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Compliance Guide for the Concentrated Aquatic Animal Production Point Source Category

Chapter 9: Solids Control for Flow-through and Recirculating Facilities

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Chapter 9: Solids Control for Flow-through and Recirculating Facilities

The ELGs regulations require facilities to implement solids control BMPs, which are intended to allow facilities to develop regional or site-specific operational measures to control the discharge of solids and other materials. The narrative BMP requirements also allow facilities and permit writers to respond to state programs that are currently working well. Some examples of solids control management practices include a combination of any and/or all of the following:

- Feed management
- Solids management
- Solids disposal
- Solids storage
- Mortality removal and disposal

Feed Management

Feed is effectively the only major source of aquaculture-derived nutrients, such as nitrogen and phosphorus, and solids in flow-through systems. Optimizing feed management by using high quality feeds and minimizing feed waste can reduce the nutrients and solids generated and released to the environment. Feed also represents the largest single variable cost of production and efficient use of feeds can result in cost savings. Accurate feeding systems and appropriate feeding levels are essential for productivity, economic efficiency, and protection of the environment.

Relatively short hydraulic residence times and continuous discharge of water make feed management an important component in controlling the amount of nutrients and solids discharged from flow-through systems.

For recirculating aquaculture systems, the loading of potential pollutants to a receiving body of water is not entirely related to feed input, but is dependent upon the effectiveness of waste capture and treatment processes within the recirculating system and on any additional effluent treatment processes used to clean the water before discharge. Minimizing waste feed will minimize the wastes that must be treated in the recirculating system and ultimately the amount of waste released to the environment. Feed management is only one factor among many in the control of potential pollution from recirculating aquaculture systems.

Examples of Feed Management Practices

1. Use high quality feeds and seek to minimize nutrient and solids discharges through optimization of feed formulation (in cooperation with feed manufacturers)

Feeds should be formulated to meet the nutritional requirements of the cultured species and for optimum feed conversion ratios and retention of protein (nitrogen) and phosphorus. Feeds should be formulated using ingredients that have high dry matter and protein apparent digestibility coefficients. Formulations should be designed to enhance nitrogen and phosphorus retention efficiency, and reduce metabolic waste output. Feeds should contain sufficient dietary energy to spare

dietary protein (amino acids) for tissue synthesis. Available phosphorus levels should be slightly in excess of the dietary requirements of the species for each life-history stage. Efforts should be made in feed formulation to keep total phosphorus levels as low as possible while maintaining appropriate available phosphorus levels. Consult a qualified aquatic animal nutritionist or feed manufacturer for information regarding feed formulation.

When facility operators evaluate feed formulations, they should consider numerous factors including, pellet stability, digestibility, palatability, sinking rates, energy levels, moisture content, ingredient quality and the nutritional requirements of the species being grown. Feeds should be formulated and manufactured using high-quality ingredients.

Pelleted feeds should be stable in water for sufficient time so the pellets remain intact until eaten. Feeds should be manufactured, stored, shipped, and handled at the farm so they contain a minimum amount of fine particles.

In the case of feeds used in recirculating systems, minimizing metabolic excretion of nitrogen from amino acids catabolized to provide metabolic energy, and minimizing nitrogen excretion in feces from indigestible protein is the top priority in feed formulation. Therefore high quality feeds for recirculating systems should have balanced amino acid profiles, e.g., profiles that meet but do not substantially exceed dietary requirements for individual essential amino acids, and contain sufficient dietary energy from carbohydrates and lipids to “spare” dietary protein for tissue synthesis.

2) Use efficient feeding practices

FT RAS

In flow-through and recirculating systems, feed can be delivered by hand, automatic feeders, demand feeders, or by mechanical feeders. Regardless of the delivery method or system, the amount of feed offered should optimize balance between growth goals and feed efficiency.

Figure 9.1. Demand feeder

The appropriate quantity of feed for a given species is influenced by feed formulation, fish size, water temperature, dissolved oxygen levels, carbon dioxide concentrations, health status, and management goals. Feed particle size should be appropriate for the size of fish in each rearing unit. Whenever possible, feed utilization should be monitored by observing feeding behavior or by looking for trends in waste feed collecting within the culture unit or waste feed exiting the culture unit.

Figure 9.2. Feed truck

Multiple feeding periods distributed over a 24-hour period will provide more uniform water quality within a recirculating system than a feeding schedule only offering feed once or twice daily.

3) Calculate feed conversion ratios by using feed and fish biomass inventory tracking systems FT RAS

Calculation of feed conversion ratios is an essential function on all aquatic animal farms. Monitoring long- and short-term changes in feed conversion ratios allows farmers to quickly identify significant changes in feed consumption and waste production rates.

4) Manage within the carrying capacity of the production system FT RAS

Flowing water carries dissolved oxygen to the culture units, receives the waste produced in the culture unit, and carries these wastes away from the culture unit to treatment units before the wastes can accumulate to harmful and undesirable levels. Dissolved oxygen is usually the first water quality parameter to limit culture tank carrying capacity, which, in simplistic terms, is the maximum fish biomass that can be supported at a selected feeding rate. Note that the culture vessel volume does not determine carrying capacity unless water flow is in excess of all other water quality based carrying capacity requirements.

Impaired water quality due to high loading and excessively high feeding rates stresses fish and reduces feed efficiency and production. High loading and high feeding rates also lead to higher levels of nutrients and solids in the effluent. Loading and feeding rates within the carrying capacity of the production system are more efficient, and minimize the discharge of pollutants.

In flow-through systems, carrying capacity is determined by incoming water quality and quantity, production goals, facility design, site characteristics, and species cultured. As such, there is no single carrying capacity value applicable to flow-through systems and carrying capacity will vary within and between facilities.

Recirculating systems, by definition, treat and reuse large portions of the system make-up water flow. Therefore, the water flow requirements through the culture units within a recirculating system can be much greater than the make-up water flow requirements that flush the system. Of primary importance is the removal of the waste metabolites: ammonia, carbon dioxide, and total suspended solids (TSS), whose production is directly proportional to feed load.

Biofilters, aeration columns, and filters/clarifiers are unit processes used to control ammonia, carbon dioxide and TSS accumulations within recirculating systems. Aquacultural engineering texts and many other publications provide the methodology to design biofilters, aeration columns, and filters/clarifiers to treat a given flow or the waste metabolites produced by a given feeding rate. However, when a unit treatment process (e.g., biofilter or aeration column) is designed, the designer should provide the expected water quality exiting a culture tank within a recirculating system to help ensure that the design will provide safe water quality for the fish when reared at maximum carrying capacity, i.e., feed loading. Operators of recirculating systems should feed at rates that do not exceed the maximum carrying capacity of the system.

5) Properly store feed FT RAS

Feed storage areas should be secure from contamination, vermin, moisture and excessive heat. Long term storage of feed can affect feed quality. Feed should be rotated (use oldest feed first) and not stored beyond the manufacturer's recommended use date. If feed can no longer be used because of spoilage or it has exceeded the manufacturer's recommendations for storage, the unusable feed should be properly disposed to prevent water quality impacts.

Care should be taken during feed handling to minimize pellet damage or crushing and reduce the creation of fine feed particles that cannot be utilized by the fish.

6) Check feeding equipment to ensure efficient operation FT RAS

Improperly adjusted or malfunctioning feeding equipment can over-feed or under-feed fish and reduce feed and production efficiency.

7) Conduct employee training in fish husbandry and feeding methods to ensure that workers have adequate training to optimize feed conversion ratios FT RAS

Solids Management

Fish fecal matter and waste feed are the major constituents of total suspended solids from culture practices in flow-through systems. Solids allowed to settle in rearing units degrade water quality and may irritate fish gills leading to disease. Solids can impact the aquatic environment and should be thoroughly collected prior to wastewater discharge.

Flow-through system effluent is characterized as high volume with low solids concentration. This effluent characteristic generally limits practical and economical solids management to the capture and removal of solids using settling basins. Solids found in flow-through systems readily settle and can be managed with practices that rely on gravitational settling before water is discharged. Practices that increase solid particle fragmentation decrease settling efficiency. These particles are much smaller and have poor settling characteristics. Fish grading, harvesting, and other activities within raceways or ponds should be conducted in a manner that minimizes the disturbance and possible discharge of accumulated solids. In rare situations, high levels of TSS in source water may warrant pretreatment systems, such as settling basins, to improve source water quality for fish culture.

Waste feed and fish fecal matter are waterborne and require separation for efficient management of water quality within the recirculating system. The solids treatment processes in a recirculating system remove a portion of the feed derived waste solids in the recirculating water. Higher solids removal efficiencies result in cleaner water within the recirculating system.

The particulate wastes discharged from the recirculating system are contained in either a small but concentrated flow (such as the intermittent backwash from a solids capture unit) and/or in a more continuous flow of displaced water (such as an overtopping flow from a pump sump that is water that has been displaced by make-up water addition) that has a concentration of solids similar to that found in the fish culture

tanks. Not all recirculating systems will have an overtopping flow, depending upon their make-up water requirements. When the solids are discharged, as with backwashing water, the concentration of solids is typically relatively high. However, if an overtopping flow is discharged from the system, it will be relatively small in volume compared to the discharge from a flow-through system.

Solids can impact the aquatic environment and should be collected as much as possible prior to wastewater discharge. Therefore, nearly all flow-through and recirculating aquaculture systems use some form of solids treatment and/or disposal to remove the concentrated slurry of captured biosolids. In some cases, it may also be necessary to treat the more dilute but relatively larger volume system overflow before this flow is discharged. As an alternate to on site treatment, either of these waste flows could be discharged to a POTW.

Examples of Solids Management Practices

1) Design and operate rearing units for efficient and rapid capture of solids from the water column, incorporating fish-free settling basins where practical FT RAS

Linear rearing units designed to promote plug flow and sufficient water velocity to prevent the settling of solids within the rearing unit allow the efficient capture of solids using quiescent zones or other settling basins. Proper facility design and construction can be an economical means of managing solids through settling in designated areas, allowing for efficient removal. Fish should be prevented from entering quiescent zones and other settling basins and removed as soon as possible when found to prevent or alleviate resuspension and subsequent discharge of solids.

Circular tanks with properly designed inlets and drains can remove the majority of solids with minimum labor for further treatment. Circular tanks can rapidly concentrate and remove settleable solids. Circular tanks are designed to promote a primary rotating flow that creates a secondary radial flow that carries settleable solids to the bottom center of the tank, making the tank self-cleaning. The self-cleaning attribute of the circular tank depends on the overall rate of flow leaving the bottom-center drain, the strength of the bottom radial flow towards the center drain, and the swimming motion of fish. The factors that affect self-cleaning within circular tanks are also influenced by the water inlet and outlet design, tank diameter-to-depth ratio, water rotational period, size and density of fish, size and specific gravity of fish feed and fecal material, and water exchange rate.

2) Remove solids from collection systems in a timely fashion FT RAS

Solids should be removed from quiescent zones with a frequency sufficient to prevent cohesion and limit release of solids-bound nutrients. The level of feed application, settling basin efficiency, and relative storage capacities of the basins will determine the removal frequency. For example, quiescent zones are typically cleaned at least every two weeks during the peak growing seasons. However, the frequency of solids removal should be determined based on factors such as facility discharge compliance limits, water quality requirements in the culture units, or labor availability.

The most common method of solids removal from quiescent zones is by suction through a vacuum head. Usually, a standpipe in each

quiescent zone connects to a common pipe that carries the slurry to an off-line settling basin. Suction is provided by head pressure from raceway water depth and gravity, or where fall is not available, by pumps. A flexible hose and swivel joint connects the vacuum head to the standpipe so the vacuum can be manipulated to clean the quiescent zone. There are other methods used to clean quiescent zones. For example, the standpipe to the off-line destination may be removed and the solids can be pushed with a broom or squeegee device to the suction port.

Settling basins should be cleaned as frequently as practical. A procedure or mechanism to remove the dewatered manure from the thickening device must be incorporated. Sludge left too long in settling basins becomes sticky and viscous making removal more difficult. Sludge accumulation may degrade water quality as nutrients are released through bacterial or physical degradation. Off-line and full-flow settling basins should be harvested when storage capacity is reached or as effluent concentrations near compliance limits.

To clean full-flow and off-line settling basins the inflow is usually diverted to another settling basin and the supernatant from the settling basin decanted. The slurry is allowed to dry sufficiently for removal by backhoe, front-end loader, or other equipment. Or the slurry may be pumped directly onto a tank truck or manure spreader. Other options include pumping the slurry out of the settling basin without diverting the flow, similar to cleaning a quiescent zone.

3) Remove solids rapidly, but gently

FT RAS

Rapid, effective, and gentle removal of waste solids within a solids treatment unit is the best approach to use when targeting optimum water quality. Waste feed and fish manure are typically fragile and labile organic particles. The longer these particles are held within the culture system, the more opportunity that dissolution forces such as hydraulic shear and micro-organisms will have to disintegrate larger particles into much finer and more soluble particles. Finer particles can more rapidly leach nutrients and biochemical oxygen demand (BOD) and these components are harder to remove from the water column than the original intact fecal pellet or waste feed pellet. Thus, if unit processes are not installed to remove fresh and intact solids rapidly, then solids decomposition within aquaculture systems can degrade water quality and thus directly affect fish health and the performance of other unit processes. Products of solid decomposition are more difficult to remove from aquacultural effluents.

Waste solids exiting the rearing tank can be removed from the bulk flow leaving the culture tank using a treatment unit such as settling basins (e.g., full-flow settlers, off-line settlers, quiescent zones, inclined [tube or plate] settlers, and swirl separators), microscreen filters (e.g., drum, disk, or belt filters), and granular media filters (e.g., bead or sand filters). In addition, ozone and foam fractionation are water treatment processes that can be used in recirculating systems to remove dissolved organic matter.

Conventional sedimentation and microscreen filtration processes are often used to remove solids larger than 40-100 µm. However, few processes used in aquaculture can remove dissolved solids or fine solids smaller than 20-30 µm, although granular media filtration has been used to remove these fine solids. Depending on the particle size distribution and the concentration of solids, conventional

sedimentation and microscreen filtration processes typically remove anywhere from 30-80% of the solids in the treated flow.

Significant degradation or re-suspension/flotation of the solids matter should be avoided, but can occur in treatment units that have relatively infrequent backwash cycles. Therefore, the best solids removal processes remove solids from the system as soon as possible and expose solids to the least turbulence, mechanical shear, or micro-biological degradation. Note that microscreen filters and swirl separators (with a continuous underflow) do not store solids for an appreciable period, unlike settling basins and most granular media filters.

Backwash of the solids capture unit will create an intermittent solids-laden flow that will require treatment before discharge, unless discharged to a POTW.

Not all recirculating aquaculture systems maintain low levels of suspended solids, as is typically the goal in recirculating systems used for sensitive species such as trout and salmon. Some species may tolerate elevated levels of suspended solids and may actually consume the algae or micro-organisms found in these solids. Such is the case for some recirculating systems used for tilapia and shrimp. Some recirculating systems rely on a combination "green water" or organic detrital algae soup (ODAS), which is an algal and activated sludge-type treatment process, combined with settling basins or granular media filters to treat the water. In these instances, the rapid removal of waste solids is not a goal because the algae and bacteria growing *in situ* within the recirculating systems may rely upon solids degradation to treat dissolved wastes and maintain the culture system water quality. Total suspended solids concentrations in these recirculating systems can exceed 150 mg/L. Thus, the associated waste management systems must consider the specifics of each recirculating aquaculture system in order to successfully achieve waste collection, transfer, storage, treatment, and utilization.

4) Frequently remove solids from settling basins FT RAS

Settling basins should be cleaned as frequently as practical. Fish manure left too long in settling basins becomes sticky and viscous making removal difficult. Fish manure accumulation may degrade water quality and can provide a substrate for bacterial growth.

A procedure or mechanism to remove the dewatered manure from the settling basin should be incorporated in the BMP plan.

5) Overflows from solids thickening tanks may require additional treatment

FT RAS

Solids thickening and storage tanks will often discharge a supernatant/overflow, which will be a relatively small volume discharge but one that contains the highest concentration of wastes discharged from an aquaculture system. Therefore, treating the thickening tank overflow can reduce the mass load of wastes discharged. Treatment can be relatively simple and inexpensive because low effluent volumes must be treated. Further removal of soluble BOD and ammonia may be required, and can be accomplished with properly designed aerated basins, aerobic lagoons, created wetlands, anaerobic filters, or other suitable technologies. Alternatively, the thickening tank overflow could be discharged to a

POTW or reused beneficially for irrigation or hydroponics.

6) When necessary, remove solids from the recirculating system's overtopping flow (if present) before it is discharged RAS

Depending upon their make-up water requirements, some recirculating systems will have an overtopping flow in addition to a concentrated backwash flow. The concentration of solids in the overtopping flow is typically similar to that found in the fish culture tanks. Depending upon the specifics of the recirculating aquaculture system, the suspended solids in the flow overtopping this system may require further treatment. Waste solids can be removed from the overtopping flow using a treatment unit such as settling basins (e.g., full-flow settlers, inclined [tube or plate] settlers, and swirl separators), microscreen filters (e.g., drum, disk, or belt filters), granular media filters (e.g., bead or sand filters), or dissolved air flotation systems.

Solids Disposal

Aquaculture solids, primarily consist of fish feces and uneaten feed, contain plant nutrients (nitrogen and phosphorus) and can often be used as a soil amendment. The composition of the solids varies among facilities according to feed formulation(s) used at the facility, treatment of the solids inside and out of the culture system, and age of the solids.

Aquaculture solids are similar to other animal manures. Some state or local governments may consider the fish manure captured in an aquaculture waste management system an industrial or municipal waste (i.e., not an agricultural waste). Check with your local or state authorities to determine your waste disposal options.

Examples of Solids Disposal Practices

1) Disposal of solids should comply with all applicable local and state regulations and done in a manner that prevents the material from entering surface or groundwaters FT RAS

Solids disposal will be a site-specific practice, based on factors such as local regulations, soil types, topography, land availability, climate, and crops grown. Disposal options might include land application on agricultural lands at agronomic rates, storage lagoons, composting, and contract hauling.

a) Land Application – Land application of aquacultural solids is the most common disposal method. Proper application of aquacultural solids provides a safe method for solids utilization while fertilizing crops and amending the soil. Fish manure in liquid form may be sprinkler irrigated directly onto agricultural land. In slurry form, fish manure may be pumped into a tank truck or manure spreader and then applied to agricultural land. Finished compost generated from aquacultural solids may also be applied onto agricultural land at agronomic rates.

Figure 9.3. Manure spreader

b) Evaporation Ponds/Lagoons – Manure slurries from aquaculture operations may be treated in evaporation ponds/lagoons that can thicken and stabilize the manure. Evaporation ponds/lagoons are effective in arid climates only. The stabilized solids can then be land applied or otherwise safely disposed.

c) Composting – Thickened and dewatered manure may be composted. Composting stabilizes the solids and produces a valuable soil amendment. Aerobic static pile composting is the most common method for composting dewatered manure. Any excess supernatant, leachate, or filtrate leftover from slurry treatment processes may require additional treatment. State and local regulations regarding composting should be followed.

d) Contract Hauling – A licensed contract hauler can be paid to remove the collected solids or thickened manure.

e) Reed Drying Beds – Depending on location and the local regulations, an aquaculture facility may have only limited and costly options available for disposal of the thickened manure. For example, transportation costs may make sludge disposal on cropland uneconomical. Disposing of the sludge on-site within created wetlands may be an attractive alternative.

A constructed reed drying bed can provide on-site treatment of a concentrated solids discharge with an uncomplicated, low-maintenance, plant-based system. Reed drying beds are vertical-flow wetland systems that have been used over the past 20 years to treat thickened sludge (1-7% solids) produced in the clarifier underflow at wastewater treatment plants and have been recently used to treat manure from commercial recirculating systems. Thickened biosolids are loaded in sequential batches onto the reed drying bed every 7-21 days. Only 2-4 inches of thickened biosolids are applied during a given application. The 1-3 week intervals between applications of thickened biosolids allow for dewatering and drying, which is facilitated by the vegetation growing on the sand bed. Reed beds have been found to have a useful lifetime of up to 10 years.

2) Use solids from earthen flow-through systems to repair embankments FT

Earthen flow-through systems accumulate solids in the rearing units during production. It is not practical or necessary to remove solids during production from earthen rearing units. When it is necessary to remove solids from earthen rearing units, the source water is diverted around or away from the rearing units and they are allowed to dry. The solids removed can be used to repair the embankments and other areas of the rearing unit. Solids should not be used to repair roads or other facility surfaces because the solids could contaminate stormwater runoff from the facility.

Solids Storage

Concentrated aquaculture solids can be stored in thickening basins that have been designed to accommodate the build-up of solids and hence provide some temporary solids storage capacity. However, solid-liquid separation becomes less effective as sludge accumulates within these basins. Increasing sludge depths can compromise settling basin hydraulics and the solids stored can rapidly ferment leading to solids flotation and dissolution of nutrients and organic matter. In some cases, the thickened sludge from thickening basins is transferred to large sludge storage structures capable of holding months of captured and thickened solids. Facility owners design solids storage structures to hold the amount of solids that they anticipate they will collect and hold at the facility prior to final disposal (e.g., land application). Facilities located in colder climates may be required to hold solids for 6 months, while facilities in warmer climates typically design storage structures to hold solids for one month. These off-line storage structures typically have zero overtopping flow and store their manure slurry contents until they can be removed for disposal.

Figure 9.4. Above ground manure storage structure

Examples of Solids Storage Practices

1) Store sludge in an appropriate facility or container FT RAS

Sludge storage structures include earthen ponds, and aboveground or belowground tanks. Earthen ponds are generally rectangular basins with inside slopes (horizontal:vertical) of 1.5:1 to 3:1. Depending on site geology and hydrology, earthen ponds can have liners of concrete, geomembrane, or clay. Because they are uncovered, earthen pond design will include the capacity for storage of rain water as well as a method for removing solids. In the case where solids will be removed via pumping, the solids must be agitated to provide a uniform consistency. Pond agitation may be accomplished with hitch-type propeller agitators that are powered by tractors or by agitation pumps. Propeller agitators work well for large ponds, while chopper-agitator pumps work well for smaller ponds. Solids removal may also be done with heavy equipment, in which case, pond design should include ramp access (maximum slope of 8:1) and suitable load capacity in the unloading work area.

Sludge may also be stored in tank structures, above and below ground. Storage tanks are primarily constructed of reinforced concrete, metal, and wood. Reinforced concrete tanks may be cast-in-place, walls, foundation, and floor slab, or they may be constructed of pre-cast wall panels, bolted together, and set on a cast-in-place foundation and floor slab. Metal tanks are also widely used, with the majority being constructed of glass-fused steel panels that are bolted together. There are many manufactured, modular tanks commercially available in reinforced concrete and metal, as well as wood.

Solids degradation during storage can produce dangerous levels of hydrogen sulfide gas, methane and hydrogen gases, and in tanks with little air exchange can contain an atmosphere that includes the aforementioned gases and is anoxic. Use OSHA confined space guidelines when considering all aspects of the human interface with a solids storage structure and take every practical precaution to prevent harm to those working around these structures.

State and local regulations regarding odors from the manure storage vessels should be considered.

Mortality Removal and Disposal

Mortality of small numbers of cultured species in aquaculture systems is a common occurrence. It is also unpredictable and highly variable among rearing units, epizootics, and facilities. A facility may experience chronic mortality of a few fish per day or a catastrophic loss caused by infectious disease or acute environmental stress. Depending on water temperature and species, dead fish either float or sink after dying, with warm water fish typically floating and cold-water fish sinking.

In flow-through systems, whether floating or sinking, dead fish tend to accumulate on the screens at the end of the rearing units.

In recirculating systems, sinking fish mortalities tend to accumulate on the exclusion screen on the bottom center drain of circular tanks or on the outlet screen of linear raceways. Floating fish will accumulate on the surface of circular tanks, where they are relatively easy to see.

The timely removal of mortalities helps decrease the probability of spreading infectious organisms and the introduction of excess nutrients into the system.

Examples of Mortality Removal and Disposal Practices

1) Remove mortalities from rearing units on a regular basis FT RAS NET

Mortalities should be removed from rearing units regularly. To accomplish this, inspect culture units to check for the presence of mortalities. Many mortalities float to the surface of the culture water and can be collected by hand or with nets.

Mortalities accumulating on screens prevent the efficient flow of water from unit to unit and represent a hazard for possible damage to the screen resulting in escape of fish from the unit or diversion of flow away from downstream units.

Dead or moribund fish can be transported by flowing water to a tank drain, where they can accumulate against screens and restrict the water flow out of the culture unit. Dead fish should be removed from culture units as soon as possible to maintain water level in the culture tank, to decrease the probability of spreading infectious organisms, and to reduce water quality deterioration. Dead fish that sink may be difficult to detect at the bottom center of large circular culture tanks or along the bottoms of net pens that are deep or contain turbid water. A procedure or mechanisms should be identified for detecting and removing dead fish from the culture units.

2) Follow recommended aquatic animal health management practices
FT RAS NET

Prevention and minimization of mortalities through proper fish health surveillance and management are the best methods for managing mortalities. Maintaining good water quality can help to prevent disease outbreaks. Most states offer diagnostic services and treatment recommendations for disease problems.

3) Do not discharge mortalities into receiving waters FT RAS NET

Appropriate screens for flow-through and recirculating systems on the outlet to receiving waters will prevent mortalities discharging into receiving waters. There are, however, permitted restoration and stock-enhancement activities where spawned carcasses are returned to waters for nutrient replacement.

Figure 9.5. Screened effluent pipe

4) Only use approved methods of mortality disposal FT RAS NET

Disposal methods are site-specific and usually governed by state or local regulations. Disposal options could include composting, rendering, use as fertilizer, incineration, burial, or landfill.