UNIVERSITY of ARKANSAS AT PINE BLUFF 1873
School of Agriculture, Fisheries and Human Sciences
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Understanding and Maintaining Older Classroom Recirculating Aquaculture Systems

C. Bauer Duke, III
Extension Aquaculture Specialist

Aquaculture in the classroom is an important educational tool. Indoor recirculating aquaculture systems (RAS) for raising fish provide hands-on learning for students in agriculture, biology, mathematics, chemistry, economics and other sciences. There is also a practical rationale for these systems, as raising fish can be less expensive than rearing other animals, while providing students the opportunity to experience nursery, grow-out and harvest phases within one school year. Additionally, aquaculture is an important agricultural crop in Arkansas and the state's fish farmers provide a wide variety of fish, including catfish, baitfish, goldfish, hybrid striped bass and sportfish.

Although more than 80 schools in Arkansas have used indoor aquaculture systems since 1995, fewer systems were actually built (Figure 1). Due to teacher migration and retirement and changes in educational strategies, some systems were taken out of service or were transferred to other schools. This fact sheet is designed to assist teachers who have inherited fallow, older aquaculture systems so they can understand how the system works as they return it to operation. Teachers should know they do not have to do this alone. Local electrical, plumbing and hardware supply stores and fish farms are often willing to help educators put a system in place at reduced cost. Parents can also contribute expertise and time, as they are often glad to assist. Frequently, time, not a teacher's ability, is the limiting factor, but the community can and will help.

Teachers interested in RAS resurrection should also consider involving teachers from other disciplines for help. These systems are useful not only for agriculture but also to illustrate the principles of biology, business, chemistry, physics and other classes. As a result, those teachers can help provide needed assistance to revamp an RAS. This ultimately helps fulfill State Department of Education goals of cooperation and interdisciplinary exercises for students and includes agriculture classes in the Science, Technology, Engineering and Math (STEM) format. This also demonstrates a student does not have to be college-bound to benefit from STEM.

FIGURE 1. Schools involved in classroom aquaculture activities and aided by UAPB Extension Specialists, 1995-2015.

Two Main Systems Used

Most of the aquaculture systems used in schools were sourced from two large aquaculture supply companies, Aquacenter, Inc. (Leland, MS) and Aquatic Eco-systems, Inc. (Apopka, FL; now Pentair Aquatic Eco-systems). As a result, these are the two major RAS formats found in schools across the state. Figure 2 shows the two-tank RAS supplied by Aquacenter, Inc. One-tank systems are essentially the same design but with one less tank. These systems gravity-feed water from the tanks through their drains to a small (⅛ or ⅙ HP) centrifugal pump. The pump then pushes water through the bead filter and to a spray bar for each tank. Water delivery through the spray bar was considered vigorous enough to aerate the water and provide sufficient oxygen for fish in the tank without extra aeration.

These older systems were suitable as long as fish were not stocked too densely, the bead filter was well-maintained and pipes remained clear so that the pump produced enough pressure to create adequate aeration for the fish and bacteria. However, if the pipes or bead filter became clogged or the pump efficiency decreased, water flow and pressure from the spray bar dropped, resulting in less force at the water surface and less oxygen transfer. These events could result in fish stress or death. Further, in the case of a pump failure or power outage, oxygen transfer stopped completely. Thus proper maintenance of these older systems, as described in the following sections, is critical to their successful operation.

Available options with these systems typically were (1) windows on the tanks for easier fish viewing and (2) flat-bottom or cone-bottom tanks. Most

FIGURE 2. An Aquacenter, Inc. two-tank system composed of two 500-gallon polypropylene tanks, a ⅙-hp pump and a bead filter. Note the two parallel pipes between the tanks; on top is the leveling pipe and below is the drain pipe.

classroom systems employed the flat-bottom tank because it could be set directly on the floor without a stand as required by the cone-bottom tanks; a financial consideration. But the cone-bottom tanks provided better cleaning and removal of solid waste. Through the years, these basic systems have been replaced with more complex offerings, and finding information or photos of the original models can be challenging. In many cases, the water pump has been replaced by airlifts, and in some systems, additional chambers were added for the water to flow through to allow solid material to settle, reducing the amount of waste reaching the bead filter.

Water Flow Through the System

The system design is simple by engineering standards. Nonetheless, the operator must understand operational and maintenance basics in order to prolong system life. The fish are kept in the culture tank, and the drain at the bottom of the culture tank allows water to flow by gravity to the pump sitting on the floor. The pump moves water to the bottom of the bead filter. The water is pushed up through the bead filter where it encounters the mass of beads floating at the top. The outer surfaces of the beads house the bacteria that serve as the system biofilter. Dissolved nitrogenous wastes (ammonia and nitrite) in the water are taken in by the bacteria. Ammonia is turned into nitrite by the *Nitrosomonas* genus of bacteria and from nitrite to nitrate by the *Nitrobacter* genus. There are other bacteria involved, but these are considered the major players. Water exits the top of the bead filter and is forcefully pushed out of the holes in the spray bar, splashing onto the surface in the culture tank, and transferring oxygen into the water that is necessary for fish survival. The flow from the spray bar also circulates water in the tank, pushing solid wastes toward the drain. At this point, the cycle begins anew.

The Bead Filter

The bead filter is a simple design, but there are aspects that are not obvious. Consequently, the bead filter tends to be the most frequent cause of difficulty for operators. The bead filters have an hourglass shape and contain 1-2 ft^3 of floating plastic beads (Figure 3). The beads float to assist in the cleaning process. The necessary bacteria only perform well when they are attached to a surface. This is why after an RAS has been in operation for awhile, the various wet surfaces feel slimy. These bacteria occur naturally, and when given enough ammonia and nitrite to absorb, will grow and multiply. If they grow too thick, bacteria at the bottom of the layer will die from lack of oxygen, and the entire layer of bacteria will break loose from the bead surface. Also, thick layers of bacteria act as a glue to stick beads together. In extreme cases, if the filter is not backwashed, the individual beads can become one large mass and water may not pass through the filter, as the mass acts as a large stopper. This is why periodic backwashing of the bead filter is so important. Backwashing causes the beads to tumble and bump against each other, reducing the thickness of the bacterial layer. Loose clumps of bacteria and other solids are purged from the filter, improving water flow.

The filter may also become clogged due to accumulation of solids. Fish add two forms of waste to the system, fecal solids from the intestines and dissolved ammonia from the gills. If the fecal solids are not removed from the system, bacteria will break down the solids, releasing yet more ammonia into the water. These classroom systems were designed so that the bead filter served two functions: to trap solids for removal as well as act as a biofilter. As water and solids enter the bottom of the filter, heavier particles will rest near the bottom while lighter solids are pushed upward to the bottom of the floating bead mass and are trapped under it. The water continues through the beads and the bacteria perform the biofiltration of the dissolved waste. As the fish grow, more feed is provided, more solids accumulate and the bacterial populations increase. In addition, any uneaten feed ends up in the bead filter as well. Consequently, as the fish grow, the bead filter must be cleaned more often.

FIGURE 3. Two bead filters with slightly different shapes. Note the 2-inch top ports for water outflow, the 1½-inch drain ports at the bottom, the air-sucking side ports with the one-way check valve and the small 1-inch flash drain. The filter in the top photo uses a check valve on the exit port while the filter in the bottom photo uses manual valves. Backwashing this filter requires closing both valves.

The bead filters in these systems usually have four ports (Figure 4). The top port and drain are 2 inches in diameter. Both of these have screens made from slotted 1½-inch pipe that extend into the unit and allow water to pass through and retain the beads in the filter (Figure 5). The third port is the smallest (¾ inch with an elbow and check valve). This is where the air is sucked in during the backwash cycle. It too has an interior screen to prevent loss of beads. The fourth port is 1 inch in diameter and is connected to a flexible hose with a valve on the end. This is the backwash valve and has no screen.

Bead filters need to be backwashed once per week to start. But as the waste load increases, it may be necessary to backwash up to 2 times per day several months into the growth cycle. When backwashing, the backwash valve should be opened for about 10 seconds. The water will flow and air will be sucked into the ¾-inch side port. The system should gurgle. If the water does not run freely or the system does not gurgle, there is a problem. In the first case, see the Clogged Bead Filter section of the fact sheet FSA9621, *Repairing and Upgrading Older Classroom Recirculating Aquaculture Systems*. In the second situation (no gurgle), the top of the bead filter must be closed for gurgling to occur. The gurgling should come from water exiting the filter below and air being sucked in (through the air port), moving through the neck of the bead filter and up through the beads. This disturbs the beads and rubs them together, thus washing them. Trapped solids and excess bacterial film are loosened and separated from the beads.

At the top of the bead filter, the outflow pipe uses a check valve or a manual valve. Make sure the manual valve is closed if there is no gurgling. If there is a check valve and no gurgle, the valve is not working and needs to be cleaned or replaced. Many check valves have a rubber hinge, and if the system is old enough, the hinge may be worn through, in which case the "flapper valve" no longer flaps. If the valve(s) are not closed, the filter will be allowed to replace water with air other than that from the side purge valve and the beads will not be agitated. This will result in poor backwashing and over time the filter will clog.

FIGURE 4. Left, a bead filter on its stand with four visible ports. Right, the same filter off the stand, with a better view of the ports.

FIGURE 5. Example of the screen in the drain port. A similar screen is used for the water delivery port and the purge port. The open hole is where the 1-inch flexible hose seen in Figure 4 has been detached. There is no screen associated with this hose, and beads will be lost if not used properly.

It is important to understand the 1-inch backwash port does not have an interior screen. If it is left open too long, beads will be lost as the water level drops and beads enter the bottom chamber. Once the filter gurgles nicely, close the backwash port and let the filter stand idle for 3 minutes. This allows loosened heavy particles to sink to the bottom of the filter while the floating beads remain at the top of the filter. Then open the valve again for 10 seconds. The initial water flow should appear dirty and become cleaner. After closing the valve, again wait 3 minutes and flush. The water should be clear within 10 seconds. If not, allow the filter to refill with water and start the process again. By refilling the filter, no beads should be lost due to a low water level.

New beads are spherical or oblong, usually about ⅛ inch in diameter and float, but they may become coated in organic or mineral deposits that make them heavy enough to sink. In this case, beads will be lost during the backwash mode. Consequently, it is advantageous to run backwash water through a net to catch any stray beads. Although rare, it is possible for older beads to wear down to a point they are able to pass through or become stuck in the slots in the interior screen. In one case, beads are lost; in the other, the bead filter may become clogged and deliver less water.

Summary

Many opportunities exist in Arkansas for schools to obtain used classroom aquaculture equipment. From an engineering point of view, these older classroom systems are simple. The culture tanks are durable and should last 15 years or more, although long-term exposure to sunlight will shorten the life of a tank. The bead filters are dependable, but must be backwashed and maintained properly. A water pump is needed to flow water through the system. Plumbing components to make all the connections are usually available at a local hardware or supply store.

The higher the fish biomass in the system, the more time will be spent on bead filter maintenance, especially backwashing. Later versions of these systems added an air system to assist in maintaining higher densities of fish. They also added at least one sump to collect solids and allow the bead filter to concentrate on biofiltration of dissolved waste. This reduces the amount of backwashing needed. The most recent versions have removed electric water pumps to eliminate electricity/water interaction. The air pump used for water flow by airlift is electrical, but is separated from water contact.

Fish may be raised in recirculating systems at a rate of 1 pound of fish per 1 gallon of water or less, but these systems cannot attain these levels without very high backwashing rates (5 times per day or more), which reduces the efficient use of water. The addition of sumps or clarifiers removes this need but also takes up more space. This is supposed to be a classroom system, not a commercial operation. So teachers need to consider 1 pound of fish per 3-5 gallons of water as the target at harvest. Information about upgrades and repairs to these older systems may be obtained in the fact sheet FSA9621, *Repairing and Upgrading Older Classroom Recirculating Aquaculture Systems.*

C. BAUER DUKE, III, is an Extension aquaculture specialist with the 1890 Cooperative Extension Program at the University of Arkansas at Pine Bluff.

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