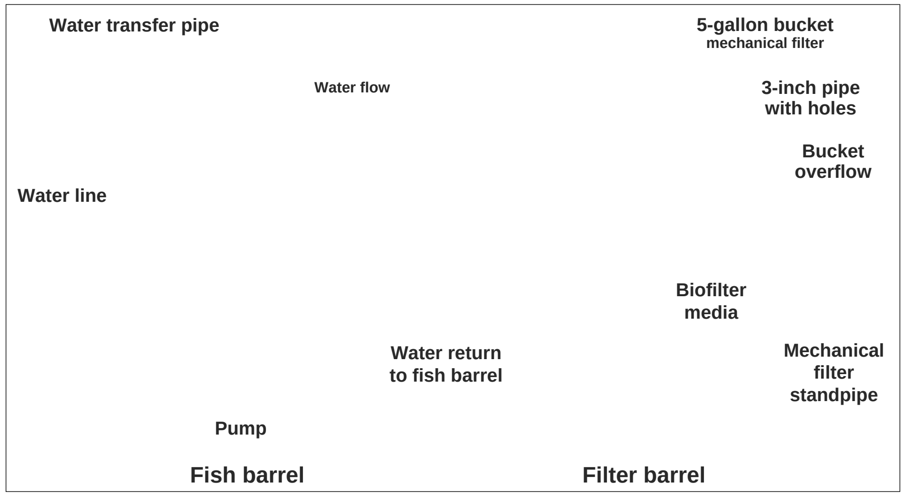
Many teachers would like to add aquatic science and/or aquaculture programs to their curricula. These programs add a hands-on

System components

A simple RAS system can be constructed from items available at nearly any home improvement store. Step-by-step instructions for building a system are described and illustrated below. There are many other options and variations one might use, but the system shown here has been classroom tested. Every RAS must include components to hold the fish, remove the solid wastes (mechanical filter), remove the dissolved nitrogenous wastes (biological filter), circulate the water, maintain the temperature, and aerate the water if necessary. Figure 1 illustrates these components and shows the path the water will follow as it travels through the system. Photo 1 shows the completed system.



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The first component is the culture vessel or fish barrel where the fish are housed. The water is lifted from the bottom of the fish barrel (by the pump) to a plastic bucket supported by plywood on the top of the filter barrel. In this bucket (mechanical filter) the water must pass through several layers of filter material that capture the uneaten feed and solid feces. Once through the filter pads, the water leaves the bucket by going through holes in the bottom of a 3-inch pipe and then out the stand pipe in the center of the bucket. The water then travels to the bottom of the filter barrel and must pass though the biofilter media (to remove nitrogenous wastes) before returning to the fish barrel.

These are the tools required to build the system:

- PVC pipe cutter or hacksaw
- Extension cord
- Goggles or safety glasses
- Saber saw or Sawzall®
- Electric drill
- Ruler or tape measure
- Hole saw to cut $1\frac{1}{4}$ and $1\frac{1}{2}$ inch
- Drill bits, $\frac{1}{4}$-inch
- Teflon® tape
- Marker
- Sandpaper
- Rubber gloves
- Screwdriver (to match bolt heads)
- Pliers or $\frac{3}{16}$-inch ratchet

Instructions

1. Gather and organize necessary tools and parts.
   a. Gather necessary parts and plumbing supplies. (see Table 2).
   b. Cut the pipes to the specified length using PVC-pipe cutters or hack saw.
   c. Label the pipes and fittings with their letter designations.
2. Prepare barrels.
   a. Obtain barrels, preferably from a food or drink processor/bottler, and rinse them thoroughly. You may also use soap barrels from a carwash. Do not use chemical barrels as there may be residue that could be toxic to the fish and/or humans consuming the fish.
   b. Using a saber saw or Sawzall®, cut the top from one barrel (filter barrel), leaving a 1- to 2-inch rim around the top edge. The rim helps maintain rigidity. (Photo 2b)

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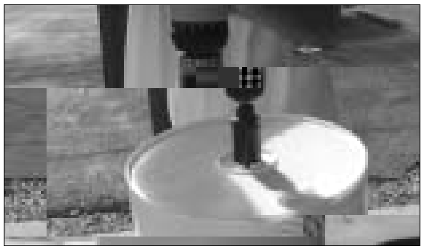

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d. Cut another 1 ¼-inch hole in the side of the 5-gallon bucket between the structural rim and the top of the bucket about 2 inches from the top. Gently remove burrs and smooth very lightly with sandpaper. This hole will be the overflow into the filter barrel in case the mechanical filter gets plugged. (Photo 3d)

3.

e. Fit a 1-inch male/slip fitting (J) through the hole in the bottom of the bucket and secure it on the inside with a 1-inch female/slip fitting (I). This joint does not have to be watertight because any leaks will fall into the filter barrel. (Photo 3e)

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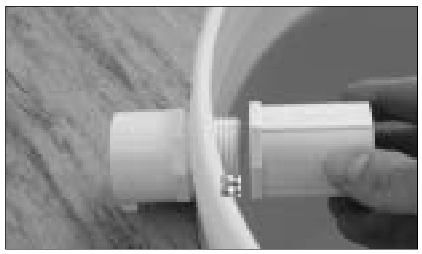
f. Repeat this procedure for the hole on the side of the bucket. This joint, however, should be as watertight as possible to prevent water from leaking between the fitting and the bucket. (Photo 3f)



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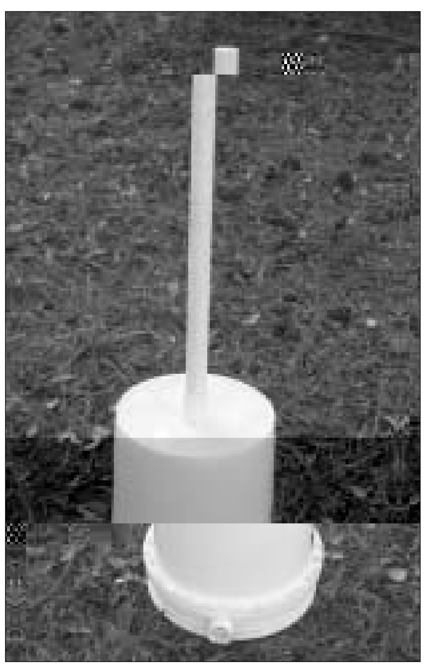
g. Slip the 22-inch piece of 1-inch pipe (A) into the male/slip fitting on the bottom of the bucket. This pipe will direct water from the mechanical filter to the bottom of the biological filter. (Photo 3g)



3.

h. Slip the 10-inch piece of 1-inch pipe (B) into the female/slip fitting on the inside bottom of the bucket. This will be the overflow from the mechanical filter into the biological filter portion of the barrel. (Photo 3h)

3.

j. Place the 3-inch pipe, holes toward the bottom, inside the bucket over the top of the 1-inch center pipe. This outer pipe forces the water to travelough the(Photo 5c)the 1-inch cebarrel..arrel. Cu(Pl2(pi242 3-inch pipe)36.8(.4*0310.02901 r 2 -1.1(4w)1367.3(M0 with t the0792he el.

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f. Cut a 1 ½-inch hole in the plywood using the traced circle from the elbow as a guide.

g. Slip a 7-inch piece of 1-inch pipe (E) into the elbow, with the other end dropping through the hole in the plywood. (Photo 4g)

5. Pump-to-filter assembly

a. Place a ¾-inch, 90-degree elbow (N) on each end of the 27-inch piece of ¾-inch pipe (F) and turn them so they are facing the same direction.

b. Slip the 35-inch piece of ¾-inch pipe (G) into one of the 90-degree elbows and the 3-inch piece of ¾-inch pipe (H) into the other 90-degree elbow.

c. Place the 35-inch piece of ¾-inch pipe through the hole in the uncut half of the top of the filter barrel. (Photo 5c)

5.

6. Attaching the pump

a. Purchase or locate a pump with a 200- to 600-gallon-per-hour flow rate.

b. If you have a pump with a ¾-inch threaded outlet, you can attach a female/slip fitting to the pump and slip the 35-inch piece of ¾-inch pipe (G) into the other side.

c. If you have a pump with a ¾-inch non-threaded outlet, you can wrap Teflon® tape around the pump outlet until it is thick enough to slip inside the ¾-inch riser pipe. You may also wish to attach a 90-degree elbow to the inlet of the pump over the inlet screen and direct it at a 45-degree angle to the bottom (optional). This will help pick up wastes and debris from the bottom of the tank.

d. If your pump has a ½-inch outlet you will need a bushing/reducer fitting that will reduce the ¾-inch riser pipe to match the pump outlet.

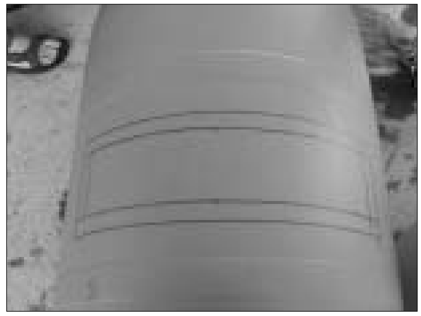
e. If you use a pump with a capacity greater than 500 gallons per hour, you may wish to insert a ball valve in the middle of pipe (F) to control the water flow to the mechanical filter.

7. Window installation (optional, but desirable for viewing fish)

   a. Place the 6-inch x 20-inch piece of Lexan® near the center of the barrel. Lexan® is more flexible than Plexiglas® and is less likely to crack or break during installation. Using a marker, trace the outline onto the side of the barrel. Have someone else hold the Lexan® flat to the curved barrel. (Photo 7a)

7.

   b. To mark the area to be cut out, measure and make a mark 1 inch in from each of the corners along the sides. Connect these marks with a straight edge to create an inner rectangle that is 1 inch smaller on all sides than the original outline. This leaves a 1-inch overlap to attach and seal the window. (Photo 7b)



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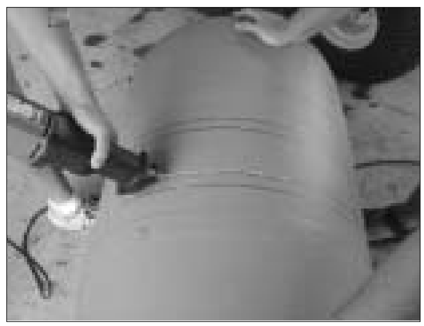
   c. Cut out the inner rectangle using the saber saw. (Photo 7c)



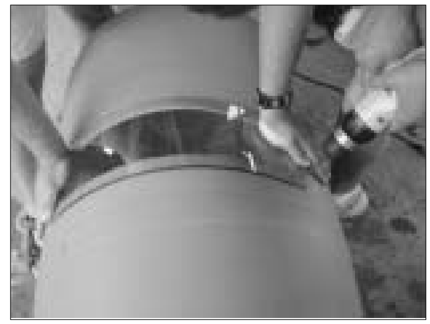
7.

   d. Smooth any rough edges with sandpaper. (Photo 7d)

7.

   e. Hold the Lexan® window firmly to the barrel, taking care to line it up.

   f. Drill the holes at the corners (½ inch from each corner), first securing them with bolts as you go. (Photo 7f)



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   g. Drill seven holes across the top (2 ¾ inches apart) and three holes down each side (2 ½ inches apart). (Photo 7g)

7.

   h. Remove the window and put on rubber gloves.

   i. Apply Plumber's Goop® liberally around the edge of the opening. (Photo 7i)

7.

j. Put plenty over the top of the drilled holes. It will take more than half the tube. Work quickly.

k. Replace the window and line up the holes. Place a drop of Goop® over each hole. Working from one end to the other, place a regular washer on the bolt and thread it through the hole. Secure a stainless steel washer and nut to each bolt on the inside of the barrel. Work quickly to thread and secure bolts before Goop® gets too stiff. (Photo 7k)

7.

l. Allow Goop® to cure for 24 hours before adding any water to the barrels.

8. Connecting the barrels

a. Thread one of the 1-inch male/slip fittings (J) into each of the tee eliminators. (Photo 8a)

8.

b. Make sure not to cross the threads and secure as tightly as possible. You may want to lubricate the threads with water.

c. Place the barrels close together and fit the remaining 7-inch piece of 1-inch pipe (E) into each of the male/slip fittings. (Photo 8c)

8.

d. Thread one of the 1-inch male slip fittings (J) into the tee eliminator on the inside of the fish barrel. Fit a ¾-inch, 90-degree elbow (N) into the slip end of the 1-inch male fitting to direct the returning water in a counterclockwise circular flow pattern. (Note: If traditional bulkhead fittings are in place, the 90-degree elbow should slide into the female fitting.)

9. Finishing up (Photo 9)

a. Move the barrels to their final location. Locating the barrels near a drain or sink makes it easier to add or remove water.

b. You may wish to consider gluing the pvc pipe joints of the pump-to-filter assembly. This is the only piping under pressure that could come apart. The other fittings should be tight enough that they don't leak. If you do find a leak, you can go back and wrap the screw fittings with Teflon® tape, glue the pipes together, or use the remaining Plumber's Goop® as a patch.

c. Fill the fish barrel with water to a few inches below the filter return pipe and check for leaks around the window.

d. Put a few gallons of water in the filter barrel and adjust the distance between

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the barrels, making sure the connecting pipe fits snugly between the barrels. The barrels are very difficult to move once full, so make sure to put them where you want them to stay.

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e. Plug in the pump (in a GFI-protected plug), circulate the water, and check for and repair any leaks.

Breaking in the system

As with any aquarium or other RAS, there is break-in period. It takes approximately 45 days for a biofilter to colonize with the appropriate bacteria (and) to break down fish wastes. This break-in phase can be helped along by the addition of a few fish to the system. Their waste will provide the food the bacteria need to get established. After the filter is populated with the bacteria, add more fish to the system.

The carrying capacity of the system is generally determined by the filter's ability to remove solids and break down the fish waste, a process called the nitrification cycle. It is described in greater detail in SRAC publication 454, "Recirculating Aquaculture Tank Production Systems: Management of Recirculating Systems." Simply put, if you do a good job of removing the solids from the system with the mechanical filter, the amount of surface area present in the biofilter will determine how much bacteria you can grow, how much you can feed the fish, and, thus, how many pounds of fish the system can hold. A general rule of thumb is that it takes at least 5 square feet of biomedia to handle 1 pound of fish being fed at 2 percent of body weight per day.

Selecting mechanical and biofilter media

The media for this system were not specified so that individuals could experiment with different media and see what works best for them. Inexpensive possibilities for mechanical filter media include sponges; pillow filling (spun nylon), available in craft stores; floor scrubbing and polishing pads (with no soap or polish residue); or a commercial fiber mat material. Look for a nontoxic material that will allow water to pass though while retaining solids. Also look for materials that can be easily cleaned.

There are a number of possibilities for biofilter material as well. Nontoxic material with a high surface area-to-volume ratio is a good place to start. Finding these materials and calculating the surface area is a great activity for students. Aquaculture supply houses have many materials, but you may be able to find something locally as well. Examples of creative biofilter materials include cut-up soda straws, PVC pipe rings or shavings from a lathe, plastic forks, plastic egg cartons, Styrofoam® packing peanuts (remember they float), etc.

Using 1 cubic foot of commercial biofill (similar to long pvc pipe shavings) that has 250 square feet of surface area per cubic foot, the system could theoretically hold 50 pounds of fish. Using the same volume of 1-inch bioballs with 160 square feet of surface area per cubic foot, the system could theoretically hold 32 pounds of fish. These commercial biomedia materials are relatively expensive ($30 to $60 per cubic foot). However, you would have to cut up 322 feet of 1-inch pvc pipe into 1-inch lengths to get the same amount of surface area as 1 cubic foot of biofill material. The cost of the pvc pipe and the effort to cut it up brings the cost of the manufactured material into perspective.

These fish capacity calculations assume that all other water quality parameters are kept at optimum levels. Holding or growing 50 pounds of fish in this system would require the addition of pure oxygen and a variety of other management strategies beyond the scope of this publication. In reality, under typical classroom conditions, this system can be expected to hold 8 to 12 pounds of hardy fish such as tilapia or koi carp. For more information on tank production of tilapia, see SRAC publications 282 and 283. For more information on koi and goldfish, see SRAC publication 7201. If you select a species that requires temperatures outside the range of normal room temperature, you will have to heat or cool the water as necessary. Adding the optional deep-water air pump with an airstone in each tank will enhance the system's performance by helping to supply oxygen to the fish and to the bacteria in the biofilter.

System maintenance

General system maintenance includes keeping track of the water quality and quantity, feeding the fish, and cleaning the mechanical filter as necessary. If one or more water quality parameters moves outside acceptable levels, the easiest solution is to exchange some of the water. To avoid problems, you might consider changing about 10 percent of the water each week. If your replacement water contains chlorine, it will be necessary to add a chlorine remover to protect the fish and the bacteria on the filter.

Classroom activities

Teachers have used the following activities to demonstrate real-world applications of the math and science principles taught in the classroom.

- Determining the volume of fish culture vessels
- Calculating feeding rates and feed conversion ratios (FCR)
- Calculating fish growth rates
- Calculating water flow and exchange rates
- Converting English units to metric units
- Determining the surface area of filter media and culture tanks
- Testing the water and analyzing its chemistry
- Developing graphs from collected data
- Examining the internal and external anatomy of fish

A similar list of activities could be developed for each of the disciplines listed in Table 1. The possibilities are limited only by the knowledge and creativity of the teacher and students.

Conclusion

A wealth of anecdotal evidence suggests that RAS systems and activities provide exciting opportunities for learning. Teachers who use these systems claim that a number of other valuable, nonacademic lessons are learned as well. They say these systems:

- Motivate marginal students to participate and develop life skills that will enable them to continue their education and/or become productive members of the workforce.
- Give students a sense of responsibility and help them learn the rewards and consequences of that responsibility.

For more information on building and using an RAS for classroom instruction, visit
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Suggested readings

SRAC 282, “Tank Culture of Tilapia”

SRAC 283, “Tilapia: Life History and Biology”

SRAC 451, “Overview of Critical Considerations”

SRAC 452, “Management of Recirculating Systems”

SRAC 453, “A Review of Component Options”

SRAC 454, “Integrating Fish and Plant Culture”

SRAC 7201, “Species Profile: Koi and Goldfish”

Soares, S. J., J. K. Buttner and Dale F. Leavitt. 2001. Aquaculture Curricula Resource Guide: A Resource Tool for the Aquacul-ture Educator. Massachusetts Deparment of Food and Agriculture, MA. 59 pp.

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SRAC fact sheets are reviewed annually by the Publications, Videos and Computer Software Steering Committee. Fact sheets are revised as new knowledge becomes available. Fact sheets that have not been revised are considered to reflect the current state of knowledge.

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