



Aquaponics Basics: How Fish, Plants, and Microbes Work Together

Integrating Fish, Plants, and Microbes for Recirculating Food Production

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This publication is intended for homeowners, educators, growers, Extension professionals, and community organizations interested in understanding the basic principles, benefits, limitations, and components of aquaponic systems.

What is Aquaponics and why does it work?

Aquaponics is a food production method that combines recirculating aquaculture, or fish farming, with hydroponic plant production. Fish release waste nutrients into the water, microorganisms convert those wastes into plant-available forms, and plants remove nutrients as they grow. When properly designed and managed, aquaponics allows water and nutrients to be reused within the system.

KEY TAKEAWAYS

- ✓ Aquaponics combines fish, plants, and microorganisms in a recirculating system.
- ✓ Fish waste provides nutrients, but solids removal and biofiltration are essential.
- ✓ Ammonia and nitrite can harm fish if water quality is not managed.
- ✓ Aquaponics can conserve water but requires reliable power, aeration, and monitoring.
- ✓ System success depends on balancing fish health, plant growth, and microbial activity.

AQUAPONICS SYSTEM DIAGRAM

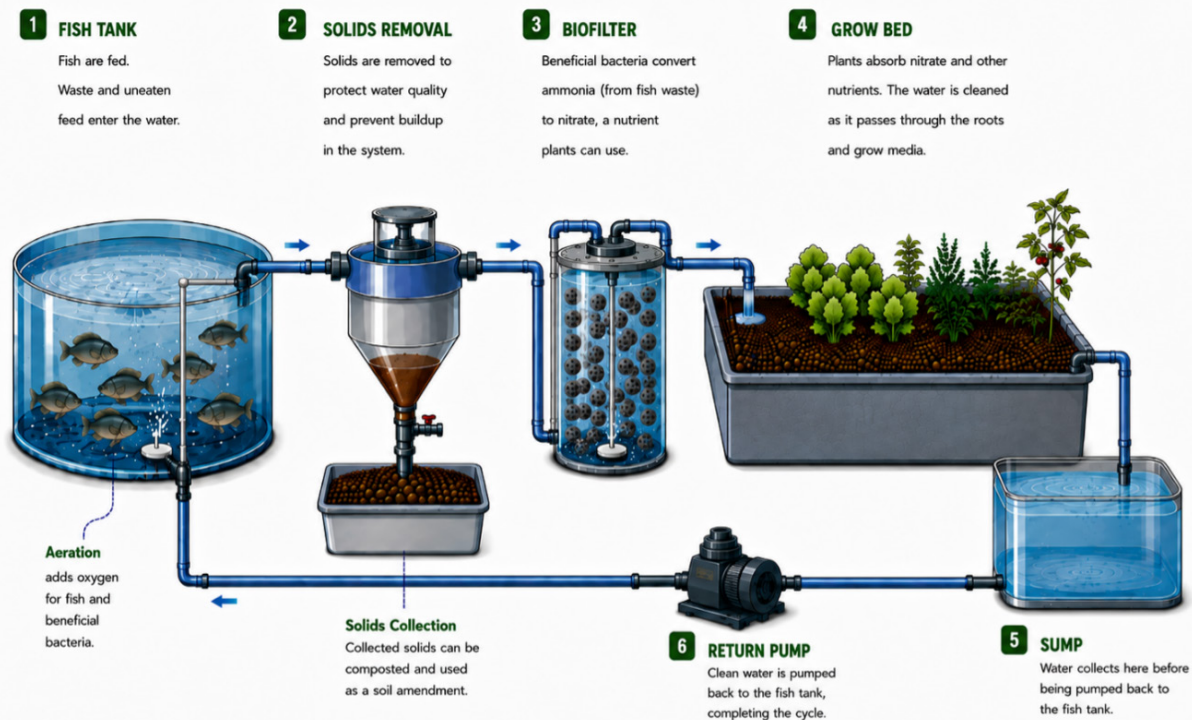


Figure 1. Basic components of a recirculating aquaponics system. Water flows from the fish tank through solids removal and biofiltration before reaching the plant growing area. Water then collects in a sump and is pumped back to the fish tank. Graphic by Matthew Recsetar using AI-assisted image generation.

Integrated fish and plant production has historical roots dating back to rice-fish culture in ancient China and Mesoamerican chinampas where crops were grown on floating islands in lakes. Modern aquaponics builds on these ideas by combining recirculating aquaculture with hydroponic plant production and using filtration, aeration, and microbial activity to convert fish waste into plant-available nutrients.

The Three Living Components of Aquaponics

An aquaponics system depends on the interaction between:

- Fish or aquatic animals that generate waste nutrients
- Microorganisms that convert waste into plant-available nutrients
- Plants that remove nutrients from the water

Maintaining balance between these components is essential for long-term system stability and productivity.

What are the benefits of aquaponics?

- Reduced water use compared to soil agriculture
- Reduced nutrient discharge into the environment
- Ability to produce fish and plants simultaneously
- Can be implemented in urban or non-arable areas
- Educational value for biology, engineering, and food systems
- Potential for year-round production in controlled environments

These benefits depend on proper system design, reliable water circulation, adequate aeration, and consistent water quality management.

Common factors to consider

- Aquaponics systems require active monitoring and management
- Water quality must be maintained for both fish and plants
- Aquaponics does not always eliminate the need for added fertilizers
- Not all crops perform equally well in aquaponic systems
- System failures (pump failures, oxygen loss, etc.) can rapidly affect fish health
- Aquaponics is not automatically organic (depending on regulations and inputs)

- Profitability depends heavily on scale, management and marketability

Why Aquaponics Matters in Arizona

Arizona's hot, dry climate and limited water resources make water-efficient food production systems especially important. Aquaponics can reduce water use by recirculating water through fish and plant production systems. However, Arizona conditions also create challenges, including high summer temperatures, evaporation, energy costs, and the need to maintain adequate dissolved oxygen for fish and beneficial microorganisms. Successful aquaponics systems in Arizona require careful attention to system design, shade, cooling, aeration, water quality, and fish and crop selection. Many of these considerations also apply to other arid and semi-arid regions where water conservation, heat management, and reliable aeration are important.

How Aquaponics Works

Although aquaponics systems vary in design, most systems contain several core components that maintain water quality and recycle nutrients. Because fish and beneficial microorganisms require oxygen, most aquaponics systems rely heavily on aeration and water circulation. Oxygen is critical to fish, biofilters, and mineralization and can be delivered via air pumps and air diffusers.

Core Components of an Aquaponics System

- Fish tanks
- Solids filtration
- Biofiltration
- Plant growing area
- Pumps and plumbing
- Aeration
- Monitoring equipment

Solids Removal

Uneaten feed and fish feces produce suspended and settleable solids that can reduce water quality if they accumulate. Solids should be removed before they break down further in the system. Many aquaponics systems draw water from or near the bottom of the fish tank so heavier solids can be carried to a clarifier or mechanical filter.

NITRIFICATION IN AQUAPONICS

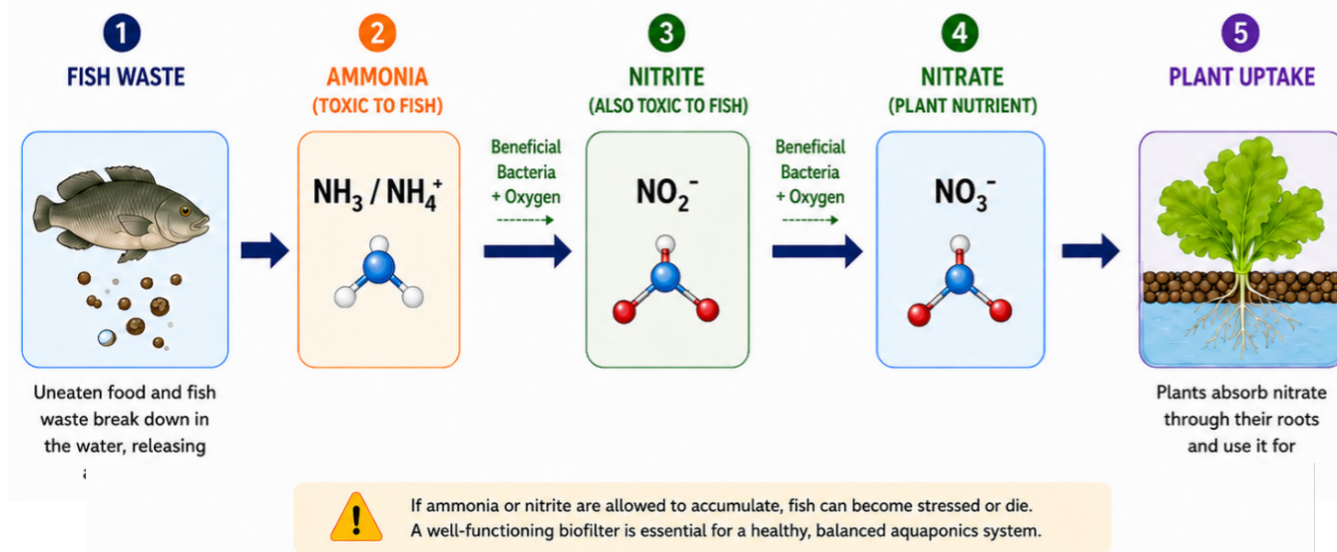


Figure 2. Simplified nitrification process in aquaponics. Beneficial microorganisms convert ammonia from fish waste into nitrite and then nitrate, a plant-available form of nitrogen. Graphic by Matthew Recsetar using AI-assisted image generation.

Solids removal methods

- Radial flow clarifiers
- Swirl filters
- Sedimentation basins
- Bead filters
- Microscreen filters

Nitrification

Nitrification involves the conversion of ammonia (released by fish) into nitrate. Nitrate is much less toxic to fish than ammonia or nitrite at typical aquaponic concentrations and is the major form of nitrogen used by plants. Ammonia is converted to nitrate by naturally occurring bacteria in the presence of oxygen that colonize surface area within the aquaponics system. Therefore, adequate surface area is required to eliminate all the ammonia produced by the fish each day, and this is done in a biofilter. A variety of media types can be used to provide surface area for the bacteria, including sand, gravel, plastic beads, and other small plastic media specially designed for biofilters. Each type has benefits and drawbacks.

Common Biofilters

- Moving bed biological reactors (MBBRs)
- Trickling filters
- Upflow biofilters
- Downflow biofilters

Solid digestion (mineralization)

Solids removed from the aquaculture system can be further broken down through aerobic digestion, also called mineralization. This process can release nutrients that were trapped in solid waste and may produce stabilized biosolids that can be used in some agricultural or garden applications, depending on local regulations and food safety considerations.

When Aquaponics Makes Sense

Situation	Why Aquaponics May Be Useful
Education	Demonstrates biology, chemistry, engineering, and food systems
Water-limited regions	Recirculation can reduce water use
Urban agriculture	Can produce food in limited spaces
High-value crops	May justify higher infrastructure and management costs
Backyard or community systems	Provides hands-on learning and small-scale food production

When Aquaponics May Not Be the Best Fit

- Reliable electricity or backup power is unavailable
- Labor for daily monitoring is limited
- Markets for fish or plants are uncertain

- Water quality testing cannot be performed regularly
- High-value crops or educational goals do not justify the added system complexity
- The operator is not prepared to manage both fish and plant health

Types of Aquaponic Systems

- **Media bed systems** – plants are grown in gravel or expanded clay media that also acts as biofiltration
- **Floating raft systems** – plants float on rafts above nutrient-rich water (also known as deep water culture systems)
- **NFT systems** – nutrient film technique systems use a thin film of water that continuously flows through channels containing plant roots

Water Quality

Parameter	Why It Matters
Temperature	Affects fish health, plant growth, and microbial activity
Dissolved Oxygen	Needed by fish and nitrifying bacteria
pH	Affects nutrient availability and ammonia toxicity
Ammonia	Toxic nitrogen form that should not accumulate
Nitrite	Toxic nitrogen form that should not accumulate
Nitrate	Plant nutrient and indicator of nitrification

Before Getting Started

Consider

- What is the purpose of the system? (education, hobby, research, or commercial production)
- Do you have available space, electricity, water source, and drainage?
- Do you know which fish species you will choose and their temperature requirements?
- Which plant species will you grow?
- Will this be to sell or for household use?
- What size system do you want and what will that cost?
- Do you need monitoring equipment for your system?
- Do you have backup aeration or emergency planning for power outages?

Basic startup steps:

1. Define the purpose of the system.
2. Select fish and crops that match the local climate and system goals.
3. Draw a system plan and estimate water flows, tank volume, filtration needs, and electrical requirements.
4. Purchase components and assemble the system.
5. Fill, circulate, and aerate the system.
6. Establish biofiltration before fully stocking fish.
7. Add fish gradually while monitoring ammonia, nitrite, nitrate, pH, dissolved oxygen, and temperature.
8. Add plants and continue monitoring system performance.
9. Harvest and make adjustments as needed.



Figure 3. Common aquaponic plant production methods. From left to right: media bed system, floating raft system, and NFT system. Photos by Matthew Recsetar.

Aquaponics can be a valuable tool for education, water-efficient food production, and integrated fish and plant production. Success depends on understanding the biological balance between fish, microorganisms, and plants, and on designing systems that maintain good water quality.

Note: Future publications in this series will address aquaponic system design, filtration, water quality management, crop selection, fish species selection, mineralization, and economic considerations in greater detail.



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