

Recirculation Technology in Finfish Aquaculture

Background

Recirculation technology allows finfish producers control over the environment in which fish are being reared. It enables producers to neutralize environmental variables such as fluctuating

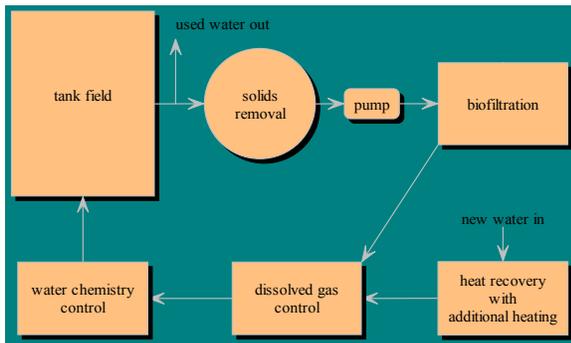


Figure 1. Schematic of a high pressure recirculation system.

temperatures and water quality parameters. Recirculation systems use land based units to pump water in a closed loop through fish culture tanks and include a series of sub-systems for water treatment. The water treatment systems may include equipment for sterilization, heating or cooling, solids removal, water chemistry control, biological filtration and dissolved gas control (Figure 1).

Divergence of Thinking: Low Pressure vs. High Pressure Systems

Recirculating aquaculture systems have developed into two basic types, low pressure (head) systems and high pressure systems. Although there are several different designs, low pressure systems use pressurized air to move the water and may

typically have fewer than six inches of head differential. These systems move large quantities of water under low pressure. Complete water exchanges in the culture tanks may occur up to seven times per hour. These frequent water changes are essential to maintain water quality. In much of North America, including Canada, high pressure systems are typically the system of choice for salmonid culture. These systems are expensive to operate compared to low pressure systems. For example, a ten horsepower pump is needed to circulate 500 gallons of water per minute with up to twenty feet of head differential. Due to these pumping requirements, complete water changes within the culture tanks occur approximately once every hour. The advantage these systems have over low pressure systems is to maintain better water quality. The remainder of this aquaculture note will concentrate on describing the component parts of a typical high pressure recirculation system.

Solids Removal

Solids removal is probably the key to maintaining water quality in recirculation systems. Solids remaining in the system contribute to poor water clarity, increased levels of ammonia, high levels of dissolved nutrients such as nitrogen and phosphorus and decreased oxygen levels. The key to solids removal is getting the fish waste (feces) and any uneaten food out of the system quickly and in as large of pieces as possible. The smaller the pieces become, the more difficult they are to remove. Solids removal starts in the fish culture tanks and usually involves at least two other

pieces of equipment, each one dealing with different particle sizes.

Culture Tanks

Circular tanks used in high pressure recirculation systems are self cleaning due to their inward sloping bottom and the circular water flow. Any solids that precipitate out of the water column move across the bottom of the tank and are concentrated in a sump in the middle of the tank. Solids removal in the tanks can be enhanced using the double drain system. This involves using two drains in the center of the tank. One drain removes about 80% of the flow from relatively clean water near the surface. The second drain removes the balance of the water flow from the bottom of the tank where most of the solids accumulate. The effluent is then redirected to a piece of equipment that has been designed to remove the larger solids, usually a swirl separator. The bulk of the water bypasses this stage and is directed to a microscreen filter which removes the smaller particles.

Swirl Separator

One of the more popular methods of removing larger solids is the swirl separator. Swirl separators are circular tanks with the upper third having vertical sides and the bottom portion cone-shaped. Swirl separators are effective because the speed of the water flow decreases substantially as the water swirls tangentially creating a whirlpool effect. The decrease in the speed of the water flow coupled with the centrifugal force exerted on the particles by the direction of the flow allow the larger particles to settle out of the water column. In order to remove the solids from the bottom of the swirl separator, a head differential is established between the water level in the swirl and the pipe that carries the solids out of the facility. When a standpipe is pulled in the line connecting the bottom of the swirl to the discharge pipe, the pressure difference forces the solids in the water into the discharge pipe. The solids can be directed to a settling pond or to a temporary storage tank at the facility. Particles as small as 100 microns can be removed from the water using a swirl separator.

Microscreen

After the water passes through the swirl separator, it may be redirected to a microscreen filter that removes even smaller particles. The microscreen may be attached to a drum, disc, belt or a set of plates. Microscreens are typically in the 60 micron size range. The most popular form is a rotating



Figure 4. Rotating microscreen drum.

drum and typically remove particles in the 60 micron range. (Figure 2). Water flows into the middle of the drum through the end. It then flows through the screen, into the drum sump and to the next piece of equipment which is usually a pump. The solids are removed from the screen with a backwash spray and captured in a collecting trough inside the drum and redirected to the waste stream.

Foam Fractionators

Particles that pass through the microscreen are very difficult to remove. Foam fractionators are used to remove the smallest particles. These are essentially columns 12 to 38 inches in diameter. The water flows downward through them countercurrent to the flow of air. The small particles adhere to the air bubbles and rise to the top of the column. As these bubbles reach the top of the column, they form a layer of foam which flows off the top of the column and is directed out of the facility in the discharge pipe.

Water Sterilization

To help control pathogens within a recirculation system, water sterilization equipment is used. Ozonation and ultraviolet radiation (UV) are two of the common types of disinfection techniques.

Ozone is injected into a chamber through which either all or a portion of the system flow goes through. It is important to monitor the amount of ozone in the water due to its toxicity to fish. Most ozone generators come equipped with monitoring devices. Ozonation has the ability to improve water clarity as well. Since UV efficacy is aided with a certain degree of water clarity, ozone treatment can be used in conjunction with UV to maximize its efficiency. Higher degrees of recirculation can often be accomplished using this equipment, but there are trade-offs from its use, primarily high capital and maintenance costs.

Biofiltration

Biofiltration is the oxidation of ammonia (a waste product of the fish) to nitrite which is further oxidized to nitrate. This is accomplished with the aid of two types of bacteria, *Nitrosomonas* and *Nitrobacter*. *Nitrosomonas* converts ammonia to nitrite, then *Nitrobacter* converts the nitrite to nitrate. Ammonia and nitrite are toxic to salmonids but they can withstand in excess of 300 ppm of nitrates. The small amount of fresh make-up water brought into the system is sufficient to dilute the nitrate levels within an acceptable range. Biofilters consist of a large chamber that houses some type of media that the bacteria grow on. Depending on the size of the media system, the chamber can be as large as six feet across and sixteen feet high (Figure 3). The depth of the media bed, coupled with the density of the media requires high pumping capacities. Silica sand is a popular media type due to its high surface area, however different shapes of plastic media are also used.

Dissolved Gas Control

After the biofiltration process, the water is very high in carbon dioxide and very low in oxygen due to the aerobic activity of the bacteria. These gas concentrations in the water must be returned to suitable levels. To achieve this, the water is aerated or degassed by passing it countercurrent to large volumes of air (Figure 3). After aeration or degassing, the water must be injected with pure oxygen if the fish are being raised at high densities, which is usually the case in most land



Figure 5. The two green columns are biofilters. Note the degassing/LHO unit at the top of the biofilter on the right.

based fish farms. There are three basic oxygen injection strategies: i) inject oxygen into the entire water flow of the system at one location, ii) treat a small portion of the water flow or iii) introduce oxygen directly into the culture tanks using ceramic diffusers. This third method is very inefficient and should not be used as a primary oxygen injection method. Low head oxygenators (LHO's) are typically used to treat the entire flow of the system (Figure 3). Oxygen is injected into the water as it passively flows down through the LHO. A small portion of the system flow can be injected with oxygen. This is known as side stream injection. Pressurized packed columns are a popular side stream injector (Figure 4). Unlike LHO's, oxygen is injected into water that is under pressure. This enables large amounts of oxygen to be dissolved in a small amount of water. The water can be then introduced directly to the culture tanks or back into the main flow of the system.



Figure 6. Pressurized packed column. Note the pump on the floor supplying water to the column.

Water Chemistry Control

Depending on the chemistry of the new water that is being introduced to the system, chemical additives may be required. With the large production of CO₂ within the system by the fish and the biofilter, low pH levels can become a management issue. Typically, some form of carbonate ion (calcium carbonate or sodium bicarbonate) is used to buffer the water against falling pH levels by increasing the alkalinity. Water hardness (calcium ion content) must also be controlled. High mineral content in the water is useful in helping the fish maintain good fin quality, especially at higher stocking densities. Calcium chloride is the most common chemical used to achieve this. If calcium carbonate is used as the pH buffer, it will also help to maintain hardness. Fish also require adequate chloride levels. The chloride ion is useful in combating nitrite toxicity and osmotic stress. Additions of

salt (sodium chloride) may be needed if chloride levels fall too low.

Heat Recovery/Heating

Maintaining control over water temperature is essential in maximizing production in any finfish aquaculture operation. Depending on the life stage, salmonids require water that is 7 to 18 degrees Celsius to maximize production. Since the water in the system will maintain its temperature, only the incoming new water needs to be heated. Oil and propane fired boiler systems are typical water heating equipment. Electric heat pumps are used as well, either in place of, or in conjunction with a boiler system.

Application of Recirculation Technology on PEI

The first, and only commercial recirculation system on Prince Edward Island was installed in a facility at Brookvale. This facility is currently owned by Cold Water Fisheries and presently produces steelhead smolts. The Cardigan Water Science Center at the Cardigan Fish Hatchery, houses a small recirculation system that is primarily used for research purposes. A demonstration scale system has been installed at Morell High School to be used as a teaching tool. Recirculation technology is becoming more significant in the finfish industry each year. The number of grow-out farms using recirculation is limited, however recirculation is becoming very prominent in finfish hatcheries.

For further information contact:

Chris Mills
PEI Department of Fisheries,
Aquaculture and Environment
Fisheries and Aquaculture Division
PO Box 2000
Charlottetown, PEI
C1A 7N8
(902) 368-5525 cdmills@gov.pe.ca