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Principles of Water Recirculation and Filtration in Aquaculture [1]

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Recirculating water systems are designed to minimize or reduce dependence on water exchange and flushing in fish culture units. These systems have practical applications in commercial aquaculture hatcheries, holding tanks, and aquaria systems, as well as small scale aquaculture projects. Water is typically recirculated when there is a specific need to minimize water replacement, to maintain water quality conditions which differ from the supply water, or to compensate for an insufficient water supply. There are innumerable designs for recirculating systems and most will work effectively if they accomplish: 1) aeration, 2) removal of particulate matter, 3) biological filtration to remove waste ammonia and nitrite, and 4) buffering of pH. These processes can be achieved by a simple composite unit such as an aquarium filter, or in larger systems, by several interconnected components.

Aeration

Water must be aerated to maintain adequate dissolved oxygen concentrations for fish and for proper functioning of the biological filter. Aeration is usually applied in the fish culture tank and again prior to or within the biological filter, that portion of the recirculating system where organic waste products are broken down through bacterial decomposition. Trickling filters and revolving plate biofilters are designed to be self-aerating. Vigorous aeration of submerged filter beds is not recommended because beneficial bacteria can be dislodged from the substrate decreasing the filter's effectiveness. Air lift pumps (Table 1) are often used to move water through the tanks, accomplishing both aeration and pumping (Figure 1). Super-intensive systems may use pure oxygen injection although this is seldom economical. The level of aeration should be sufficient to sustain dissolved oxygen levels above 60% saturation throughout the system.

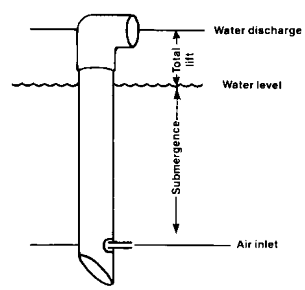

Figure 1 .

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Removal of particulate matter

Solids resulting from fish waste and uneaten feed conribute a portion of the oxygen demand and toxic ammonia in the system and should be concentrated for removal. This can be accomplished in a settling basin with reduced water turbulence, or by mechanical filtration through porous material such as sponge, screen, sand or gravel. Solids that accumulate will gradually be mineralized (broken down) by bacterial action and their volume reduced. Although this process adds additional oxygen demand to the system, it reduces the need for frequent cleaning if the solids do not become re-suspended or interfere with normal water flow. Mechanical filters require regular cleaning since they are prone to clogging when dirty. To prevent excess amounts of solids from accumulating in the biofilter, small particles of matter are usually removed prior to, or as the first component of biofiltration.

Biological filtration

Fish and other aquatic organisms release their nitrogenous wastes primarily as ammonia (NH_3) excreted across the gill membranes. Urine, solid wastes, and excess feed also have undigested nitrogen fractions, and are additional sources of ammonia. Ammonia is toxic to fish and can exert sublethal stress at concentrations of less than 0.05 mg/l ammonia nitrogen (NH_3-N), resulting in poor growth and lower resistance to disease.

To control ammonia levels in recirculating water systems, extensive surface area is provided for bacteria which biologically oxidize ammonia to relatively harmless nitrate (NO_3^-). Bacterial nitrification is a two-stage process resulting first in the transformation of ammonia to nitrite (NO_2^-), then a further oxidation of nitrite to nitrate. Nitrite is also toxic to fish at low concentrations, hence, both reactions must occur for successful biofiltration.

The bacteria responsible for these reactions occur widely in soil and water environments and can be easily innoculated into biofilters from natural sources, or with material from established filters. To ensure bacterial populations are sufficient to remove ammonia and nitrite at rates required during operation, a biofilter is typically conditioned for several weeks by adding ammonia and monitoring its breakdown prior to stocking fish.

Media for biofilters can be virtually any substrate which provides maximum surface area for bacterial growth: oyster shell, gravel, nylon netting, plastic rings, corregated fiberglass panels, and sponge foam pads are among popular choices (Figure 2). In designing biofilters, the principal concerns should be maximum surface area for bacterial growth, high dissolved oxygen levels, uniform water flow through the filter, sufficient void space to prevent clogging, and proper sizing to ensure adequate ammonia removal capability. The required size of a biofilter is difficult to predict since filter surface area, fish density, and water flow are important considerations. A 3-to-l tank volume to biofilter volume is usually more than sufficient.

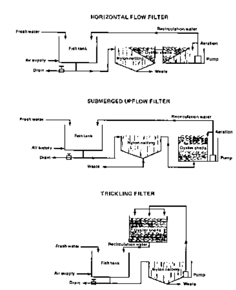

Figure 2 .

Management

Recirculating water systems should be designed for simplicity of operation and economic feasability. Sufficient time must be allowed for conditioning of the biofilter prior to introducing fish. Ammonia and nitrite concentrations must be checked frequently. Dissolved oxygen should be sustained above 60% of saturation and periodically verified. Alkalinity, hardness, and pH need to be measured and adjusted, if necessary, at regular intervals. Filters should be inspected and cleaned as required. Medications used to treat fish diseases may be toxic to bacteria in the biofilter. An ability to isolate fish tanks for disease treatment should be provided. Frequent monitoring of the performance of the recirculating system will allow the manager to improve and refine its operation over time.

Buffering of pH

Fish metabolism and bacterial nitrification result in the formation of acids that lessen the buffering capacity of water and lower the pH. Most fish can tolerate a pH range of 5-10, however, a range of 6.5-to-8.5 is preferred for most aquaculture species. To replace lost alkalinity and sustain the buffering capacity of water, carbonate (CO_3^{2-}), in the form of limestone, bicarbonate of soda, or other common sources is added. Often, biofilter media (oyster shell) or some other component of the system (concrete tanks) serve as a source of carbonates. Depending on the species cultured, frequent monitoring of water hardness, alkalinity and pH may be required.

Table 1.

Table 1. Approximate pumping rates for airlifts of various diameters and % submergence.

Pipe sizes for discharge pipe (in.)	Capacity at submergence (gal/min)		
	70%	60%	50%
1	13	10	9
1-1/4	20	14	12
1-1/2	28	22	16
2	50	40	30
3	110	100	75
4	260	200	160