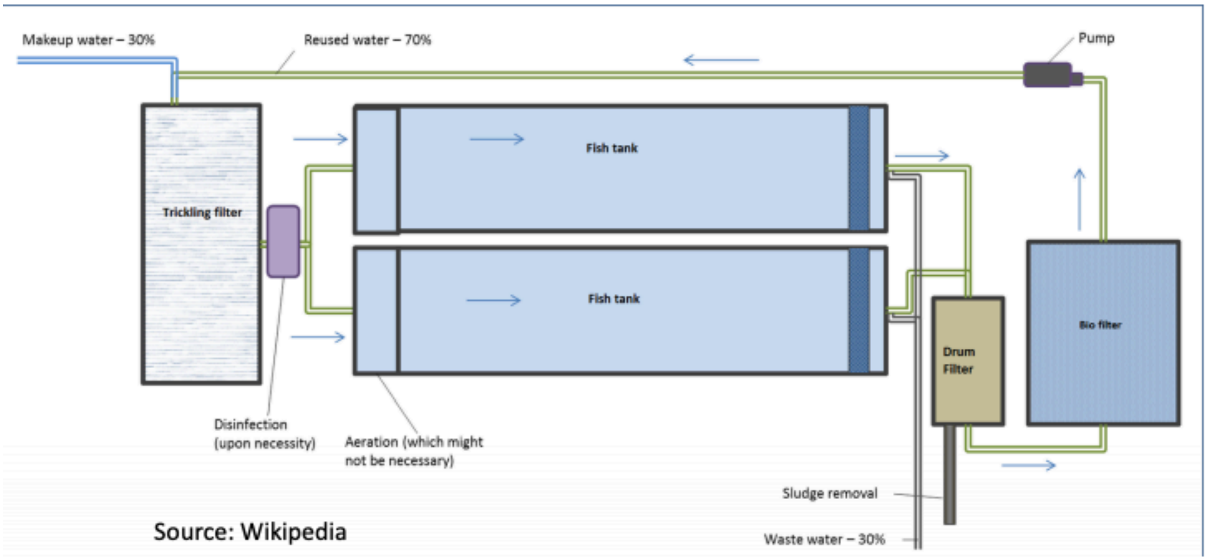
AQS415 PRINCIPLES OF AQUACULTURE ENGINEERING

Week 9. Recycling Aquaculture Systems (RAS)

Recirculating aquaculture systems (**RAS**) are used in home aquaria and for fish production where water exchange is limited and the use of biofiltration is required to reduce ammonia toxicity. Other types of filtration and environmental control are often also necessary to maintain clean water and provide a suitable habitat for fish. The main benefit of RAS is the ability to reduce the need for fresh, clean water while still maintaining a healthy environment for fish. To be operated economically commercial RAS must have high fish stocking densities, and many researchers are currently conducting studies to determine if RAS is a viable form of intensive aquaculture.

The specific set-up of RAS systems vary depending on the species being reared, the planned intensity of farming, as well as the experience and philosophy of system engineers. In general, they must address some fundamental challenges – and this list is partial: 1. Control of intake water (site- and water source selection, pre-treatment if necessary, and on-going monitoring and control; access to emergency supplies is a great insurance). 2. Tight biosafety controls to prevent introduction and internal proliferation of disease 3. Continuous removal of dead fish, particulate and dissolved solids (sludge removal, clarification) 4. Removal of nitrogen wastes (biofiltration) 5. Management of dissolved gases (oxygen, CO_2, dissolved nitrogen, etc; requiring both oxygenation, aeration and degassing systems) 6. Management of pH, alkalinity and temperature (both for fish and biofilter bacterial requirements) 7. As dictated by the above: excellent operating expertise and –routines, supported by effective monitoring and control systems.



Source: Wikipedia

Opportunities and challenges of RAS culture Opportunities: • Farming in a controlled environment What comes in, and what goes out, is controllable, and the rearing environment can be kept stable and deliver consisten growth conditions yearround. • Flexibility in choosing locations for fish farming. The limited water requirements changes the map of future fish production. Farming can take place inland, in arid areas, remote from large rivers and lakes and the coast. By siting farms near significant seafood markets, savings on transportation and logistics can contribute significantly to the overall project economy – both by cutting transport distances per se and by reducing the amount of ice that is flown around the world at airfreight rates. • Flexibility in choosing species for farming. A controlled environment facilitates farming different species outside their normal climate zones, while closed, land-based farming technology eliminates risk of escape of fish into the natural environment. Preventing spread of pathogens . • High yield potential. Farming with high fish density has become increasingly feasible and continues to do so; technology is maturing, experience is rapidly accumulating. RAS is set to enter the mainstream for intensive grow-out farming with species have not previously been economically viable. • Circular economy-ready. Water conservation, control and utilization of waste and by-products, steadily improving know-how for integration with other land-based industry (utilization of waste and nutrients for energy, aquaponics, feed production, etc), are all features of RAS that are in line with principles of the circular economy. Challenges: • Most industrial experience with RAS has been with robust species such as tilapia or catfish, or early life stages of sensitive species such as Atlantic salmon. The more sensitive the species, the greater the requirements for planning, investments and highly stable operations. • Access to qualified personnel. Careful operational management is required at high rearing densities; not just the fish, but also its environment, is under direct management. Access to supporting services and proper training of personnel is essential. • Excellent monitoring and control systems are essential; response times and proper mitigating measures can leave a time window as low as 10-15 minutes to prevent total loss of stock (though it should be noted - short available response times are also prevalent in intensive cage culture and during live-carrier transport of farmed fish).

Biofiltration

All RAS relies on biofiltration to convert ammonia (NH_4^+ and NH_3) excreted by the fish into nitrate. Ammonia is a waste product of fish metabolism and high concentrations (>.02 mg/L) are toxic to most finfish. Nitrifying bacteria are chemoautotrophs that convert ammonia into nitrite then nitrate. A biofilter provides a substrate for the bacterial community, which results in thick biofilm growing within the filter.[4] Water is pumped through the filter, and ammonia is utilized by the bacteria for energy. Nitrate is less toxic than ammonia (>100 mg/L), and can be removed by a denitrifying biofilter or by water replacement. Stable environmental conditions and regular maintenance are required to ensure the biofilter is operating efficiently.

Solids removal

In addition to treating the liquid waste excreted by fish the solid waste must also be treated, this is done by concentrating and flushing the solids out of the system. Removing solids reduces bacteria growth, oxygen demand, and the proliferation of disease. The simplest method for removing solids is the creation of settling basin where the relative velocity of the water is slow and particles can settle at the bottom of the tank where they are either flushed out or vacuumed out manually using a siphon. However, this method is not viable for RAS operations where a small footprint is desired. Typical RAS solids removal involves a sand filter or particle filter where solids become lodged and can be periodically backflushed out of the filter.[7] Another common method is the use of a mechanical drum filter where water is run over a rotating drum screen that is periodically cleaned by pressurized spray nozzles, and the resulting slurry is treated or sent down the drain. In order to remove extremely fine particles or colloidal solids a protein fractionator may be used with or without the addition of ozone (O_3).

Oxygenation

Reoxygenating the system water is a crucial part to obtaining high production densities. Fish require oxygen to metabolize food and grow, as do bacteria communities in the biofilter. Dissolved oxygen levels can be increased through two methods, aeration and oxygenation. In aeration air is pumped through an air stone or similar device that creates small bubbles in the water column, this results in a high surface area where oxygen can dissolve into the water. In general due to slow gas dissolution rates and the high air pressure needed to create small bubbles this method is considered inefficient and the water is instead oxygenated by pumping in pure oxygen.[8] Various methods are used to ensure that during oxygenation all of the oxygen dissolves into the water column. Careful calculation and consideration must be given to the oxygen demand of a given system, and that demand must be met with either oxygenation or aeration equipment.

pH control

In all RAS pH must be carefully monitored and controlled. The first step of nitrification in the biofilter consumes alkalinity and lowers the pH of the system.[10] Keeping the pH in a suitable range (5.0-9.0 for freshwater systems) is crucial to maintain the health of both the fish and biofilter. pH is typically controlled by the addition of alkalinity in the form of lime ($CaCO_3$) or sodium hydroxide (NaOH). A low pH will lead to high levels of dissolved carbon dioxide (CO_2), which can prove toxic to fish.[11] pH can also be controlled by degassing CO_2 in a packed column or with an aerator, this is necessary in intensive systems especially where oxygenation instead of aeration is used in tanks to maintain O_2 levels.

Temperature control

All fish species have a preferred temperature above and below which that fish will experience negative health effects and eventually death. Warm water species such as Tilapia and Barramundi prefer 24 °C water or warmer, where as cold water species such as trout and salmon prefer water temperature below 16 °C. Temperature also plays an important role in dissolved oxygen (DO) concentrations, with higher water temperatures having lower values for DO saturation. Temperature is controlled through the use of submerged heaters, heat pumps, chillers, and heat exchangers. All four may be used to keep a system operating at the optimal temperature for maximizing fish production.