Recirculating Aquaculture System Engineering: Design, components and construction

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Introduction

Most fish and crustacean aquaculture is undertaken in earthen ponds or large tanks with flowing water. Pond culture requires large areas of flat land and significant quantities of clean groundwater. Flow-through tank aquaculture requires less land but needs more water per kg of fish produced to maintain good growing conditions within the tank. Recirculating aquaculture systems re-use water over and over, cleaning the waste from the water and providing oxygen to the fish. Because water is reused, recirculating fish production systems utilize only a fraction of the water required by traditional fish production techniques. A small domestic well producing three to five gallons per minute, when coupled with the proper recirculating technology, can be used in the production of thousands of kilo of fish annually. There is no doubt that fish can be reared in large quantities and at high densities in recirculating systems. However, the economic viability of growing fish in recirculating systems is not ascertained. Before initiating the fish culture using recirculating technology, essential googleprinciples involved in the technology being used must be understood. In almost every successful application, highly technological solutions that have been evaluated are incorporated into the aquaculture systems.

The most important consideration in the design of recirculating systems is the development of an efficient water treatment system. Recirculating production systems must be designed with many fundamental waste treatment processes. These processes, referred to as "unit processes", include the removal of waste solids (both faeces and uneaten feed), the conversion of ammonia and nitrite-nitrogen (a non-toxic form of dissolved nitrogen), the addition of dissolved oxygen to the water, and the removal of carbon dioxide from the water. With less robust species and depending upon the volume of new water used, a process to remove fine and dissolved solids as well as a process to control bacterial populations may need to be applied.

Design Description

A typical recirculating aquaculture system consists of several sub-systems. The selection of components of each sub-system is driven by many factors, ranging from cost to operational advantages. The overall goal is to develop a facility and to standardize a process that could be replicated by others, with allowances for modifications to fit other site-specific characteristics. While the design described herein can be used as a model for the system design; aquaculture is a rapidly developing science and the latest technological advances should be factored into a final design. Site specific, such as climate, availability of reliable water and power sources, and water chemistry are just a few of the factors that could affect the decision to planning a project.

In a recirculation system, it is necessary to treat the water continuously to remove the waste products excreted by the fish, and to add oxygen to keep the fish alive and system function in efficient way. A recirculation system is quite simple. Water flows from the fish culture tank to a mechanical filter and further on to a biological filter before it is aerated and stripped of carbon dioxide and returned to the fish tanks. This is the basic principle of recirculation. Several other facilities such as oxygenation for providing higher oxygen requirements, ultraviolet light or ozone for disinfection, automatic pH regulation, heat exchanging, etc. can be added depending on the exact requirements.

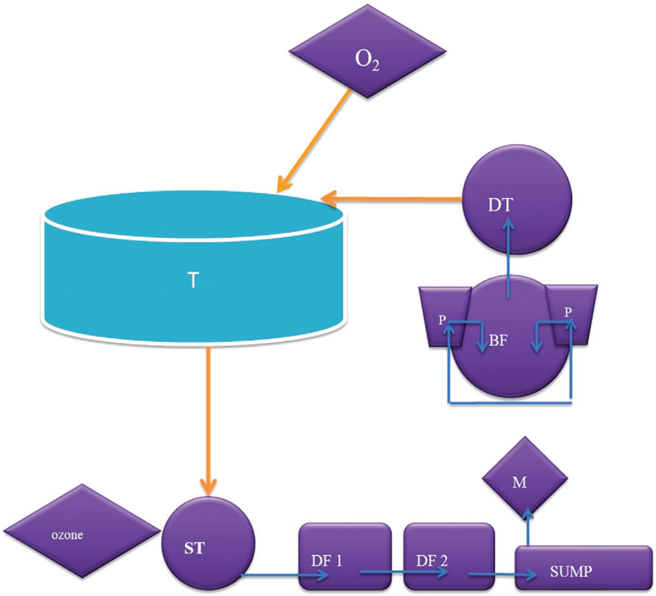


Figure 1. Schematic diagram overview of a typical RAS construction design and its components (Note: T-Tank, ST-Settlement Tank, DF-Drum Filter, M-Motor, BF-Bio-Filter, P-Protein skimmers, DT-Degassing Tank, O_2-Oxygen generators)

Table 1: Different components of the RAS

SNo	Name of the component	Material/ Capacity	Design
1	Tanks	Cement, Fiber, Metal	Circular, Rectangular, Raceways
2	Pipelines	PVC, UPVC and Metal	NA
3	Sedimentation tank	Cement, Fiber, Metal	Conical, cylindrical or in a combination of both
4	Mechanical filters	Drum filters, Rapid Sand Filters (RSF)	Fiber and Metal
5	Storage sump	Cement, Fiber	As per the convenience
6	Pumping system	Centrifugal pump of assorted capacity	NA
7	Biological filter	Cement, Fiber, Metal	Cone shape, cylindrical or combination of both
8	Protein skimmers	Fiber and Metal	Cone shape, cylindrical or combination of both
9	Degassing unit	Fiber and Metal	
10	Oxygen generator/ Aeration System	5 LPM, 10 LPM and 15 LPM	Air blowers, Oxygen concentrators and Nanobubblers
11	Disinfestation		UV and Ozone

Fish culture tank

Effective and quick removal of waste from the culture water and the capability to effectively manage the fish within the culture system should be the prime drive for the selection of culture tank. The environment in the fish-rearing tank must meet the needs of the fish, in respect of both water quality and tank design. Choosing the right tank design, such as size and shape, water depth, self-cleaning ability, etc. can have a considerable impact on the performance of the species reared. If the fish is bottom dwelling, the need for tank surface area is most important, and the depth of water and the speed of the water current can be lowered, whereas pelagic species such as Indian pompano will benefit from larger water volumes and show improved performance at higher speeds of water. In a circular tank or a square tank with cut corners, the water moves in a circular pattern making the whole water column of the tank move around the center. The organic particles have a relatively short residence time of a few minutes, depending on tank size, as the hydraulic pattern in the tank provides self-cleaning effect. A vertical inlet with horizontal adjustment is an efficient way of controlling the current in such tanks.

In a raceway, the hydraulics have no positive effect on the removal of the particles. On the other hand, if a fish tank is stocked efficiently with fish, the self-cleaning effect of the tank design will depend more on the fish activity than on the tank design. The inclination of the tank bottom has little or no influence on the self-cleaning effect, but it will make complete draining easier when the tank is emptied.

Circular tanks take up more space compared to raceways, which adds to the cost of constructing a building. By cutting off the corners of a square tank, an octagonal tank design appears, which give better space utilization than circular tanks, and at the same time, the positive hydraulic effects of the circular tank are achieved. It is important to note that the construction of large tanks will always favor the circular tank as this is the strongest design and the cheapest way of making a tank. A hybrid tank type between the circular tank and the raceway called a "D-ended raceway" also combines the self-cleaning effect of the circular tank and the efficient space utilization of the raceway. However, in practice, this type of tank is seldom used, presumably because the installation of the tank requires extra work and new routines in management. Tank outlets must be constructed for optimal removal of waste particles, and fitted with screens with suitable mesh sizes. Also, it must be easy to collect dead fish during the daily work routines.

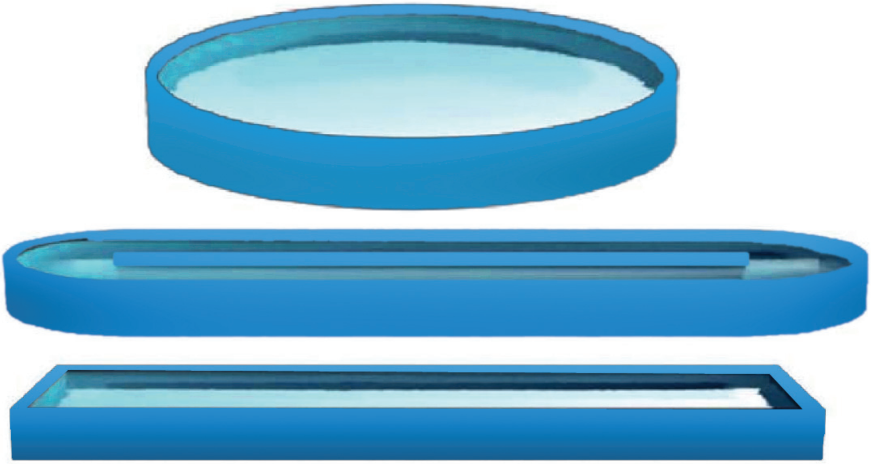


Figure 2. Different types of Fish tanks: Circular, D-ended raceway and Raceway type Source: Jacob Bregnballe, A Guide to Recirculation Aquaculture (FAO, 2015)

Table 2. Different tank designs give different properties and advantages. Rating1-5, where 5 is the best. Source: Jacob Bregnballe, A Guide to Recirculation Aquaculture (FAO, 2015)

S. No.	**Tank properties**	**Circular Tank**	**D-ended raceway**	**Raceway type**
1	Self-cleaning effect	5	4	3
2	Low residence time of particles	5	4	3
3	Oxygen control and regulation	5	5	4
4	Space utilization	2	4	5

Sufficient oxygen levels for fish welfare are an important perameter in fish farming and are usually kept high by increasing the oxygen level in the inlet water to the tank. Control and regulation of oxygen levels in circular tanks or of similar type, is relatively easy because the water column is constantly mixed making the oxygen content almost the same anywhere in the tank. In a raceway, however, the oxygen content will always be higher at the inlet and lower at the outlet, which also gives a different environment depending on where each fish is swimming.

FILTRATION: Mechanical filtration

Mechanical filtration of the outlet water from the fish tanks has proven to be the only practical solution for the removal of suspended organic and inorganic wastes. Almost all solid wastes originate in RAS from the formulated diet provided to the cultured animal. The prolonged building of this waste can lead to a decline in water quality, inducing stress upon the animal. This stress is a direct result of the partial smothering of gills and indirectly the excessive proliferation of pathogens that inhabit the suspended particles. The increase in the biological oxygen demand as the solid waste decomposed by bacteria is also of particular concern. The removal of this type of waste is usually the first stage in serial filtration design and is significantly important in the overall process.

Particle size distribution must be considered when solid removal is to be carried out due to production requirements and removal cost. Figure 3 displays the size distribution based on a recirculation system for the hybrid striped bass. Particles between the sizes of 1.5 - 30 microns are the most common. At the extreme end, particles with more than 105 microns in size exhibit the next most common concentration. While the particle size range of 30-70 microns are the least common.

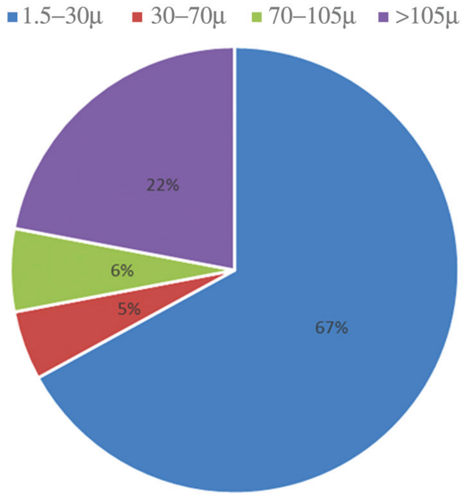


Figure 3. Particle size distribution by weight in a RAS stocked with striped bass (Timmons and Lorsordo, 1994)

Solid removal in aquaculture is often carried out utilizing physical and mechanical processes originating from other industries. These processes range from gravity separation to physical screening (Table 3). Generally, gravity separation or sedimentation involves the settling of suspended particles over a given period of time. This is commonly accomplished in a large, slow-flowing water course. The clean supernatant is collected from the upper section of the water column while the solids are collected at the lower section. Physical separation on the other hand entails the forced partitioning of solids and water. This is accomplished by forcing waste water through a bed of media or a screen.

Table 3. **Techniques utilized for the separation of suspended solids from aquaculture wastewater (Tommons et al., 2002)**

SlNo	Filter design	Solid size removed (microns)	Head loss (m)	Total suspended solids removed (%)
1	Sedimentation	>100	0	40-60
2	sludge collector			80
	Screen filters			
	Drum filter	>90		10-25
	Drum filter	>60		41
	Triangal filter	>80		24-33

3	Granular filter			20-60
	Pressurized sand	>20	0.1-3	50-95
	Rapid sand			67-91
4	Swirl Separator	1-75	14-35	37.1
	Radial-flow separator			77.9
5	Foam fractionation	<30		<50
6	Ozonation	<30		
7	Membrane filtration	0.05		>95
		0.1		94
		0.22		91
		0.45		85
		0.65		72
		1.2		69
8	Membrane filtration	0.05		99.65

The following considerations are taken care while selecting the suspended solids removal process within a system:

1. Hydraulic loading rate (HLR)
2. Solid removal capability
3. Head loss
4. Water loss during the backwash
5. Resistance to bio-fouling
6. Size of filter

Today almost all recirculating aquaculture systems use drum filters fitted with micro-screen of 40 to 100 microns mesh cloth for filtering the outlet water of fish culture tanks. The other best alternative for these screened filters is Rapid Sand Filter (RSF). RSF functions on the principle of porosity through different gradient materials like sand and charcoal.

Drum filters

The drum filter is by far the most commonly used type of micro-screen, and the design ensures the gentle removal of particles.

Working principle of the drum filter

1. Water to be filtered enters the drum.
2. The water is filtered through the drum's filter elements. The difference in water level inside/outside the drum is the driving force for the filtration.
3. Solids are trapped on the filter elements and lifted to the backwash area by the rotation of the drum.
4. Water from rinse nozzles is sprayed from the outside of the filter elements. The rejected organic materials are washed out of the filter elements into the sludge tray.
5. The sludge flows together with water by gravity out of the filter, escaping the fish, for external wastewater treatment.

Micro-screen filtration has the following advantages

- Reduction of the organic load of the biofilter.
- Making the water cleaner as suspended particles are removed from the water.
- Improving conditions for nitrification as the biofilter does not clog.
- Stabilizing effect on the biofiltration processes.

Rapid Sand Filters

Sand filtration is a very basic and cost effective method of treating contaminated water. Sand filtration utilizes the filtering properties of sand and produces clean water that is perfectly safe for fish. Moreover, as this process requires little or no chemicals or replaceable parts or even minimal operator training but only demands for some amount of periodic maintenance, it is one of the best option of water treatment for recirculating aquaculture system.

In this process, typically, the water is let to pass through a bed of sand that makes the larger suspended particles settle in the top layers of sand. Smaller particles of organic sediment left in the sand filter are consumed by microscopic organisms including bacteria which 'stick' in the layers of slime that form around the sand particles. The clean water which passes through the filter is safe to recirculate.

There are three types of sand filters: rapid sand filters, up-flow sand filters and slow sand filters. The most commonly used type is the rapid sand filters. These filters employ a layer of activated carbon or anthracite coal above the sand to remove organic compounds, thereby enhancing the taste and odor of raw water. The space between sand particles is larger than the smallest suspended particles, hence the smaller particles also trapped and filtered out. The particles that escape through the surface layers are trapped in the subsequent layers of sand. It has to be noted that if the surface layer sieves all the particles, the filter will quickly clog. Rapid sand filters can be cleaned by passing water upward through the filter after blowing compressed air up through the bottom. This air blowing process breaks up the compact media filter.

Advantages

- Filters out much smaller particles than drum filters can.
- Filters out virtually all particles larger than their specified pore sizes.
- They are reasonably strong and so can withstand pressure differences across them of (typically 2–5 atmospheres).
- They can be cleaned (back flushed) and reused.

Disadvantages

- Rapid sand filter works fully on mechanical power, hence, high energy requirement.
- Water loss from the system will be more due to back wash for cleaning the clogged sand.
- Flow rate will change in due course in the system due to sand clogging.

Fiber Drum filter **Metal (SS) Drum filter** **Rapid Sand Filter (RSF)** **Gravimetric filtration (Sedimentation tank)**

Figure 4. Different types of mechanical filters used in RAS facility

Foam fractionation

Many of the fine suspended solids and dissolved organic solids that build up within recirculation systems cannot be removed with traditional filtration mechanisms. Foam fractionation is used to remove and control the build-up of these solids. In this process, air is introduced into closed column of water for creating foam at the surface of the column by churning, which removes dissolved organic compounds by physically adsorbing on the rising bubbles. Fine particulate and dissolved solids are trapped within the foam at the top of the column, which can be collected and removed. The main factors affected by the operational design of the foam fractionator are bubble size, contact time between the air bubbles and dissolved organic compounds. Foam fractionation is a suitable process in seawater and the efficiency increases with increasing salinities. It is related to the increasing surface tension allowing smaller air bubbles in seawater and thereby with a higher filter area. Foam fractionation is working very efficiently from a salinity of 12 ppt and more.

Figure 5. Protein skimmer used for removing dissolved fraction of solids

BIOFILTRATION

Not all the organic matter is removed in the mechanical filter; the finest particles will pass through together with dissolved compounds such as phosphate and nitrogen. Phosphate is an inert substance, with no toxic effect, but nitrogen in the form of free ammonia (NH_3) is toxic and needs to be transformed into non-toxic form in the bio-filter. The breakdown of organic matter and ammonia is a biological process carried out by bacteria in the bio-filter. Heterotrophic bacteria oxidize/breakdown the organic matter by consuming oxygen and producing carbon dioxide and ammonia. Nitrifying bacteria convert ammonia into nitrite and finally into nitrate.

Bio-filters or Bio-balls are typically constructed using plastic media giving a high surface area per m^3 of bio-filter. The bacteria will grow as a thin film on the media thereby occupying an extremely large surface area. A well-designed bio-filter aims to reach high surface area per m^3 without packing the bio-filter so tight that it should not get clogged with the organic matter under operation. It is therefore important to have a high percentage of free space for the water to pass through and to have a good overall flow through the bio-filter together with a sufficient back wash procedure. Such back-wash procedures must be carried out at sufficient intervals once a week or month depending on the load on the filter. Compressed air is used to create turbulence in the filter whereby organic matter is ripped off. The bio-filter is shunted during the washing, and the dirty water in the filter is drained off and discharged before the bio-filter is connected to the system again.

Efficiency of bio-filtration depends primarily on

- Water temperature
- pH level

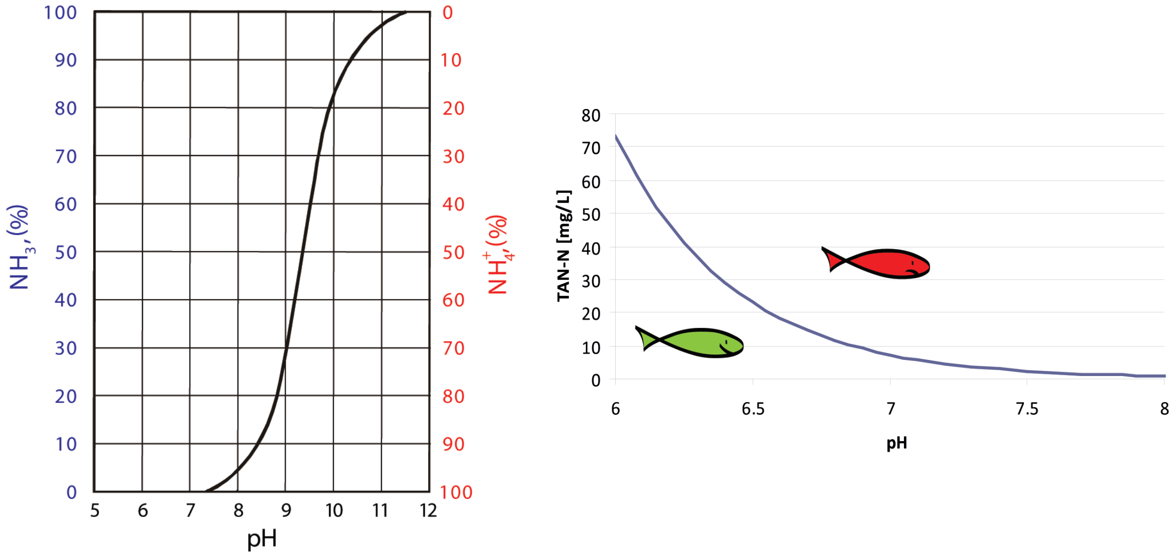


Figure 6: The equilibrium between ammonia (NH_3) and ammonium (NH_4^+) at 20 °C and pH relation with TAN.

To reach an acceptable nitrification rate, water temperatures should be kept within 10 to 35 °C (optimum around 30 °C) and pH levels between 7 and 8. The water temperature will most often depend on the species reared and as such is not adjusted to reach the most optimal nitrification rate but to give optimal levels for fish growth. Regulation of pH in relation to bio-filter efficiency is however important as a lower pH level reduces the efficiency of the bio-filter. The pH should therefore be kept above 7 in order to reach a high rate of bacterial nitrifying. On the other hand, increasing pH will result in an increasing amount of an ionised ammonia (NH_3^-), which will enhance the toxic effect. The aim is therefore to find the balance between these two opposite aims of adjusting the pH. A recommended adjustment value is between pH 7.0 and pH 8.3.

Two major factors affect the pH in the water recirculation system:

- Production of CO_2 from the fish and from the biological activity of the bio-filter
- Acid produced from the nitrification process
- Consumption of alkalinity in the nitrification process

Bio-filteration Types

1. Trickling filter

Trickling filters are one of the earliest and commonly utilized biological filtration systems in aquaculture. The trickling filter is so designed that water flows over suspended media and into a sump at the bottom. It is suspended as being relatively simplistic and cost effective due to their basic construction and operation. In addition, they may also function as a degassing and oxygen columns. Trickling filters have the advantages of being able to tolerate difference in hydraulic and organic loads, minimizing maintenance requirement. However, the major disadvantage of trickling filters is the utilization of low surface area of the media which requires larger volumes of media and floor space. Trickling filters can become clogged due to a lack of passive biofilm shedding and rapid heterotrophic growth, as the filter is never completely submerged and the flow rate is limited by media density and space availability as well as the solids produced due to the bacteria.

2. Rotation Biological Contactor (RBC)

Rotating biological contactor works on the principle of trickling filter but in a different configuration. Oxygen is acquired through air and water but is facilitated by a mechanical rotation of the media. Generally 40% of the medium is submerged at any point of time. Once again clogging can become a problem through the lack of passive biofilm shedding and excessive heterotrophic bacterial growth. This can lead to a decrease in nitrification and bio-filter efficiency.

3. Fluidized Bed Rector (FBR)

A fluidized bed reactor (FBR) is fundamentally an up-flow filter that flows continuously, which maintains the media in the suspension as a fluidized manner. As opposed to the trickling and RBC filter, the FBR has the advantage of utilizing smaller media directly increasing the relative specific surface area. Reduced volumetric requirement of media and the potential to reduce fluid retention times, size and cost of the nitrification process are the advantages of FBR. Nitrification rates are increased significantly in a FBR but can require high flow velocity and an active backwashing scheme to maintain efficiency. The use of low-density media can help to reduce this problem and minimize energy requirements.

4. Submerged Filter

Submerged filters are primarily referred to as fixed-packed bed filters. These filters work by passing water, either by an upwelling or downwelling flow through a fixed medium. Generally, any type and size of media can be used within the filter housing to achieve the greatest surface area. The design and construction of submerged filters can be simple, compact and inexpensive. However, due to their compactness and fixed media particulate tends to settle within the filter voids. This can be managed by either 1) adjusting the organic loading rate or 2) implementing an active backwashing schedule to maintain bio-filter efficiency.

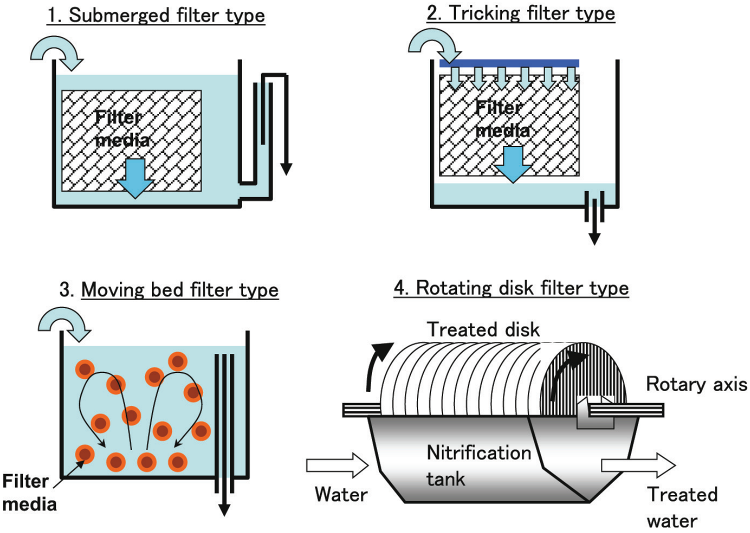


Figure 7. Schematic diagram of diffrent types of biofilter for RAS

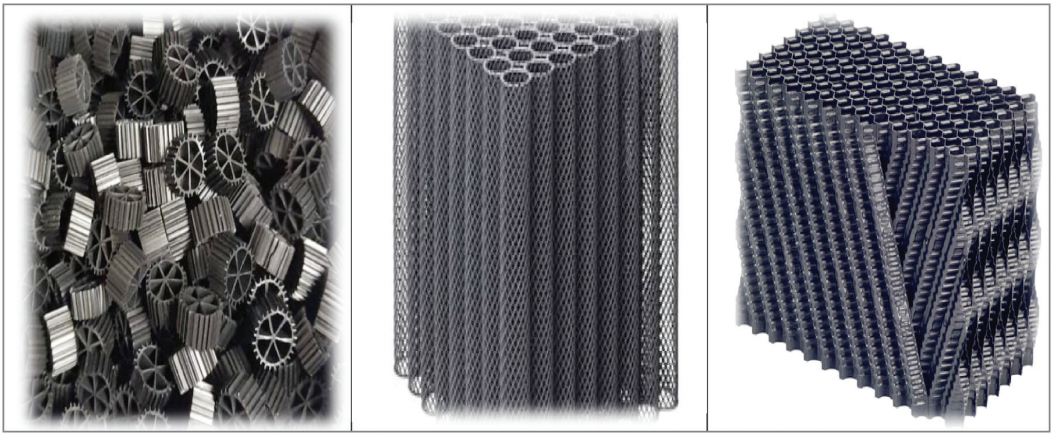


Figure 8. Types of filter bed media used in RAS facility

5. Floating Bead Filters (FBF)

Floating bead filters (FBF) are similar to submerged filters except a floating polyethylene bead is utilized as the media. These beads range from 0.998 mm to 6.9 mm in diameter with a majority of commercial applications utilizing a 3 mm bead. FBF display advantages due to their ability to maintain high solid capture and low head loss during high organic loading rates. The FBF was also tested as a bi-clarifier (functioning as a solid removal and biological filter in one). Backwashing of FBF is also more efficient where less water is required at a low velocity to sufficiently remove solids from the medium.

DEGASSING AND AERATION

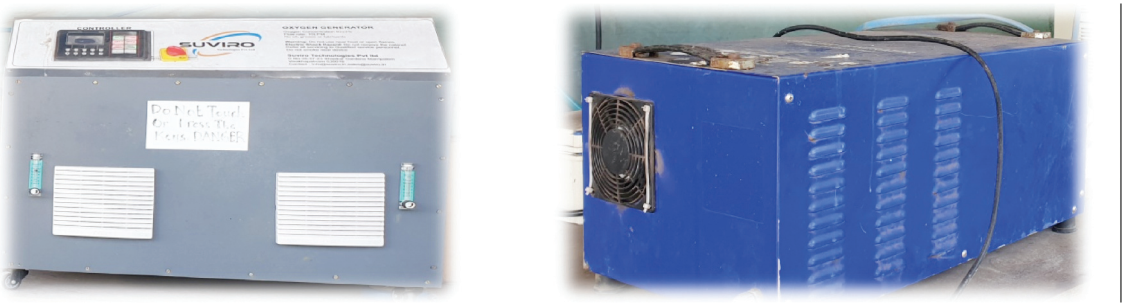
Before the water runs back to the fish tanks, accumulated gases which are detrimental to the fish must be removed. This degassing process is carried out by aeration of the water, and the method is often referred to as stripping. Fish respiration as well as the bacterial activity increase the carbon dioxide (CO_2) production in the system. This also gets enhanced even after using pure oxygen in the system. Free nitrogen (N_2) is another byproduct of ammonification and nitrification process. Accumulation of these carbon dioxide and nitrogen gas levels will have detrimental effects on fish welfare and growth. Under anaerobic conditions, hydrogen sulfide (H_2S) can be produced, especially in saltwater systems. This gas is extremely toxic to fish, even in low concentrations, and fish will be killed if hydrogen sulfide is generated in the system.

Aeration can be accomplished by pumping air into the water whereby the turbulent contact between the air bubbles and the water drives out the gases. This underwater aeration makes it possible to move the water at the same time. The aeration well system is however not as efficient for removing gases as the trickling filter system, also called a degasser. In the trickling system, gases are stripped off by physical contact between the water and plastic media stacked in a column. Water is led to the top of the filter over a distribution plate with holes, and flushed down through the plastic media to maximize turbulence and contact, the so-called stripping process.

OXYGEN SUPPLY

The aeration process of the water, which is the same physical process as degassing or stripping, will add oxygen to the water through a simple exchange between the gases in the water and the gases in the air depending on the saturation level of the oxygen in the water. The equilibrium of oxygen in water is 100% saturation. When the water has passed through the fish tanks, the oxygen content will be lowered, typically down to 70%, and the content is reduced further in the bio-filter. Aeration of this water will typically bring the saturation up to around 90%, in some systems 100% can be reached. Oxygen saturation higher than 100% in the inlet water to the fish tanks is however often preferred in order to have sufficient oxygen available for high and stable fish growth.

Saturation levels above 100% calls for a system using pure oxygen. Pure oxygen is often delivered in tanks in the form of liquid oxygen, but can also be produced on the farm through an oxygen generator. There are several ways of making super-saturated water with oxygen contents reaching 200-300%. Typically high pressure oxygen cone systems or low-head oxygen systems, such as oxygen platforms are used. The principle is the same. Water and pure oxygen are mixed under pressure whereby the oxygen is forced into the water. In the oxygen cone, the pressure is accomplished with a pump creating a high pressure of typically around 1.4 bar in the cone. Pumping water under pressure into the oxygen cone consumes a lot of electricity. In the oxygen platform, the pressure is much lower, typically down to about 0.1 bar, and water is simply pumped through the box mixing water and oxygen. The difference between the two kinds of systems is that the oxygen cone solution uses only a part of the circulating water for oxygen enrichment, whereas the oxygen platform is used for the main recirculation flow often in combination with the overall pumping of


10 LPM Oxygen concentrator
5 LPM Oxygen concentrator


Nanobubbler
Air Blower

Figure 9. Different types/capacity of aeration systems

water around in the system. Whatever method is used, the process should be controlled with the help of oxygen measurement. The best way of doing so is to have the oxygen probe measuring after the oxygenation system at normal atmospheric pressure, for example in a measurement chamber delivered by the supplier. This makes the measurement easier than if it were made under pressure, since the probe will need to be wiped clean and calibrated, from time to time.

DISINFECTION

Disinfection means the removal, deactivation or killing pathogenic microorganisms. UV disinfection works by applying light in wavelengths that destroy DNA in biological organisms. In aquaculture pathogenic bacteria and single-celled organisms are targeted. The treatment has been used for medical purposes for decades and does not impact the fish as UV treatment of the water is applied outside the fish production area. It is important to understand that bacteria grow so rapidly in organic matter that controlling bacterial population in traditional fish farms has limited effect. The best control is achieved when effective mechanical filtration is combined with a thorough bio-filtration to effectively remove organic matter from the process water, thus making the UV radiation work efficiently. The UV dose can be expressed in several different units. One of the most widely used is micro Watt-seconds per cm^2 ($\mu Ws/cm^2$). The efficiency depends on the size and species of the target organisms and the turbidity of the water. In order to control bacteria and viruses the water needs to be treated with roughly 2000 to 10000 μ Ws/cm^2 to kill 90% of the organisms, fungi will need 10000 to 100000 and small parasites 50000 to 200000 $\mu Ws/cm^2$. UV lighting used in aquaculture must work under water to give maximum efficiency; lamps fitted outside the water will have little or no effect because of water surface reflection.

UV generator Ozone generator

Figure 10. Two different methods used in RAS water treatment

The use of ozone in fish farming has been criticized because the effect of over-dosage can cause severe injury to the fish. In farms inside buildings, ozone can also be harmful to the people working in the area as they may inhale too much ozone. Thus correct dosage and monitoring of the loading together with proper ventilation are crucial to reach a positive and safe result. Ozone treatment is an efficient way of destroying unwanted organisms by the heavy oxidation of organic matter and biological organisms. In ozone treatment technology microparticles are broken down into molecular structures that will bind together again and form larger particles. By this form of flocculation, microscopic suspended solids too small to be caught can now be removed from the system instead of passing through the different types of filters in the recirculation system. This technology is also referred to as water polishing as it makes the water clearer and free of any suspended solids and possible bacteria adhering to these. This is especially suitable in hatchery and fry systems growing small fish, which are sensitive to microparticles and bacteria in the water. Ozone treatment can also be used when the intake water to a recirculation system needs to be disinfected.

WATER MOVEMENT: PUMPS

Different types of pumps are used for circulating the processed water in the system. Pumping normally requires a substantial amount of electricity, and low lifting heights and efficient and correctly installed pumps are important to keep running costs at a minimum. The lifting of water should preferably occur only once in the system, whereby the water runs by gravity all the way through the system back to the pump sump. Pumps are most often positioned in front of the bio-filter system and the degasser as the water preparation process starts here. In any case, pumps should be placed after the mechanical filtration to avoid breaking the solids coming from the fish tanks. Calculation of the total lifting height for pumping is the sum of the actual lifting height and the pressure losses in pipe runs, pipe bends, and other fittings. This is also called as the dynamic head. If water is pumped through a submerged bio-filter before falling down through the degasser, counter pressure from the bio-filter will also have to be accounted for.

The total lifting height in most intensive recirculation systems today is around 2-3 meters, which makes the use of low-pressure pumps most efficient for pumping the main flow around. However, the process of dissolving pure oxygen into the water requires centrifugal pumps as these pumps are able to create the required high pressure in the cone. In some systems where the lifting height for the main flow is very low, the water is driven without the use of pumps by blowing air into aeration wells. In these systems, the degassing and the movement of water are accomplished in one process, which makes low lifting heights possible. The efficiency of degassing and moving of water is however not necessarily better than that of pumping water up over the degasser, because the efficiency of aeration wells in terms of using energy and the degassing efficiency is lower than using lifting pumps and stripping or trickling the water.

2 HP Motor pumps 1 HP Back wash pump

2 HP Submersible pumps 0.5 HP Back wash pump

Figure 11. Different types/capacity of motor pumps used to RAS facility

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