AQS415 PRINCIPLES OF AQUACULTURE ENGINEERING

Week 13. Integrated Systems- Example of Aquaponics I

Aquaponics refers to any system that combines conventional aquaculture (raising aquatic animals such as snails, fish, crayfish or prawns in tanks) with hydroponics (cultivating plants in water) in a symbiotic environment. In normal aquaculture, excretions from the animals being raised can accumulate in the water, increasing toxicity. In an aquaponic system, water from an aquaculture system is fed to a hydroponic system where the by-products are broken down by nitrifying bacteria initially into nitrites and subsequently into nitrates that are utilized by the plants as nutrients. Then, the water is recirculated back to the aquaculture system.

As existing hydroponic and aquaculture farming techniques form the basis for all aquaponic systems, the size, complexity, and types of foods grown in an aquaponic system can vary as much as any system found in either distinct farming discipline.

Aquaponics consists of two main parts, with the aquaculture part for raising aquatic animals and the hydroponics part for growing plants.[16][17] Aquatic effluents, resulting from uneaten feed or raising animals like fish, accumulate in water due to the closed-system recirculation of most aquaculture systems. The effluent-rich water becomes toxic to the aquatic animal in high concentrations but this contains nutrients essential for plant growth.[16] Although consisting primarily of these two parts, aquaponics systems are usually grouped into several components or subsystems responsible for the effective removal of solid wastes, for adding bases to neutralize acids, or for maintaining water oxygenation.[16] Typical components include:

- *Rearing tank*: the tanks for raising and feeding the fish;
- *Settling basin*: a unit for catching uneaten food and detached biofilms, and for settling out fine particulates;
- *Biofilter*: a place where the nitrification bacteria can grow and convert ammonia into nitrates, which are usable by the plants;[16]
- *Hydroponics subsystem*: the portion of the system where plants are grown by absorbing excess nutrients from the water;

- *Sump*: the lowest point in the system where the water flows to and from which it is pumped back to the rearing tanks.

Depending on the sophistication and cost of the aquaponics system, the units for solids removal, biofiltration, and/or the hydroponics subsystem may be combined into one unit or subsystem,[16] which prevents the water from flowing directly from the aquaculture part of the system to the hydroponics part. By utilizing gravel or sand as plant supporting medium, solids are captured and the medium has enough surface area for fixed-film nitrification.[16] The ability to combine biofiltration and hydroponics allows for aquaponic system, in many cases, to eliminate the need for an expensive, separate biofilter.

Live components

An aquaponic system depends on different live components to work successfully. The three main live components are plants, fish (or other aquatic creatures) and bacteria. Some systems also include additional live components like worms.

Plants[edit]

Further information: Rhizofiltration

A Deep Water Culture hydroponics system where plant grow directly into the effluent rich water without a soil medium. Plants can be spaced closer together because the roots do not need to expand outwards to support the weight of the plant.

Plant placed into a nutrient rich water channel in a Nutrient film technique (NFT) system

Many plants are suitable for aquaponic systems, though which ones work for a specific system depends on the maturity and stocking density of the fish. These factors influence the concentration of nutrients from the fish effluent and how much of those nutrients are made available to the plant roots via bacteria. Green leaf vegetables with low to medium nutrient requirements are well adapted to aquaponic systems, including chinese cabbage, lettuce, basil, spinach, chives, herbs, and watercress.[17][18]

Spinach seedlings, 5 days old, by aquaponics

Other plants, such as tomatoes, cucumbers, and peppers, have higher nutrient requirements and will do well only in mature aquaponic systems with high stocking densities of fish.[18]

Plants that are common in salads have some of the greatest success in aquaponics, including cucumbers, shallots, tomatoes, lettuce, chilis, capsicum, red salad onions and snow peas.[19]

Some profitable plants for aquaponic systems include chinese cabbage, lettuce, basil, roses, tomatoes, okra, cantaloupe and bell peppers.[17]

Other species of vegetables that grow well in an aquaponic system include watercress, basil, coriander, parsley, lemongrass, sage, beans, peas, kohlrabi, taro, radishes, strawberries, melons, onions, turnips, parsnips, sweet potato, cauliflower, cabbage, broccoli, and eggplant as well as the choys that are used for stir fries.[19]

Fish (or other aquatic creatures)[edit]

Filtered water from the hydroponics system drains into a catfish tank for re-circulation.

Main article: Aquaculture

Freshwater fish are the most common aquatic animal raised using aquaponics due to their ability to tolerate crowding, although freshwater crayfish and prawns are also sometimes used.[20][16] There is a branch of aquaponics using saltwater fish, called saltwater aquaponics. There are many species of warmwater and coldwater fish that adapt well to aquaculture systems.

In practice, tilapia are the most popular fish for home and commercial projects that are intended to raise edible fish because it is a warmwater fish species that can tolerate crowding and changing water conditions.[18] Barramundi, silver perch, eel-tailed catfish or tandanus catfish, jade perch and Murray cod are also used.[17] For temperate climates when there isn't ability or desire to maintain water temperature, bluegill and catfish are suitable fish species for home systems.

Koi and goldfish may also be used, if the fish in the system need not be edible.

Other suitable fish include channel catfish, rainbow trout, perch, common carp, Arctic char, largemouth bass and striped bass.[18]

Bacteria[edit]

Further information: Nitrogen Cycle

Nitrification, the aerobic conversion of ammonia into nitrates, is one of the most important functions in an aquaponic system as it reduces the toxicity of the water for fish, and allows the resulting nitrate compounds to be removed by the plants for nourishment.[16] Ammonia is steadily released into the water through the excreta and gills of fish as a product of their metabolism, but must be filtered out of the water since higher concentrations of ammonia (commonly between 0.5 and 1 ppm)[*citation needed*] can impair growth, cause widespread damage to tissues, decrease resistance to disease and even kill the fish.[21] Although plants can absorb ammonia from the water to some degree, nitrates are assimilated more easily,[17] thereby efficiently reducing the toxicity of the water for fish.[16] Ammonia can be converted into safer nitrogenous compounds through combined healthy populations of 2 types of bacteria: *Nitrosomonas* which convert ammonia into nitrites, and *Nitrobacter* which then convert nitrites into nitrates. While nitrite is still harmful to fish due to its ability to create methemoglobin, which cannot bind oxygen, by attaching to hemoglobin, nitrates are able to be tolerated at high levels by fish.[21] High surface area provides more space for the growth of nitrifying bacteria. Grow bed material choices require careful analysis of the surface area, price and maintainability considerations.

Hydroponic subsystem[edit]

Main article: Hydroponics

Plants are grown as in hydroponics systems, with their roots immersed in the nutrient-rich effluent water. This enables them to filter out the ammonia that is toxic to the aquatic animals, or its metabolites. After the water has passed through the hydroponic subsystem, it is cleaned and oxygenated, and can return to the aquaculture vessels. This cycle is continuous. Common aquaponic applications of hydroponic systems include:

- *Deep-water raft aquaponics*: styrofoam rafts floating in a relatively deep aquaculture basin in troughs. Raft tanks can be constructed to be quite large, and enable seedlings to be transplanted at one end of the tank while fully grown plants are harvested at the other, thus ensuring optimal floor space usage.[22]
- *Recirculating aquaponics*: solid media such as gravel or clay beads, held in a container that is flooded with water from the aquaculture. This type of aquaponics is also known as *closed-loop aquaponics*.[*citation needed*]
- *Reciprocating aquaponics*: solid media in a container that is alternately flooded and drained utilizing different types of siphon drains. This type of aquaponics is also known as *flood-and-drain aquaponics* or *ebb-and-flow aquaponics*.[*citation needed*]
- *Nutrient film technique channels:* plants are grown in lengthy narrow channels, with a film of nutrient-filled water constantly flowing past the plant roots. Due to the small amount of water and narrow channels, helpful bacteria cannot live there and therefore a bio filter is required for this method.[22]
- Other systems use towers that are trickle-fed from the top, horizontal PVC pipes with holes for the pots, plastic barrels cut in half with gravel or rafts in them. Each approach has its own benefits.[23]

Since plants at different growth stages require different amounts of minerals and nutrients, plant harvesting is staggered with seedlings growing at the same time as mature plants. This ensures stable nutrient content in the water because of continuous symbiotic cleansing of toxins from the water.[24]

Biofilter[edit]

In an aquaponics system, the bacteria responsible for the conversion of ammonia to usable nitrates for plants form a biofilm on all solid surfaces throughout the system that are in constant contact with the water. The submerged roots of the vegetables combined have a large surface area where many bacteria can accumulate. Together with the concentrations of ammonia and nitrites in the water, the surface area determines the speed with which nitrification takes place. Care for these bacterial colonies is important as to regulate the full assimilation of ammonia and nitrite. This is why most aquaponics systems include a biofiltering unit, which helps facilitate growth of these microorganisms. Typically, after a system has stabilized ammonia levels range from 0.25 to .50 ppm; nitrite levels range from 0.0 to 0.25 ppm, and nitrate levels range from 5 to 150 ppm.[citation needed] During system startup, spikes may occur in the levels of ammonia (up to 6.0 ppm) and nitrite (up to 15 ppm), with nitrate levels peaking later in the startup phase.[citation needed] In the nitrification process ammonia is oxidized into nitrite, which releases hydrogen ions into the water. Overtime a person's pH will slowly drop, so they can use non-sodium bases such as potassium hydroxide or calcium hydroxide to neutralize the water's pH[16] if insufficient quantities are naturally present in the water to provide a buffer against acidification. In addition, selected minerals or nutrients such as iron can be added in addition to the fish waste that serves as the main source of nutrients to plants.[16]

A good way to deal with solids buildup in aquaponics is the use of worms, which liquefy the solid organic matter so that it can be utilized by the plants and/or other animals in the system. For a worm-only growing method, please see Vermiponics.[citation needed]

Operation[edit]

The five main inputs to the system are water, oxygen, light, feed given to the aquatic animals, and electricity to pump, filter, and oxygenate the water. Spawn or fry may be added to replace grown fish that are taken out from the system to retain a stable system. In terms of outputs, an aquaponics system may continually yield plants such as vegetables grown in hydroponics, and edible aquatic species raised in an aquaculture. Typical build ratios are .5 to 1 square foot of grow space for every 1 U.S. gal (3.8 L) of aquaculture water in the system. 1 U.S. gal (3.8 L) of water can support between .5 lb (0.23 kg) and 1 lb (0.45 kg) of fish stock depending on aeration and filtration.[25]

Ten primary guiding principles for creating successful aquaponics systems were issued by Dr. James Rakocy, the director of the aquaponics research team at the University of the Virgin Islands, based on extensive research done as part of the *Agricultural Experiment Station* aquaculture program.[26]

- Use a feeding rate ratio for design calculations
- Keep feed input relatively constant

- Supplement with calcium, potassium and iron
- Ensure good aeration
- Remove solids
- Be careful with aggregates
- Oversize pipes
- Use biological pest control
- Ensure adequate biofiltration
- Control pH