# Planning for an AQUACULTURE SYSTEM in the Classroom

# CONTENTS



*Funding for the Aquaculture in Agriculture project is provided by the North American Association for Environmental Education and the National Oceanic and Atmospheric Administration eeBLUE Aquaculture Literacy Initiative's Aquaculture Literacy Mini-Grants Program.*

*Cohn, A., Flight, C., Frederick, A., Gallagher, J., Harpaz, G., Hauser, E., Kenney, A., Lang, A., Rekeweg, M., Van Leuven, T., Weaver, S., Wright, C., and Yalcin, K. 2025. Planning for an Aquaculture System in the Classroom. Maryland Sea Grant Publication UM-SG-TS-2025-01.*

# INTRODUCTION

## Bringing Aquaculture to the Classroom: A Collaborative Effort

The National Council for Agricultural Education (The Council) recently took a deep dive into their aquaculture resources. They found a mix of valuable content that was overly technical and a bit outdated. At the same time, Maryland Sea Grant (MDSG) had been searching for ways to help educators bring aquaculture into their classrooms. Their exploration led them to Career and Technical Education (CTE) programs, which turned out to be a promising gateway for integrating aquaculture into agricultural education.

As MDSG began developing new, teacher-friendly resources, they connected with The Council. That partnership sparked the formation of a dedicated team focused on updating and expanding aquaculture materials to better serve today's agricultural educators.

Teaming up with University of Maryland Extension, Carroll County Public Schools, Wisconsin Sea Grant, University of Wisconsin-Stevens Point Northern Aquaculture Demonstration Facility, and Fishnet restaurant, MDSG and The Council worked on this project through the eeBlue Aquaculture Literacy mini grant program entitled Aquaculture is Agriculture (4351410 eeBlue Aquaculture Literacy Mini Grant)—funded by the North American Association for Environmental Education (NAAEE) and the National Oceanic and Atmospheric Administration (NOAA).

Through this project, MDSG coordinators connected with agricultural educators from Canton Central School in New York and Mackay High School in Idaho. These educators brought their classroom experience to the table, helping to identify the most essential elements for an effective aquaculture teaching resource.

To ensure the final product truly meets teachers' needs, the team also conducted virtual interviews with educators from across the country who are actively using recirculating aquaculture systems (RAS) in their classrooms. Their insights were invaluable.

The result? A comprehensive, easy-to-follow resource guide designed to help educators take their first steps in selecting and setting up a RAS. Whether you're just beginning to explore aquaculture or looking to expand your program, this guide was built with you in mind—by educators, for educators.

This guide includes three sections:

1. Considerations before designing and implementing a recirculating aquaculture system
2. Best practices and proactive measures
3. System design and species selection

# PART I:

## Considerations Before Designing and Implementing a Recirculating Aquaculture System


### INTRODUCTION:

The initial planning stages for using recirculating aquaculture systems (RAS) in the classroom are essential to overall success. This section of Planning for an Aquaculture System in the Classroom identifies fundamental decisions and choices to assess your physical space, select an appropriately sized RAS, and involve school administrators, staff, teachers, and students in the project. This section covers key early decisions in four major categories:

1. Human Resources and Building Capital
2. Space Requirements and Physical System Considerations
3. Water Access and System Management
4. Educational Priorities

### HUMAN RESOURCES AND BUILDING CAPITAL

1. **Find a mentor.** Prioritize this step. Talk to your state Career and Technical Education (CTE) department, Department of Natural Resources staff, and/or local science supervisor to find other educators/professionals involved in aquaculture in your area.
    - Seek advice from a mentor on fish supply, permitting, fish feed, system design, and species selection.
2. **Engage project personnel.** Connect with the administration, facilities personnel, IT team, other school staff, and students who will be "founding members" of the aquaculture project. Motivate your local team and generate interest in the project.
3. **Build a community.** Involve parents and local businesses to leverage support for RAS as a project based learning model.
4. **Consider funding source.** With your project team, determine how to purchase the initial RAS system. Ensure you have the funding to sustain and maintain the project. Think beyond the initial system to the care and maintenance stages. Costs will include water quality testing kits, fish feed, backup equipment, etc.

## SPACE REQUIREMENTS AND PHYSICAL SYSTEM CONSIDERATIONS

Many common problems in RAS arise due to issues with the physical space where the RAS is located. Consider the following checklist to decide if your space is right for RAS.

- Space can support the weight of the RAS. Water is very heavy (about 8 pounds per gallon). A basement, greenhouse, or large shop space is usually best for larger systems. At a minimum, for larger systems, the space should have a concrete floor and drain. Stands, shelves, or tables that might be suited for a smaller aquarium should also be able to support the weight of the system with water, animals, plants, etc.
- Space is located away from doorways.
- Space is large enough for the full size of the RAS, with room to move around the RAS. For smaller aquariums, the space should allow access to all of the plumbing and filtration components.
- RAS, pipes, and power cords can be located away from foot traffic.
- Space is located away from windows/direct sunlight, or there is a way to mitigate direct light with blinds.

- Space has access to a reliable water source.
- Space has electricity, specifically via ground fault circuit interrupter (GFCI) outlets.
- Space has a proper amperage rating on the breaker box system to support the RAS based on your facilities manager's recommendations.
- The RAS will be visible. Visibility of the RAS will increase awareness and interest. A best practice is providing a live video stream of the RAS, which enhances the visibility of the RAS for the class and other community members.
- If any modifications are needed to ensure the space is suitable for RAS, work with administration and facilities personnel to receive permission.

## WATER ACCESS AND SYSTEM MANAGEMENT

Consider the following points to ensure your system is sustainable.

1. **Water access.** You will need to periodically drain water from the RAS and/or change water. Ensure your space is equipped for water changes. Ensure you have access to dechlorinated water, including a ready supply of non-chlorinated water stored for emergencies.
2. **Fish outcomes.** Consider what happens to the fish in your RAS at the end of the school year. Options may include holding the fish from year to year, releasing native fish in partnership with your state's natural resources agency, and consuming the fish in cooperation with other programs, such as a school culinary program.
3. **System access.** Ensure staff and/or students will be able to access the system on weekends or over extended break periods.

## EDUCATIONAL PRIORITIES

A RAS can be an excellent interdisciplinary learning tool. Consider the following as points to incorporate into your RAS education program.

- RAS may tie into CTE programs as well as Science, Technology, Engineering, and Mathematics (STEM) programs.
- Maintaining RAS can teach life skills such as responsibility and self-efficacy, in addition to meeting science and career education goals.
- Working with RAS can play into career pipelines and impart trade skills.
- Caring for the fish in a RAS is beneficial for caretakers' mental health.
- Consider specific, applicable agricultural science and science education standards.
- Educators may be motivated for many reasons, ranging from a personal passion to creating new courses and supporting existing courses.

When you have selected a space for your RAS and addressed these initial considerations, move to **Part 2: Best Practices and Proactive Measures.**

# PART 2:

## Best Practices and Proactive Measures

### INTRODUCTION

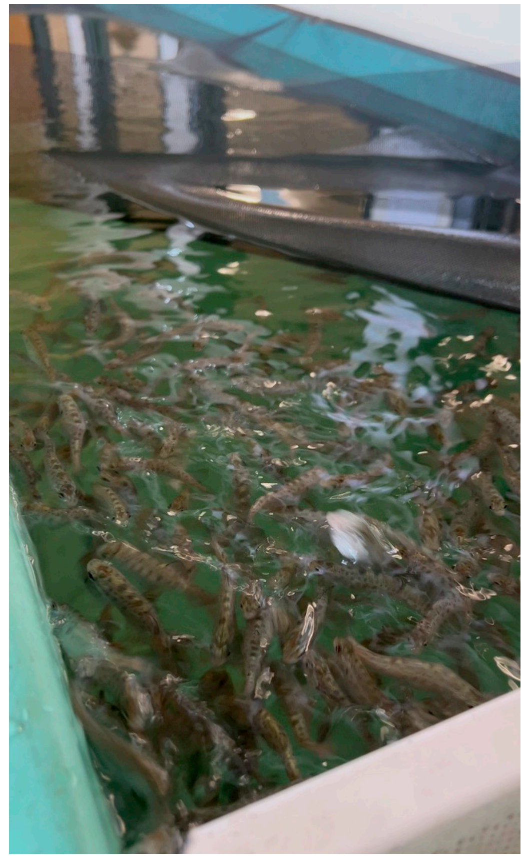
A recirculating aquaculture system (RAS) grows aquatic species while filtering and reusing the water. Recirculating aquaculture systems can range in size, from smaller tabletop aquariums to larger, special-design systems. In all RAS, maintaining water quality is paramount to allow fish and beneficial bacteria to exist in balance. This section presents best practices for maintaining a healthy RAS in the classroom.

#### Find a local peer network and/or mentors.

- Contact your state's career and technical education office and your local science supervisor to find other teachers working with aquaculture in the classroom.
- Reach out to aquaculture experts in the state natural resources agency, Sea Grant or agriculture Extension, 4-H, or state fish hatchery.

#### Develop maintenance schedules and student rotations.

- It is important that students take on the responsibility of maintaining the RAS.
- Plan how students will maintain the RAS. System design should be student-friendly and engage every interested student. Consider student talents and interests. Some jobs may rotate while others stay consistent throughout the school year.
- Keep records. Daily observations of water quality and fish behavior teach students about normal behavior and track important changes in system water quality. Make a plan to collect and record the following information:
    - o Daily water quality observation
    - o Daily fish count and fish behavior observations
    - o Daily mortality count
    - o Weekly to monthly fish sampling (length/weight) and/or growth observations
- Perform weekly data analysis with students in which the group examines patterns.
- Establish a weekly cleaning schedule. Consider weekends and extended breaks. Prep materials in advance for any weekend activities. Weekly water exchange in the system should be about 25% of water per week.
- Establish a feeding schedule based on species, life stages and growth rates.



- Perform a daily water leak check.
- Establish a pump maintenance inspection schedule, including flow rate, equipment function. Ensure correct flow and exchange rate of the tank (averages suggest a minimum of two tank exchanges per hour).
- Create and follow an end-of-day checklist, including:
    - Water topped off
    - Pumps on
    - Aerators on
    - Tank covers in place
    - Equipment put back where it belongs
- Create and follow a safety checklist, including:
    - Detailed safety check
    - Biosecurity
    - Inspection of equipment placement
- Annual system shutdown plan, over the summer or other break periods:
    - Drain water
    - Scrub tank without soap and dry
    - Take pumps offline and clean them
    - Let the biofilter media dry out (out of the sun to preserve beneficial bacteria) and store

### Maintain optimal water quality.

- Test your water and know where you are starting. Suggested tests include:
    - Dissolved Nitrogen
    - Alkalinity
    - pH
    - Chlorine
    - Hardness
    - Iron

*Note: May be able to seek assistance from your local university Extension service, town/county water or city managers, local bottling plant, or pet stores.*

- Ensure the flow rate of the system is maintaining at least two exchanges of total fish tank volume per hour.
- Consider what your final or maximum biological load (number and size of organisms) should be in your system. Initially stock your system with a lower density of fish.
- Condition the system for a week to three weeks before introducing fish. Run the system for several weeks prior to adding fish to ensure that the biofilter has been activated and can accommodate the biomass of fish and waste production.
- Know how to recognize common signs of a problem, including discolored water, excessive algae, odd solids in the water, or a bad smell.

### Mitigate noise from RAS.

- Locate the air pump in a separate room and/or use insulation to reduce noise. Consider whether an air pump is necessary.
- Consider the impact of noise on surrounding classrooms.
- Consider whether you will be able to communicate with students over the noise.
- Check decibel levels. There are apps to help with this.

### Ensure electric elements of RAS are safely installed.

- Ensure power cables are kept away from water.
- Use a drip loop in power cables.
- Ensure adequate cord length.
- Check outlets for covers.
- Ensure that outlets are high enough to be out of danger.
- Know how much power is available (total kilowatts).

### Manage equipment and prepare for emergency needs.

- Have replicates of all pipe sizes and fittings including bulkhead fittings.
- System design should include ways to turn off flow of water so you can replace parts of the system without needing to completely drain the system.
- Check to be sure equipment will not cause damage to the classroom space, due to weight or other factors.
- Be prepared for a power outage. Ensure you have needed equipment on hand and have a way to power equipment. Consider alarms, battery-powered equipment, generators, oxygen tanks, auxiliary water lines, and alternate locations to release or hold fish in the event of an emergency.

### Observe fish health and address issues.

- Have a fish health contact, like someone at your state natural resource agency.
- Observe fish behavior and tank conditions. Check for fish breathing heavily at the surface or rubbing at the sides of the tank. Count fish daily and check for uneaten food on the bottom of the tank or in the sump.

- Feed the fish, not the tank. Check to see if fish are responsive to feed by tossing a few food pieces into the tank. If fish respond to the food normally, add the rest of the daily feed. Other feed best practices:
  - o Plan for light feeding on weekends.
  - o Store food in watertight and rodent-proof containers. Check expiration dates on feed and consider freezing or preserving food. Ensure food is fresh, not moldy or rancid.
  - o Daily rate of gain should be lower than a production hatchery. Calculate and explain daily feed rates to students.
- If you identify an issue, common solutions can include:
  - o Testing water quality
  - o Limiting fish stress with lower light levels, fewer student interactions, or skipped feedings
  - o Performing a water change or adding water softener salt as treatment
  - o Consulting an expert if you suspect disease
- Know your school's procedure for disposing of biological waste such as effluent and mortalities. Remove mortalities quickly and track conditions for patterns. Make students aware early that fish will die. Plan euthanization and culling procedures based on approved techniques and procedures. Have a media plan with your school in case of media inquiries.

### Maintain biosecurity.

- Use sterile techniques in all procedures and ensure students understand the importance of sterile nets, boots, etc.
- Ensure there is adequate space for equipment and material storage. Hang nets and other equipment rather than laying them on a table or floor.
- Use aquaculture equipment only for aquaculture. Designate equipment for each system or piece of equipment.
- Use a disinfectant approved for aquaculture.
- Establish biosecurity protocols, like self-reporting procedures and disinfectant protocols.
- Place appropriate biosecurity and safety signage around the space.
- Develop a protocol for introducing new fish, including a quarantine period and proactive treatments.

### Plan for an oxygen source.

- Ensure there is enough oxygen entering the RAS based on the number of fish in the system.
- Consider using air pumps or an air compressor to maintain optimal oxygen levels.

### Decide how to manage physical access to the system during and outside of school hours and/or holidays.

- Consider whether students or staff will be able to access the system on weekends.
- Ensure there is someone who can take over feeding and maintenance if you are away for a period of time.
- Ensure everyone who needs access to the system has access to it.
- Ensure the system is being maintained over breaks.

# PART 3:

## System Design and Species Selection

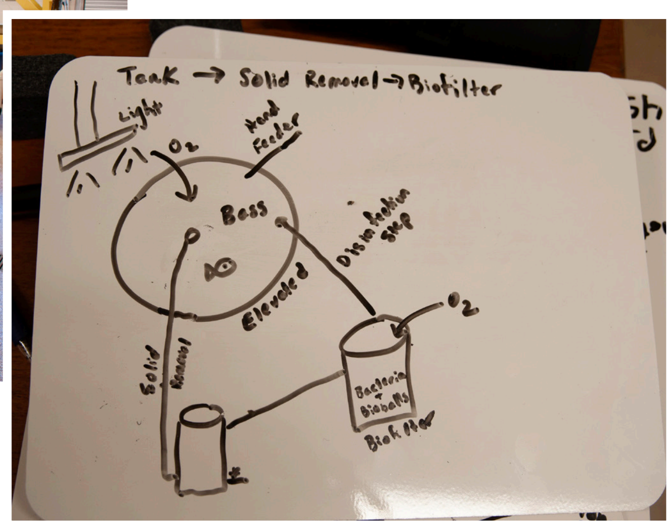
### INTRODUCTION

Indoor recirculating aquaculture systems (RAS) provide a variety of hands-on opportunities for students. Regardless of RAS size, students will learn important principles of biology, chemistry, engineering, mathematics, agriculture, as well as develop life skills and confidence. There are a variety of RAS designs available. This guide highlights two popular designs: a smaller tabletop aquarium and a larger floor design. Consider your space, educational goals, budget, and other factors to select the system and species that are right for your project.

### SELECTING A SYSTEM

Is a small tabletop version or large floor version right for you? Consider the following factors:

- System dimensions and your space: be sure to build in additional space around the RAS for students to work in.
- Budget: a larger system will require a larger budget
- Time available: a smaller tabletop system will likely be less time-intensive to construct and maintain.
- Experience level: novices who have not raised fish before may consider starting with a small system to learn the basics. You can always scale up in the future.



## System Requirements

<table>
<tr><th>Tabletop model</th><th>Floor model</th></tr>
<tr>
<td><br>• 18x30 inch footprint<br>• Supportive stand able to support the tank weight (usually 80-200 pounds)<br>• Access to power (GFCI outlet)<br>• Electrical capacity to power an aquarium pump rated for 20 gallons (~20 watt)<br>• Generally least expensive option</td>
<td><br>• 64 square feet of space will account for system footprint and access space<br>• Access to power (GFCI outlet)<br>• Floor drain<br>• Access to water<br>• Aeration source (compressor or air pumps)<br>• Floor must support the weight (usually around 2,000 pounds). Should be on the ground floor of the building or basement.<br>• Estimated electrical requirement of 60 watts<br>• Generally more expensive</td>
</tr>
</table>

*Note: This system requirements table includes information for two example systems. Please refer to Appendix A for a tabletop model building guide and to Appendix B for a floor model building guide. Consider using these models as a base guideline. There are many ways to customize these models to fit your space and needs. The desktop design model was developed as a publicly available source from the National Agriculture in the Classroom program (National Agriculture in the Classroom, 2018).*

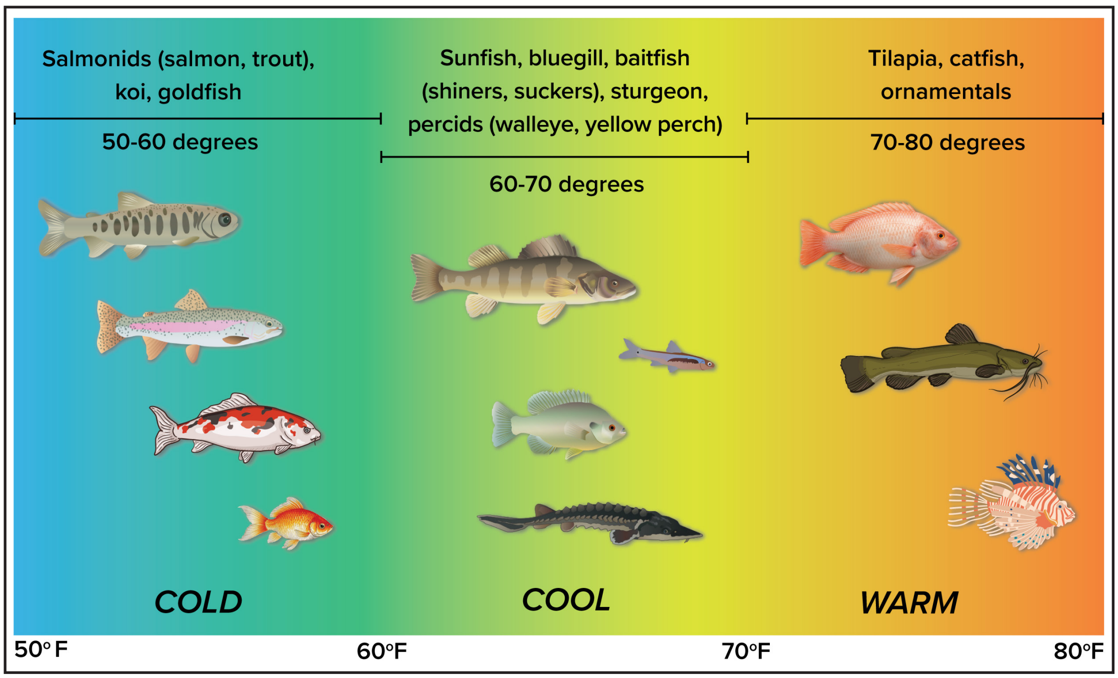
## SELECTING FISH SPECIES

Before selecting fish species, assess the environment of your RAS space and consider local fish supply. This is part of the decision-making process; consider these aspects carefully before purchasing, transporting, and stocking fish.

### Temperature

A best practice is to select a fish species with an optimal temperature range aligned to the average water temperature in your RAS space. This will save time and money.

- Determine the temperature extremes and average temperatures of the RAS space.
- Consider whether heat and/or air conditioning are consistent throughout the week.
- Consider whether you have the ability to monitor and control the temperature, maintaining a constant temperature, or if the fish may need to survive some temperature fluctuations.




### Lighting

Your tank should not be exposed to direct sunlight. Assess your RAS space for lights that may turn on suddenly and lights directly over the tank. Consider dimmers, blinds, and/or a darkened tank in very bright environments. Ensure fish have areas to shelter from bright light.

### Fish Availability

Consider what fish can be supplied in your area. There may be opportunities to procure fish for free. Consider fish native to your area.

### Biological Load

Consider how large fish will grow and what biological load your system can handle. Always start smaller than you think. For example, for ornamental aquarium fish, a good rule is 1 inch of fish per gallon of water. A floor tank can take about 0.25 pounds of fish per gallon or 30 kilograms of fish per cubic meter at maximum densities.

# RESOURCES

## Other System Design Guides

- How to Build a Low-Cost, Small-Scale Aquaponic System
    - Franchini, A., Izursa, J. L., & Little, N., (2024). How to Build a Low-Cost, Small-Scale Aquaponic System (FS-2023-0698). University of Maryland Extension. go.umd.edu/FS-2023-0698
- Classroom Aquaponics System Assembly and Maintenance Guide
    - National Agriculture in the Classroom. (2018). Classroom aquaponics system assembly and maintenance guide. https://cdn.agclassroom.org/media/uploads/2018/06/11/Aquaponics_Instructions.pdf

## Nutrients and Biological Factors

- How to Start a Biofilter
    - DeLong, D. P., & Losordo, T. M. (2012). How to start a biofilter. SRAC Publication No. 4502. https://srac.msstate.edu/pdfs/Fact%20Sheets/4502%20How%20to%20Start%20a%20Biofilter.pdf
- Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds.
    - Wurts, W. A. & Durborow, R. M. (1992). Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds. SRAC Publication No. 464. https://www.ncrac.org/files/inline-files/SRAC0464.pdf
- EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers

## Additional Educational Resources

- Fish Oil, Really? - Lessons on Omega-3 fatty acids from Maryland Sea Grant
- Maryland Sea Grant K-12 Resources
- Maryland Sea Grant Aquaculture Education
- University of Wisconsin Stevens Point Aquaculture Resources
- An Overview of Aquaponic Systems: Hydroponic Components
    - https://www.ncrac.org/files/inline-files/hyroponic_components.pdf
- University of Maine Center for Cooperative Aquaculture Research
- Illinois-Indiana Sea Grant Curriculum: Aquaponics: Farming Fish, Growing Greens
- Northeastern Regional Aquaculture Center Publications
- Southeastern Regional Aquaculture Center Fact Sheets

# APPENDIX A

## Classroom Aquaponics System Assembly and Maintenance Guide

# Table of Contents

# Materials


**Assembly Materials:**

- 12-14 quart clear storage tub (approximately 17"L x 12"W x 6"D)*
- 20-24 quart clear storage tub with lid (approximately 17"L x 12"W x 10"D)*
- Measuring tape
- Drill or drill press
- 1" spade drill bit
- 3/4" spade drill bit
- 1/4" spade drill bit
- Swamp Cooler Overflow Drain Kit* (This is a seasonal/regional item. If it cannot be found at your local hardware store, it can be purchased online.)
    a. 1/2" MPT threaded overflow pipe with hex head
    b. Rubber washer
    c. 3/4" nylon nut
    d. Nylon drain with 3/4" garden hose threads on outside and 1/2" FPT threads on inside
- 40-90 gal/hr submersible fountain pump*
- Flexible tubing *(to fit the submersible fountain pump discharge opening)
- De-chlorinated water, approximately 15 quarts (see De-chlorination Procedure on page 9)
- Plastic cup, jar, or bottle, approximately 3" wide and 5" tall*
- Expanded clay pellets, 10 quarts*
- 10-1/2" Brooder clamp light with porcelain ceramic socket*
- 42 watt twist CFL daylight high wattage light bulb with medium base*
- Timer (for the light)*

**De-chlorination Materials:**

- Tap water conditioner

**Initial Cycle and Maintenance Materials:**

- Ammonium chloride*
- Freshwater aquarium water test kit that measures pH, ammonia, nitrite, and nitrate*
- Aquarium thermometer*
- Goldfish, 5-7 adult fish
- Fish food (goldfish flakes)
- Aquarium fish net*
- Aquarium fish cave*
- 5 small seedling plants (basil or other small herbs, lettuces, or any other small plant that tolerates wet soil well)

*These items are included in the **Classroom Aquaponics Kit**, which is available for purchase from agclassroomstore.com.

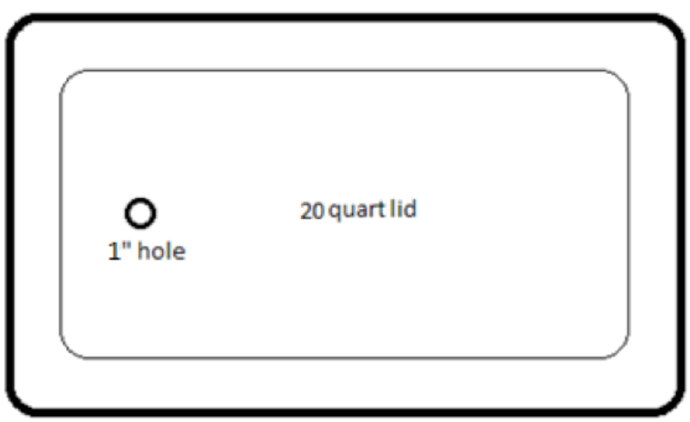
# Assembly Instructions

1. Assemble all materials and tools. The Classroom Aquaponics Instructional Video is available at https://www.youtube.com/watch?v=PF-HSttrLME&feature=youtu.be
2. Using the drill and 1” spade bit, drill a 1” hole in the bottom of the 12-quart storage tub, 3 inches away from the sides of the tub.

**STEP 2:**

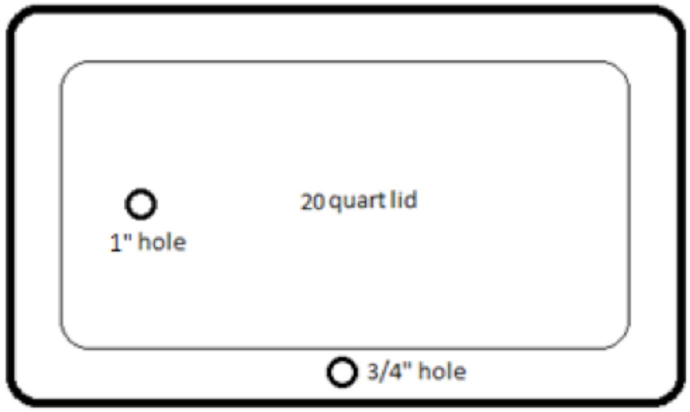

3. Drill a matching 1” hole in the lid of the 20-quart storage tub, such that the holes line up exactly when the 12-quart tub is nested on top of the lid. These holes are for the drain tube that will allow water to drain from the grow bed to the fish tank.

**STEP 3:**



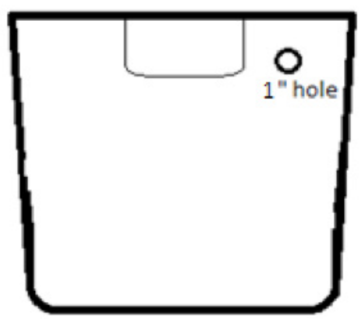
4. Drill a 3/4” hole approximately 1/2” from the edge of the lid or at the top of the front side of the 20-quart tub. This hole is for adding fish food.

STEP 4:



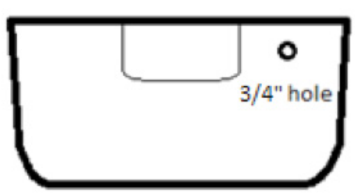

5. Drill a 1” hole near the top of one side of the 20-quart storage tub. This hole is for the pump cord and the water tube.

STEP 5:



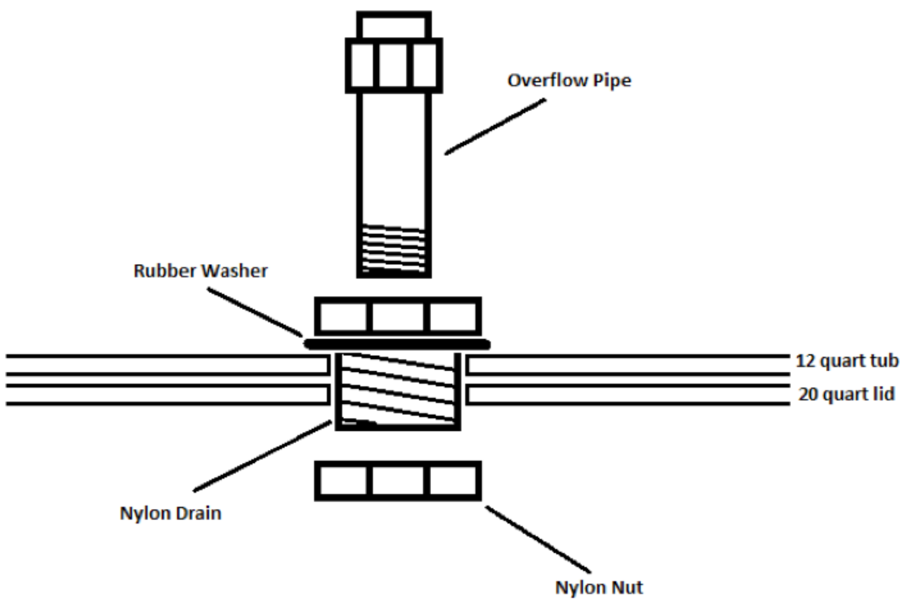

6. Drill a 3/4” hole near the top of one side of the 12-quart storage tub. This hole is for the water tube and must be located above the level of the drain tube.

STEP 6:



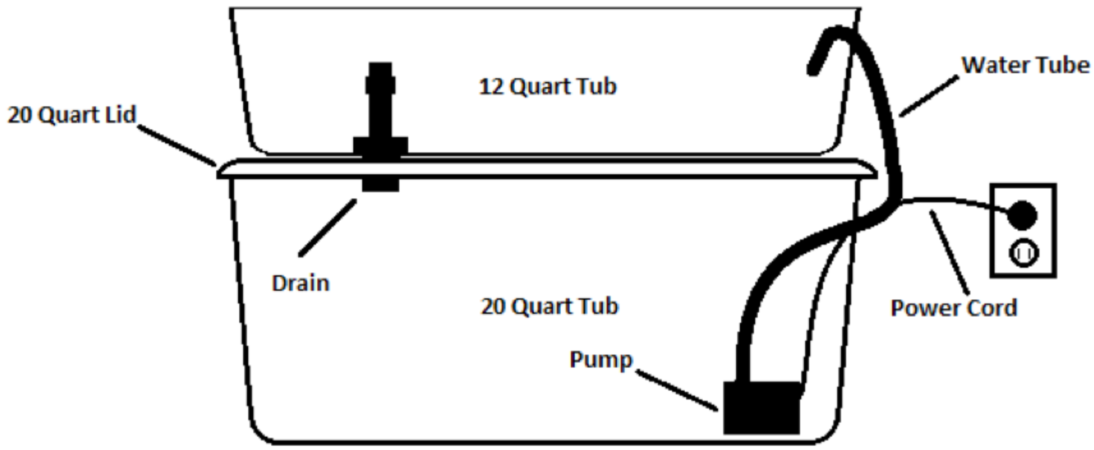
7. Install the swamp cooler overflow drain tube:
    a. Set the 12-quart tub on top of the 20-quart tub lid so that the 1” holes line up.
    b. Slide the rubber washer onto the threads of the nylon drain from the Swamp Cooler Overflow Drain Kit.
    c. Thread the nylon drain through both 1” holes, and lightly hand tighten. The drain should now extend through the bottom of the 12-quart tub and through the lid of the 20-quart tub.
    d. Thread the nylon nut onto the end of the nylon drain and hand tighten securely. Do not overtighten, as the nylon nut will deform and break.
    e. Thread the 1/2” overflow pipe into the inside threads of the nylon drain and hand tighten securely.
    f. You should now have a drain tube that sticks up inside the 12-quart tub and a drain through the bottom of the tub and the lid below into the 20-quart tub.

STEP 7:



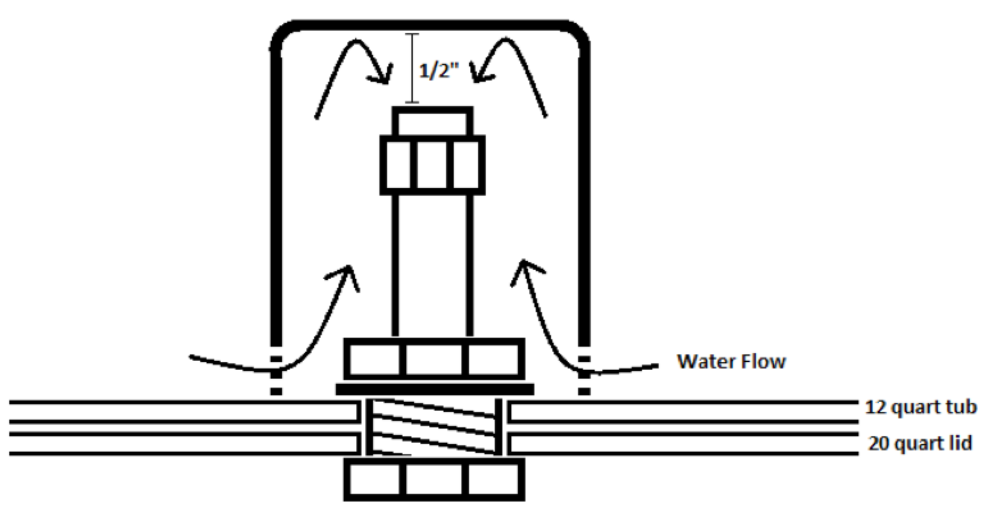

8. Install the pump.
    a. Place the water pump inside the 20-quart tub, either on one side near the bottom or on the bottom. Use the suction cups to attach it to the tub.
    b. Thread the pump power cord through the 1” hole next to the water tube.
    c. Thread the flexible water tube through the hole in the side of the 20-quart tub next to the pump power cord. Then thread the tube through the hole in the side of the 12-quart tub. The tube should extend about 3-4” into the 12-quart tub and about 6-8” into the 20-quart tub when they are stacked on top of each other.
    d. Push the small plastic outlet sleeve into the outlet of the pump.
    e. Slide the water tube snugly over the outlet sleeve.
    f. Turn the pump flow adjustment all the way up.

STEP 8



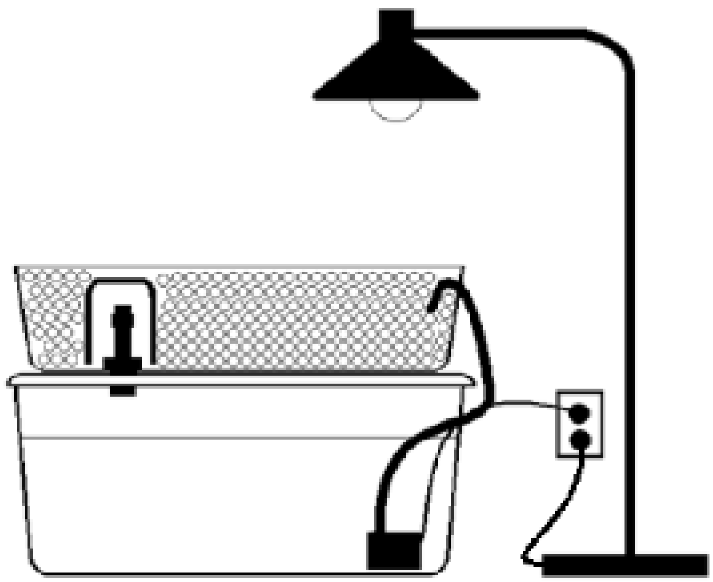

9. Fill the 20-quart tub about 3/4 of the way full of de-chlorinated water (approximately 15 quarts; see De-chlorination Procedure on page 9).
10. Set the upper tub/lid assembly on top of the 20-quart tub.
11. Plug in the pump, and verify that water is flowing from the bottom tub into the top tub with no leaks or spills. The upper tub should fill up to the top of the drain pipe, and then drain through the pipe back into the bottom tub.
12. Construct the drain cover.
    a. In order to prevent the drain from becoming clogged with clay pellets, plant roots, or other items, construct a drain cover. The cover can consist of any plastic cup-shaped object that is tall enough to leave at least a 1/2" space between the cover and the top of the drain tube when it is inverted over the drain tube. Soda bottles with the top cut off, plastic mayonnaise jars, or plastic cups are all good candidates.
    b. To construct the drain cover, simply obtain a cup-shaped object that leaves at least 1/2" of head room between the top of the drain and the cover. Drill several 1/4" holes around the rim of the cover so that water can flow inside when it is inverted over the top of the drain tube.
    c. Place the drain cover over the top of the drain.

STEP 12:



13. Rinse the clay pellets to remove any clay dust. With the drain cover in place, add clay pellets to the 12-quart tub until it is nearly full (about 10 quarts of clay pellets).
14. Plug the grow light into the timer. Set the timer so that the light is on for 16 hours during the day and off for 8 hours at night. Place the system underneath the grow light so that the light reaches the grow bed evenly. Keep the bottom tub (where the fish will be located) in the shade to limit algae growth.

STEP 14



15. Congratulations! You've constructed an aquaponics system! Now follow the instructions to run an initial cycle before adding fish and plants.

# De-chlorination Procedures

1. Determine whether your municipal water provider uses chloramine in the municipal water supply. Most small municipalities do not use chloramine, but many larger municipalities do.
2. If your water provider **does not** use chloramine, simply allow the water to sit in a container for a minimum of 24 hours, allowing the chlorine gas to off-gas.
3. If your water provider **does** use chloramine, purchase a tap water conditioner from any store that sells aquarium supplies. Follow the directions on the package to de-chlorinate the water.
4. If you are not able to determine whether your municipal water provider uses chloramine, err on the side of caution and follow Step 3 above.

(Stewardson, 2016)

# Initial Cycle Instructions

The initial cycle of an aquaponics system is very important. During this time, several important biochemical reactions (collectively known as “nitrification”) begin, which prime the environment for fish, bacteria, and plants to survive and thrive. Introducing contaminants or “bad” bacteria during this stage can have potentially catastrophic effects.

The initial cycle consists of three major phases. First, ammonia is introduced into the system by artificially adding ammonium chloride. During this phase, the nitrogen compounds in the system change form between “free” ammonia and ammonium, and vice versa. Free ammonia is extremely toxic to fish, while ammonium is relatively harmless. The higher the pH in the system, the higher the concentration of the toxic ammonia. Thus, it is important to closely monitor pH as well as the ammonia levels.

In the second phase, the ammonia (including both types) attracts nitrosomonas bacteria, which feed on the ammonia and convert it into nitrite. Nitrite is also extremely toxic to fish, behaving like carbon monoxide for humans. It is critical to watch for nitrite levels that are too high.

During the third phrase, nitrite attracts nitrospira bacteria, which feed on the nitrite and convert it to nitrate. Nitrate is harmless to fish and very beneficial to plants. Plants can efficiently absorb the nitrogen from nitrates.

1. Ensure that the water in the system is clean and has been de-chlorinated (see De-chlorination Procedures on page 9).
2. Ensure that the water is being cycled through the system by the pump.
3. Add ammonia to the system a drop or two at a time, testing after each addition, until you get a reading between 2 and 4 parts per million (ppm). If you exceed 6 ppm, just drain some of the water from the system and replace it with fresh water. (Note: If you’ve added ammonia but are getting a zero reading, you may have added too much ammonia and overwhelmed the test. Exchange some of the water for fresh water and repeat until you get a good reading.)
4. Test and record ammonia, pH, nitrite, and nitrate levels DAILY until the system is fully cycled.
    a. **Temperature:** A temperature reading between 77 and 84° F will promote good bacterial growth.
    b. **pH**: Try to keep the pH level in the range of 7.0–7.2. If you need to adjust the pH of the system, use a commercially available pH adjuster, which can be purchased at any store which sells aquarium supplies.
    c. **Ammonia:** If ammonia drops below below 2–4 ppm (Good news! Bacteria are working!), add more until you get back to that level.
    d. **Nitrite:** Once you see nitrites (you won’t initially), start checking for nitrates as well.
    e. **Nitrate:** At some point after the nitrite spike, you should see a nitrate spike. After the nitrate spike, look for ammonia and nitrite levels to drop.
5. Once ammonia and nitrite levels have both dropped to 0.5 ppm or less, the system is ready to accept fish and plants. At this point, you no longer need to add ammonia as the fish will produce enough.
6. Add fish as you would for any aquarium:
    a. Add 5-7 adult fish to the system.

b. Place bag containing fish from the pet store in the water, and allow the temperature to equalize (approximately 15-30 minutes).
c. Add approximately 1 cup of aquarium water to the bag, reseal, and allow to float again for 10 minutes.
d. Repeat the previous step until the bag is full, then use a net to transfer the fish from the bag to the aquarium.

7. Add plants:
    a. Clean any soil from the root systems of the seedlings to prevent contaminants from entering the aquaponics system.
    b. Gently nestle the roots of the seedlings in the clay pellets until the roots are completely covered in the moist pellets.

# System Maintenance Instructions

1. Maintain the water temperature between 77 and 84° F. Depending on the preferences of your fish species, you may need to adjust up or down.
2. Feed fish 2-3 times per day. At each feeding, give the fish no more food than they can consume in 2 1/2 minutes. Fish should be fine without feedings over the weekend.
3. Check water chemistry at least once per week. With fish and plants in the system, the chemical levels should be maintained as follows:
    a. pH – between 7.0 and 7.2
    b. Ammonia – less than 0.25 ppm (if higher, do a 20% water exchange)
    c. Nitrite – less than 5 ppm (any higher and you should do a 20% water exchange)
4. Monitor the water level. The bottom tub should be about 1/2 to 3/4 full.

# References


Bernstein, S. (2015). How to start an aquaponics system: Part 2. Retrieved from https://www.maximumyield.com/cycling-part-ii-starting-up-an-aquaponics-system-without-fish/2/1127

Stewardson, G. A. (2016). Standard operating procedure for Technology and Engineering Education's aquaponics system. Unpublished manuscript, Utah State University, Logan, UT.

# APPENDIX B

University of Maryland Extension
Solutions in your community

Sea Grant Maryland

Extension Bulletin, EB-423
May 2015

# The Aquaculture in Action Model: Recirculating Aquaculture System Design for the Classroom

Successfully incorporating an aquaculture program into the classroom requires an efficient and compact recirculation aquaculture system (RAS). These systems can take on many different shapes and sizes but all have a few common key components: 1) a grow-out tank for fish; 2) a mechanical filter (sump) for removing solids; 3) a biological filter (biofilter) for removing nutrients; and 4) pumps for moving and aerating water.

Teachers can purchase a number of "off the shelf" systems for their classrooms. In many cases, however, the disadvantages of purchasing a pre-packaged system may outweigh the advantages.

Increased cost, size and system design issues can make many systems inaccessible (budget or space constraints) or lead to problems over time (inadequate filter/flow capacity). Building a RAS provides teachers/students the opportunity to better understand system function and the role of each key component.

This publication describes the 260-gallon RAS developed by Maryland Sea Grant Extension for the

"Aquaculture in Action Program" (figure 1). This RAS system has been successfully constructed and used by K-12 teachers and students since 1998.

**Figure 1. The RAS system has been successfully constructed and used by K-12 teachers and students since 1998**

### The Aquaculture in Action RAS Costs about $800 to Construct

Tables 1 and 2 list the tools and materials needed to build a classroom RAS system. Aquatic Ecosystem part numbers are provided for your convenience and reference. Many parts, however, can be found in local hardware stores and aquarium supply stores.

**Table 1. List of tools needed to construct a RAS system**

| Item | Quantity | Part Number | System Component |
|---|---|---|---|
| Power drill with 5/16"drill bit | | | |
| Hole saws- 1¾ " 2 ", 3¼ " | | | |
| Metal file / Sandpaper | | | |
| Jigsaw | | | |
| Hacksaw or PVC Pipe cutters for up to 2" pipe | | | |
| Flathead screwdriver | | | |
| Pipe wrench or channel locks | | | |
| Razor blades | | | |
| Ruler | | | |
| Wax marker | | | |

**Table 2. List of materials needed**

| **Item** *(pipe thread specification or size)* | **Quantity** | **Part** | **System Component** |
|---|---|---|---|
| Transparent tank, flat bottom (12” dia, 4’ H) | 1 | T4 | Biofilter |
| Polyethylene tank, round, 48”x30” | 1 | TP210 | Tank |
| 32-gallon Rubbermaid Brute Trash Container | 1 | | Sump |
| Mag drive pump, 700gph, 60W | 1 | MD7 | Water pump |
| Air pump, 4.5psi (Rena 300) | 2 | | Air pump (biofilter) |
| 2” bulkhead (FIPT x FIPT) | 2 | TF6 | Tank & sump |
| 1” bulkhead (FIPT x FIPT) | 1 | TF3 | Biofilter |
| ¾” bulkhead | 3 | TF2 | Sump & Biofiler |
| 2” male adapter (MNPT x Slip) | 2 | 436020 | Tank & sump |
| 1” male adapter (MNPT x Slip) | 1 | 436010 | Biofilter |
| ¾” male adapter (MNPT x Slip) | 3 | 436007 | Sump & biofilter |
| ¾” male 90° ell (insert x MNPT) | 2 | 113B | Sump & biofilter |
| ½” male 90° ell (insert x MNPT) | 1 | 113A | Pump |
| ¾” female adapter | 1 | 435007 | Sump |
| ½” female adapter (FNPTi x insert) | 1 | 117A | Pump |
| ¾” male plug (NPT) | 1 | 62028 | Sump |
| 2” flexible coupling | 1 | FC5 | Tank to sump |
| 2” sweep elbow | 1 | SP20 | Tank to sump |
| 1” 90° Ell (Slip x Slip) | 1 | 406010 | Biofilter |
| ¾” 90° Ell (Slip x Slip) | 3 | 406007 | Sump & Biofilter |
| 2” ball valve (Slip x Slip) | 1 | SBW17 | Tank to sump |
| ¾” ball valve (Slip x Slip) | 1 | SBW13 | Sump |
| 2” strainer (MNPT) | 1 | 270561 | Tank |
| 1” strainer (MNPT) | 1 | 175255 | Biofilter |
| ¾” PVC pipe | 4 ft. | | |
| 1” PVC pipe | 2 ft. | | |
| 2” PVC pipe | 1 ft. | | |
| hose clamps | 4 | | |
| ¼" x 1½" brass bolts or stainless steel | 16 | | Window |
| ¼" brass nuts | 16 | | Window |
| Tube of 100% silicon | 1 | | |
| Teflon tape | 1 | | |
| Teflon paste (pipe dope) 8oz | 1 | | |
| PVC glue 8oz | 1 | | |
| PVC primer 8oz | 1 | | |
| ¾” ID clear flexible tubing | 8 ft. | | |
| 5/8” ID clear flexible tubing | 2 in. | | |
| 3/16" ID aquarium tubing | 64 ft. | | |
| 12” x 12” x ¼” plexiglass panel or Lexan | 1 | | |
| Kaldness media | ½ cu. ft. | Pond pet | Biofilter |
| | | | |

## Construction

### *Part 1: Tank Bulkhead (BH) Construction*

Cutting the bulkhead: Place tank upside down and mark 6” from the bottom of tank (figure 2). Place the center of the 3¼” hole saw on the mark and cut out a hole for the 2” bulkhead (figure 3). File the sides of the hole with a metal file to remove rough edges. Also lightly file or sandpaper the area of the tank around the hole (inside and outside). This prepares the tank surface so the silicone sealant will adhere to it better.

**Figure 2. Mark 6” inches from bottom of tank**

**Figure 3. Cut a hole for the 2” bulkhead**

Installing the 2” bulkhead: Prior to gluing the 2” bulkhead on the tank, complete a dry installation of the bulkhead to ensure proper placement and fit. Separate the 2” bulkhead into its three pieces (female- threaded end, male-threaded end and gasket).

Place the gasket on the male-threaded end. Insert the male-threaded end with gasket into the drilled hole from the inside of the tank. Thread the female-threaded end onto the male-threaded end from the outside of the tank to insure a smooth fit. Once you are comfortable with the bulkhead placement and fit, you can glue the bulkhead in place.

Take the bulkhead off the tank, leaving the gasket on the male-threaded end. Apply a uniform and continuous bead of silicon on the gasket. Insert the gasket into the drilled hole from the inside of the tank. Apply a bead of silicon to the edge of the female-threaded end of the bulkhead. Rethread the bulkhead.

Most bulkheads are reverse threaded; that is, they tighten by turning the opposite direction than normal. You should be able to get the bulkhead almost fully tightened by hand. Use channel locks for final tightening but exercise caution not to over tighten and pinch the gasket, which can lead to leaks (figure 4).

**Figure 4. View from inside the tank**

While tightening the gaskets, silicone will squeeze out. Smooth the excess silicone around both the inside and outside of the bulkhead with your finger. Smoothing the silicone improves the seal by removing air bubbles that can result in leaks. It also has a much nicer appearance. This seal and any others should be allowed to sit for 24 hours before testing (figure 5).

**Figure 5. View from outside the tank**

*You will use this standard bulkhead procedure (SBP) several times in the construction of your system.*

### *Part 2: Sump: Inflow Bulkhead Construction*

Place the trash can upside-down and mark 6" from the bottom. Using the SBP that you constructed, place a 2" bulkhead into the trash can/sump (figure 6). It is important that the trash can bulkhead is level with the tank bulkhead. If these two bulkheads are not level with each other, there will be stress on both units, which could lead to leaks.

**Figure 6. Using the SBP, place a 2" bulkhead into trash can/sump**

### *Part 3: Tank to Sump Bulkhead Plumbing*

Using a hacksaw or pipe cutter, cut four 3" sections of 2" PVC pipe. File or sand any rough edges.

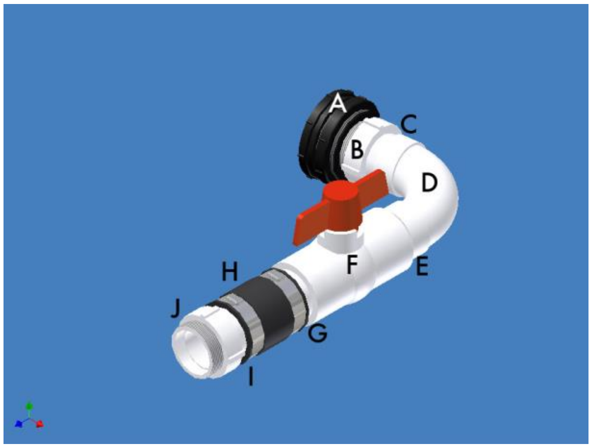
The tank- to-sump plumbing assembly should follow the specific order shown in schematic 1. Before any pieces are attached, thread 2" male adapters to the tank (A & B) and trashcan sump (J), respectively.

Use Teflon© tape or pipe dope on the threads to make a leak-proof seal.

Dry fit the assembly to check for proper fit. Assembly order: 3" section of 2" PVC pipe (C) to 2" sweep elbow (D) to 3" section of 2" PVC pipe (E) to 2" ball valve (F) to 3" section of 2" PVC pipe (G) to 2" flexible coupling (H) to 3" section of 2" PVC pipe (I).

*Note - Issues with fit may require longer segments of 2" PVC pipe.*

**Schematic 1. Assemble the tank-to-sump plumbing in the exact order shown**




If all of the pieces fit together and the tank and sump join properly, proceed with gluing the assembly together.

*Note – Prior to gluing, prime all PVC surfaces that will be glued. To apply glue, use the applicator that is attached to the lid of the PVC glue, applying the glue in a continuous layer to both surfaces to be joined. This process should be done when you are ready to join two pieces together because the glue dries very quickly. Take special care to insure that there are no gaps in the glue since this could lead to leaks.*

Remove the 2” flexible coupling (H) – **this is the only section not glued**. Glue the 3” section of 2” PVC pipe (I) into the 2” male adapter (J) on the trashcan sump. Working away from the tank (A), begin gluing the remaining pieces together. Finally, make sure the 2” flexible coupling (H) slides completely and evenly over the 3” sections of PVC pipe and tighten the metal clamps. This completes the plumbing assembly (figure 7).

**Figure 7. The completed plumbing assembly allows water to move from tank to pump**

### *Part 4: Sump Drain Construction*

If not already done, detach the sump from the tank by loosening the 2” flexible coupling. At 180° opposite the sump’s 2" bulkhead, mark 2½” from the bottom of the sump, place the center of the 1¾” hole saw on the mark and cut out a hole for the ¾” bulkhead. Thread a ¾” bulkhead into the sump using the SBP.

Completing the drain assembly (figure 8): Thread a ¾” male adapter (B) to the bulkhead (A) using Teflon tape or pipe dope. Using PVC primer and glue, start at the adapter and construct the drain assembly in the following order: 1½” section of ¾” PVC pipe (C) to ¾” 90° ell (D) to 1½” section of ¾” PVC pipe (E) to ¾” ball valve (F) to 1½” piece of ¾” PVC pipe (G) to ¾” female adapter (H). Finally, thread a ¾”male plug (I) to seal off the drain. This final step is optional and is intended as added insurance against leaks or accidentally leaving the ball valve open.

**Figure 8. Adding a 3/4" male plug (I) to seal off the drain is optional but can be added insurance against leaks or accidentally leaving the ball valve open**


## *Part 5: Sump: Outflow Construction*

Orient the sump with the inflow bulkhead on your left and the drain on your right. Using a 1¾" hole saw, drill a hole centered between the inflow bulkhead and drain, and 3½" from the top of the sump. Thread the ¾" bulkhead into the sump using the SBP.

External Plumbing (figure 9): On the outer bulkhead, thread the ¾" male 90° ell using Teflon tape or pipe dope. Attach a 4 ft. section of ¾" (ID) clear flexible tubing to the male 90° ell. Secure the tubing with a hose clamp.

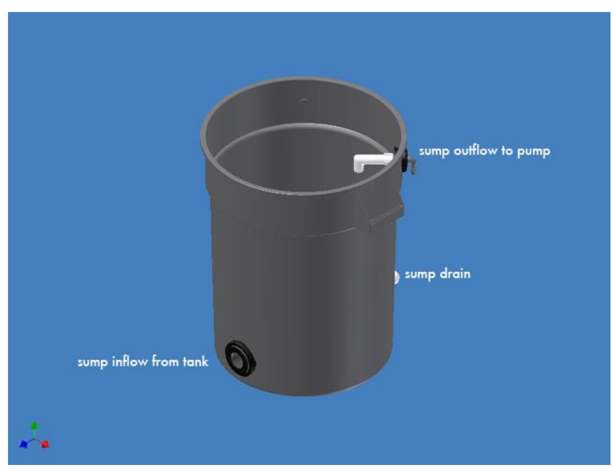
**Figure 9. When installing the external plumbing, be sure the 90° ell and the tube are perpendicular to the floor**

Internal Plumbing (figure 10): On the inner bulkhead, thread a ¾" male adapter. Follow the adapter with a 3" section of ¾" PVC pipe, ¾" 90° ell, and a 5" section of ¾" PVC pipe going down into the sump. This orientation draws water from below the sump's surface and eliminates the entry of air that could affect the water pump. It is not necessary to glue these pipes.

**Figure 10. The internal plumbing draws water from below the sump's surface**

The final configuration of the sump (minus the sump-to-tank plumbing) is detailed in schematic 2.

**Schematic 2. Final sump configuration**

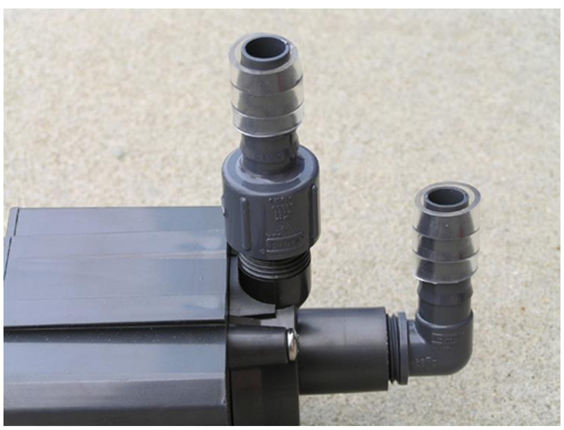


## *Part 6: Pump: Inflow/Outflow Construction*

Thread the 5/8" male 90° ell into the inlet of the pump using Teflon tape or pipe dope. **Do not** over tighten the male 90° ell or the receiving end of the pump may crack. Make sure when you are finished, the male 90° ell is oriented in the proper direction to receive the flexible tubing from the sump.

Put a 1" section of 5/8" clear flexible tubing over the male 90° ell. This sleeve will allow a snug fit for the ¾" clear flexible tubing coming from the sump. Attach a 5/8" female adapter to the outlet of the pump using Teflon tape or pipe dope. Put a 1" section of 5/8" clear flexible tubing over the 5/8" female adapter. This sleeve will allow a snug fit for the ¾" clear flexible tubing going to the biofilter (figure 11).

**Figure 11. Clear flexible tubing will ensure a snug fit for tubing going to the biofilter**



Trim the ¾" clear flexible tubing coming from the sump so that there is a straight path for the water from the sump to the pump inflow. Slide a hose clamp over the ¾" clear flexible tubing coming from the sump, attach the tubing to the male 90° ell with sleeve, and tighten the clamp. Attach a 4' section of ¾" clear flexible tubing to this 5/8" female adapter with sleeve and secure it with a hose clamp (figure 12).

**Figure 12. Use hose clamps to secure clear flexible tubing**

*This ¾" clear flexible tubing will be trimmed after the biofilter inflow is constructed.*

## *Part 7: Biofilter Inflow Construction*

Using a 1¾" hole saw, drill a hole centered 24" from the bottom of the transparent flat bottom tank biofilter). Thread a ¾"bulkhead into the biofilter using the SBP (figure 13).

**Figure 13. Thread a ¾" bulkhead into the biofilter using the SBP**

Thread a ¾" male 90° ell to the outer bulkhead using Teflon tape or pipe dope. Rotate the male 90°

ell so that it points straight down. Trim the ¾" clear flexible tubing from the pump outflow to the appropriate length so there is a straight path for water flow. Attach the section of ¾" ID flexible tubing from the pump outlet to the male 90° ell and secure with a hose clamp (figure 14).

**Figure 14. Rotate the male 90° ell so that it points straight down**

Thread a ¾" male adapter into the inner bulkhead. Since this piece is entirely internal and leakage is not a concern, you do not need to use Teflon tape or pipe dope. Follow the adapter with a 1½" section of ¾" PVC pipe, a ¾" 90° ell (rotated straight down) and a 20" section of ¾" PVC pipe. **Do not** glue this assembly (figure 15).

**Figure 15. Since this piece is entirely internal and leakage is not a concern, you do not need to use Teflon tape or pipe dope**

### *Part 8: Biofilter Outflow Construction*

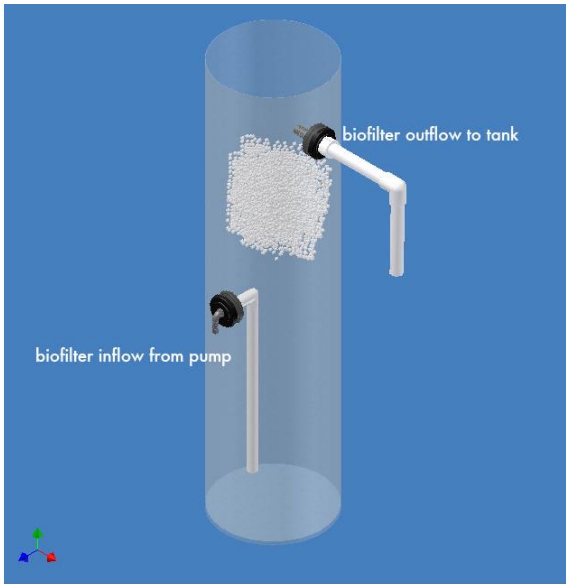
Orient the biofilter so the inflow is on your left. From the biofilter inflow, move 90° counterclockwise to mark the placement of the outflow. Using a 2" hole saw, drill a hole centered 6" from the top of the biofilter. Thread a 1" bulkhead into the biofilter using the SBP. Thread a 1" strainer to the inner bulkhead (Teflon tape or pipe dope is not needed). **Do not glue**.

The strainer can be removed from the bulkhead for cleaning. Thread a 1" male adapter to the outer bulkhead using Teflon tape or pipe dope. Follow the adapter with a 10" section of 1" PVC, a 1" 90° ell, and a 12" section of 1" PVC pipe. Gluing is not recommended, allowing pipes to be easily removed for later adjustments you may make (figure 16).

**Figure 16. Do not glue this section in case you want to make adjustments later**

The final configuration of the biofilter should look like schematic 3.

**Schematic 3. Compare your biofilter installation to this diagram**



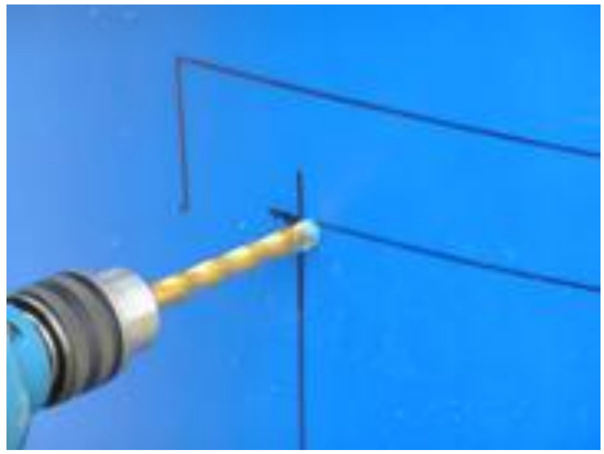

### *Part 9: Window Construction (optional)*

Mark a 1" edge along four sides of a 12" x 12" piece of Plexiglas, creating a 10" x 10" box. These form the lines along which you will drill the holes for the bolts (figure 17).

**Figure 17. Using a 12x12 piece of Plexiglas, you can add a window to your system**

Outline the 12" x 12" window on the side of the tank, centering it about half way between the bottom and top of the tank. Mark a 2" edge along the inside of this outline, creating an 8" x 8" box on the tank's side (this will be the actual window size). Drill 5/16" holes on each corner of the 8" x 8" square to allow for a starting point for the jig saw (figure 18).

**Figure 18. Drill starting holes with the jigsaw**



Using the jig saw, fit the blade into one of the starter holes just drilled, and cut along a line of the 8" x 8" square. Continue until the window is cut out (Figure 19).

**Figure 19. Continue cutting with the jigsaw until the space for the window is cut out**

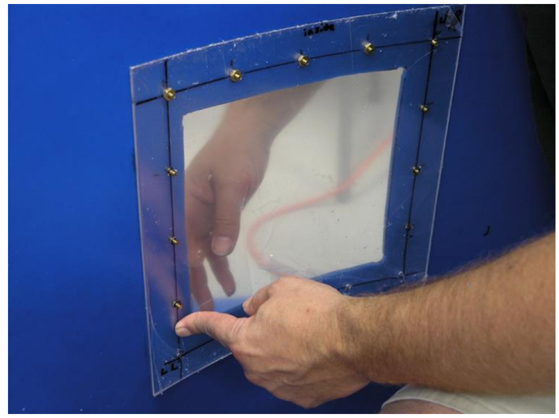
Take the 12" x 12" piece of Plexiglas and mark a dot in each corner of the 10" x 10" box. Then place three more dots on each of the four lines of the box, making sure to evenly space the dots (final count of 16 dots). Using a 5/16" drill bit, drill a hole at each dot. Drilling a hole slightly larger than the bolt size will prevent cracking the Plexiglas. Backing the Plexiglas with a piece of wood, holding it down firmly, and drilling at a steady speed also will prevent cracking (figure 20).

**Figure 20. Drilling at a steady speed will help prevent cracking**

From inside of the tank, center the 12" x 12" piece of Plexiglas over the cut window in the tank. With the help of a partner, hold it firmly in place. Using the window as a template, drill holes in the tank that correspond to those in the Plexiglas. Remember that the tank has a slight curve and the Plexiglas must be held in that position when the holes are lined up and drilled.

Start by drilling the top and bottom center holes, then working out to the corner holes. The side holes should be done last. As each hole is drilled, place a ¼" x 1½" brass bolt through the two aligned holes from the outside, threading a ¼" brass nut on from the inside until it is hand-tight. Using this technique, the window can be assembled one time without gluing (figure 21).

**Figure 21. Do a trial fit of the window without gluing**



Disassemble the window, marking the top right-hand corner. This mark will be used as a reference when placing the window the second time. Apply a thick bead of silicone along the window's 10" x 10" outline, covering all the holes. Apply another bead near the window's opening edge on the inside of the tank. Attach the 12" x 12" piece of Plexiglas to the tank with the nuts and bolts (nuts should be on the inside of the tank), following the same pattern as when you assembled it the first time (centers then corners) (figure 22).

**Figure 22. Apply silicone and attach with nuts and bolts**

Tighten all nuts by hand and then finish tightening using pliers and a screwdriver. Be careful to tighten each nut a little at a time to get uniform tightening. Do not over tighten or the Plexiglas may crack. As you tighten, excess silicone will be squeezed out on both the inside and outside of the tank. Remove and smooth the excess silicone inside the tank. Leave the silicone on the outside until it hardens, which will prevent smearing it on the window. Remove the hardened bead of silicone with a razor blade.

### *Part 10: System Set Up*

A convenient feature of Aquaculture in Action RAS is that it can be easily taken apart and reassembled if you need to move it.

Connect tank to sump (figure 23):

Make sure the two PVC ends are fully inserted into the flexible coupling. Note that the ball valve is in the open position to allow water flow between the tank and sump. Thread a 2" strainer to the inner bulkhead on the tank. This will prevent small fish from swimming into the sump.

**Figure 23. Use a strainer to prevent small fish from swimming into the sump**

Connect sump to biofilter (figure 24):

Attach the ¾" clear flexible tubing from the sump outflow to the male 90° ell of the pump. Attach the ¾" clear flexible tubing from the pump outflow female adapter to the biofilter inflow's male 90° ell. All tubing should be as straight as and free from kinks as possible to allow unobstructed flow. The more pipe or tubing the water flows through (with its corresponding friction), the less the flow rate will be, so trim any extra tubing. Finally, make sure the pump is placed where it won't be easily disturbed.

**Figure 24. All tubing should be as straight and as free from kinks as possible to allow unobstructed flow**

Connect biofilter to tank (figure 25):

Fill the biofilter with ½ cubic ft. of Kaldness filter media. Orient the biofilter so the outflow pipes are going into the tank. Attach the air pumps to the side of the biofilter or tank using strong Velcro tape. Place two weighted air lines with air stones in both the tank and biofilter.

**Figure 25. Orient the biofilter so the outflow pipes are going into the tank**

The final configuration of your RAS system should look like schematic 4.

**Schematic 4. Compare the system you built to the diagram**


Filling/Testing the System

Once the system is completed, give it 24 hours for all the glued, threaded, and fitted components to set. After 24 hours, fill the system, turn on the pumps and test for leakage. The only way to know that the system is not leaking is to fill it to capacity, run the pump, and wait at least 24 hours. Some small drips may occur but these can be easily fixed with 100% silicon or sometimes they seal themselves. A steady leak will need to be fixed and the system tested again. If no leaks occur, you are ready to start conditioning the water in preparation for adding fish.

Note: It may take several days for the Kaldness filter media to become neutrally buoyant and circulate in the biofilter.

**Water, Biofilter Conditioning & Maintenance**

***Part 1: Water***

Prior to starting your system, it is important to know and understand the source of your water. This information will help you make decisions about any corrections or remediation of the water needed prior to introducing fish. Your water source should be tested for pH, alkalinity, and calcium hardness. These initial tests are important because they affect other water quality parameters essential for fish culture.

You can assume that your water source is chlorinated unless your water comes from a well. If water is chlorinated, remember to either use a tap water purifying chemical that will remove chlorine or let the water sit for 24 hours to allow chlorine to de-gas naturally. The tap water profile should fit the following parameters:

| | | |
|---|---|---|
| **pH** | **6.5-9.0 (-log [H+])** | Indicates the hydrogen ion concentration in water. |
| **Alkalinity** | **75-200 parts per million (ppm) (e.g. expressed as mg $CaCO_3$)** | Buffering capacity of the water; indicates the quantity of bases in the water; carbonates, bicarbonates, hydroxides, phosphates, and berates. |

It is important to remember that carbon dioxide production from the biological filter will tend to drive the pH of the system lower as hydrogen ions accumulate from the disassociation of carbonic acid. This can be a problem if the tap water's pH and alkalinity are low. If the alkalinity level is not sufficient, the pH could continue a downward trend. A pH level below 6.0 can become dangerous for fish; below 5.0 is very critical and most often deadly for fish.

**Tap water often falls into one of three profiles:**

**1. *Soft, acidic water with low alkalinity*:**

**Precautions**:

Water with hardness levels below 50 ppm, pH below 6.5, and alkalinity below 50 ppm will be prone to pH fluctuations with the inability to self-correct.

**Modifications:**

One of the easiest solutions is to add agricultural limestone ($CaCO_3$) or calcium chloride ($CaCl_2$) to increase hardness and baking soda ($NaHCO_3$) to increase the alkalinity.

**2. *Neutral water with moderate levels of hardness and alkalinity:***

**Precautions:**

This water falls in the acceptable parameters and requires only regular monitoring.

**Modifications:**

None unless changes occur to profile.

**3. *Hard, basic water with high alkalinity:***

***Precautions:***

Instances of high pH (over 9.0) are very rare and would most likely be corrected when $CO_2$ is produced by the processes of the biological filter. Water with high hardness and/or alkalinity is generally considered beneficial since this will keep pH fluctuations to a minimum, reducing stress on the fish.

***Modifications:***

None unless changes occur to profile.

For more in-depth information on water quality and aquaculture, go to the Southern Regional Aquaculture Center at https://srac.tamu.edu/index.cfm/event/CategoryDetails/whichcategory/25/

## *Part 2: Biofilter Conditioning*

A well-established biofilm consisting of *Nitrosomonas* and *Nitrospira* on the Kaldness filter media may take a few weeks to form and depends on such factors as the water temperature, amount of food (ammonia) and oxygen available, and pH of the water. The bacteria also do not form simultaneously but rather in a sequence.

After *Nitrosomonas* has begun to convert ammonia to nitrite, the population of *Nitrospira* will start to increase. If for some reason the process is delayed or interrupted, increased levels of nitrite could kill the fish. This is the danger with stocking a new system too quickly.

Water testing, especially when starting a new system, is critical for the health of the system. With proper water testing, you will be able to detect the increase and decline in both the ammonia as *Nitrosomonas* becomes established and in the nitrite levels as *Nitrospira* becomes established.

Adding a few inexpensive aquarium fish to your system is the simplest start-up for a biofilter. These fish will naturally carry the beneficial bacteria and introduce them to the system, while also providing an ammonia source of food for the nitrification process.

There are several ways to speed up the process of biofilm formation in your aquaculture system. A commercial brand of prepared *Nitrosomonas* and *Nitrospira*, available as liquids or powders, will add large amounts of bacteria to a system. However, you will need to supply food for the bacteria to become established, so follow the rules of slowly stocking a system with fish. Using supplements can cut days off of the natural rate of biofilm establishment in an aquaculture system.

Supplementing the system with a nitrogen-containing compound is a second way to boost the bacterial population of a system. Formulas for boosting biological activity are:

For Ammonium Chloride

Number of gallons of water X .0113 = grams (g) to add to the system (to raise the ammonia level to 1 ppm in the system).

***Example: Ammonium Chloride***

250 gal X .0113 = 2.83g (add 2.83g to raise the ammonia level to 1 ppm in the system).

For Ammonium Hydroxide

Number of gallons of water X .0135 = grams to add to the system (to raise the ammonia level to 1 ppm in the system).

Periodic water testing will help you monitor the progress of your biofilm and the nitrification process. This will help you gain a better idea of when the system is ready for more fish.

## *Part 3: Maintenance*

Daily observations will insure that your system is working properly. Weekly water quality measurements will alert you to any issues with the biofilter or aeration systems. Changing 25% of the water monthly month will help maintain good water quality. Make sure the water you use for exchanges is chlorine free and approximately equal to the temperature and salinity of the culture tank.

**Conclusions**

Classrooms throughout Maryland are using the Aquaculture in Action RAS model as a tool for teaching science. The integrated nature of aquaculture provides a foundation for success in science, technology, engineering and mathematics (STEM) education.

For more information about incorporating aquaculture into the classroom, visit http://www.mdsg.umd.edu/topics/k-12-aquaculture-education/k-12-aquaculture-education

**Credits:**

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This publication, *The Aquaculture in Action Model: Recirculating Aquaculture System Design for the Classroom* (EB-423), is a series of publications of the University of Maryland Extension and Maryland Sea Grant College. The information presented has met UME peer review standards, including internal and external technical review. For more information on related publications and programs, see http://www.mdsg.umd.edu/topics/k-12-aquaculture-education/k-12-aquaculture-education