depends on its density, shape and size. Dense, small, round particles settle out faster than less dense, larger, flat particles. In general, for our 100-percent recirculating pond, the larger the settling basin volume is in relation to the pond volume, the greater the amount of solids that will settle out.

Taken too far, this could get quite absurd, with the settling basin approaching the size of the pond! So, let me suggest a more reasonable rule of thumb. What little research has been published suggests that settling times of 15 minutes or more are required to remove heavier wastes. Thus, we want the pond water to spend at least 15 minutes moving through the settling basin before it goes on to the next part of the filter system and ultimately returns to the pond. For reasons that will be explained in part two of this article, we also want to pump one complete pond volume through the filter system at least every two hours. These two criteria suggest that the settling basin volume should be roughly 1/8th the total pond volume. For instance, a 1000-gallon pond should have a settling basin that holds about 125 gallons.

To improve operating effectiveness, the basin should be about 2 feet deep and slope upwards toward the end where the water exits. A drain valve should be placed at the deep end for daily solids removal. The effectiveness of settling basins can be improved further by the intermittent placing of objects in the basin to restrict the flow of water. Brushes, fiber mats or any other form of partial barrier can be used to slow the velocity of suspended solids in the water, forcing them to settle out. In this way, smaller basins can serve larger ponds.

An advanced form of gravitational settling — one more appropriate for intensive fish farming and rearing ponds with very high fish loads — involves the use of "hydroclones" and centrifuges. These devices accelerate pond water around a circular route at rates many times that of gravity. Thus, the separation of solids is more rapid and effective compared with ordinary gravitational separation in sumps and basins. Because accelerated gravitational separation is so much more effective, a hydroclone or centrifuge system can be much smaller than a standard settling basin, and may be worth considering in situations where space constraints prevent construction of a simple settling basin.

A hydroclone for a typical ornamental pond might be a cone 1 or 2 feet in diameter, tapering down to 3 inches as it reaches a depth of several feet. Water enters at the top of the hydroclone and is directed along the cone's outer wall at high velocity. Solid wastes settle to the outer wall, drift downward and drop out through the sludge outlet at the bottom. Clean water exits from a pipe placed about 1 foot below the surface at the center of the cone. Commercial units are available, although they are quite expensive.

The alternative to settling is screening. For our purposes, a screen can be any porous barrier with a fixed mesh size that is placed in the flow of water. Coarse screens — such as a grid of ½-inch PVC pipe spaced ¼-inch apart, or egg crate lighting grills — can be used to removed leaves and other large debris. Window screening stretched across a frame will trap particles down a few millimeters in diameter. Thin foam sheets and nylon floss held between two egg crate lighting grills can provide very fine mechanical filtration. Cleaning involves daily washing of the screens, and intermittent replacement.

Even better mechanical filtration can be obtained with a somewhat different "screen:" a gravity sand and gravel filter. In this design, water flows over a layered bed of sand and gravel and then trickles down between the grains. The scrubbed water exits at the bottom of the bed, leaving the solids behind. Gravity sand filters require daily backwashing to keep the bed from clogging.

Although the quest for ever finer mechanical filtration might seem worthwhile, keep in mind that the better the screen is at removing solids, the more frequent will be the cleaning requirements. At the extreme, diatomaceous earth filters certainly offer the best capability for removing ultrasmall particles, but they are totally impractical for pond filtration. They are so effective that they literally require hourly backflushing and cleaning.

The do-it-yourselfer has a wide variety of options for building a mechanical screen filter. The size, mesh size and number of stages can be varied. Personal experience suggests that you will get more mechanical filtration and fewer maintenance headaches if you keep your filter screens thin but give them a large surface area.

There are several commercial alternatives available as well. Danner Manufacturing (160 Oval Dr., Central Islip, NY 11722) sells a thin foam screen wrapped around a plastic cylinder under the product name Supreme Poolmaster Universal. This filter is very effective for small ponds (under 500 gallons), but several can be ganged together for larger ponds.

Another option — one that is most suited for large ponds over several thousand gallons — is the standard swimming pool pressurized sand filter. Using a coarse sand (1 mm in diameter) or even #3 aquarium gravel, pressurized sand filters are very efficient mechanical scrubbers. Although a pressurized sand filter is easy to install and operate, there are a number of drawbacks to these units. First, the pumps used with rapid sand filters consume lots of electricity and are very noisy. Unless you have some remote place to house the filter, the noise can ruin the pond setting. Second, daily backwashing means high water consumption — a couple of hundred gallons per day. Third, because the sand bed is quite deep, over time it tends to clog to the point where backflushing is useless. Once this happens, the filter sand must be replaced.

Keep in mind that the solids removed by a mechanical filter of any design remain in contact with the pond water until they are flushed from the filter. They are still "available" for bacterial decomposition that will degrade water quality. Therefore, as I have already noted, you should flush the mechanical filter at least once each day. Less frequent cleaning means that the results of mechanical filtration will be largely cosmetic.

Of course, it is quite feasible to combine a settling basin with mechanical screening. Designs are open to the imagination. You could, for instance, start with a settling basin with a water course of brushes, followed by a coarse mesh screen, and end with a fine sand bed.

We now come to the topic of removing DOC. DOC removal in standard freshwater aquariums is commonly accomplished with the use of granular activated carbon (GAC). GAC, however, is quickly fouled by particulate matter, planktonic algae and other substances that abound in the average ornamental pond, but which are much more scarce in aquariums. A 1000-gallon pond might require 8.8 pounds of GAC or more each month! Thus, GAC is not a practical approach to DOC control in ornamental ponds unless you are quite wealthy.

Frequent partial water changes will, of course, keep DOC levels down. But this can get very expensive with large ponds, and many parts of the country are experiencing water shortages that limit such activity. Moreover, if your fish pond is heavily stocked, nothing short of a 50-percent water change every day would matter.

An alternative method for removing DOC is the foam fractionator (more commonly known as a protein skimmer). This is a simple device that uses a rising column of bubbles to extract the DOC from the water. In fact, you have probably seen foam fractionation at work in your pond without realizing it. The appearance of a white scummy froth at the base of a waterfall is caused by bubbles coated with DOC.

Foam fractionation works by adsorption, taking advantage of the fact that many DOC molecules have a polar structure, with one end that is attracted to water and one end that is repelled by it. The repelled end will attach itself to the surface of air bubbles rising through a column of water, and when the bubble is removed from the water the DOC molecule goes with it.

Foam fractionators for hobbyist pond use are not commonly available commercially, but they are quite simple to build using ordinary PVC pipe. Water is pumped into the foam fractionator through a standard spa jet. A valve placed before the spa jet controls the water flow, and here again the flow should allow at least one pond volume turnover every two hours. A constriction in the throat of the jet — called a venturi — causes a pressure drop as water moves through the nozzle. An air tube is centered above the venturi, and air is drawn into the water flow at the location of the pressure drop. The air-water mixture moves up the fractionator column and adsorption occurs. The DOC-enriched foam collects at the top of the column and ultimately builds up to the point where it spills out through the exit port. The water moves back down the column in a counter-current flow and is stripped of additional DOC before passing down and around to the water exit column.

You can operate the foam fractionator on its own pump, independent of the main pond pump, or you can hook it in series or in parallel to the main pond pump. The most important thing is to move approximately one pond volume through the foam fractionator every two hours. This means that large ponds could require several units ganged together.

Depending on the conditions in your pond, it may take a few hours or a few days before your foam fractionator begins to produce results. Do not be surprised if the foam you get is not as thick and rich as the kind that bubbles out of marine aquarium foam fractionators. Freshwater systems tend to produce "thinner" foams. You can adjust the foam by playing with the three regulating mechanisms until the consistency is as thick as will flow smoothly.

In the second half of this article, I will discuss the design criteria for the last component of our supplementary pond filtration system: the biological filter for detoxifying nitrogenous wastes. The final task will be to combine the three elements together.

#### Building a Pond Foam Fractionator

The main body of the pond foam fractionator consists of two columns attached at the bottom by a 180-degree elbow. The larger column is the main column (A) where DOC adsorption occurs. The smaller column — the water exit column (K) — stabilizes the water level in the main column and allows clean water to exit.

The main column (A) is constructed of 4-inch PVC pipe. It should be roughly 8 inches long. The top is fitted with a 4-inch-to-2-inch reducer (B). A small section of 2-inch PVC pipe (C) — which will vary in length depending up your particular situation — connects to a 2-inch-to-1-inch reducer (D). Lastly, a section of 1-inch flex-hose (E), which serves as the foam exit port, is attached to the top and directed away from the pond.

The bottom end of the main column is fitted with a 4-inch by 2-inch sanitary T-fitting (F). The 2-inch opening will house the water inlet spa jet (G). The air tube (H) for the spa jet must extend above the water level in the main column.

Below the sanitary T-fitting is a 2-inch-long section of 4-inch pipe, followed by a 4-inch-to-3-inch reducer (I). Next comes the 180-degree turn, composed of two 90-degree elbows (J). The water exit column is made of 3-inch PVC pipe (K). It is about 10 inches long and is fitted with a 90-degree elbow (L) on top.

This foam fractionator uses three regulating mechanisms. First, as already mentioned, the water exit column (K) controls the height of the water in the main column. Second, a valve (M) is placed before the water inlet to regulate the venturi effect in the spa jet (G). Third, the actual length of the small section of 2-inch PVC pipe (C) on the top of the main column can be adjusted to alter the consistency of the foam.

If you place the foam fractionator in the pond or settling basin, there is no need to cement this unit together. You certainly do not want to cement the top section, which may require adjustment over time.

All the parts you will need to build a pond foam fractionator are available at your local plumbing supply store, except the spa jet. Spa jets can be purchased at any pool and spa retail outlet. The last item you will need is a pump (or you can tap off your main filter pump).

Part Two>>