CHAPTER 7

BEST MANAGEMENT PRACTICES AND TREATMENT TECHNOLOGIES CONSIDERED FOR THE CONCENTRATED AQUATIC ANIMAL PRODUCTION INDUSTRY

7.1 INTRODUCTION

EPA evaluated a variety of concentrated aquatic animal production (CAAP) industry best management practices (BMPs) and wastewater treatment technologies. BMPs are management strategies and practices that CAAP facility operators use to increase production efficiencies while reducing either the effluent volume or concentrations of pollutants in the effluent stream. Examples of BMPs include feed management, health management, and mortality removal. Wastewater treatment technologies are used at a facility to remove one or more pollutants from the effluent stream. For example, primary settling of solids is a technology used at a facility to capture solids from the facility's effluent. EPA evaluated a variety of treatment technologies and practices, including those presented in this chapter, as a part of the analyses used to support the development of the final regulation.

7.2 BEST MANAGEMENT PRACTICES

7.2.1 Feed Management

Feed is the primary source of pollutants to CAAP systems. Feed management recognizes the importance of effective, environmentally sound use of feed. Facility operators should continually evaluate their feeding practices to ensure that feed is consumed at the highest rate possible. For pond systems, pond biomass, though difficult to estimate accurately, can be helpful in determining how much feed to add to a particular pond. For all systems, observing feeding behavior and noting the presence of excess feed can be used to adjust feeding rates to ensure maximum feed consumption and minimal excess.

The primary operational factors associated with proper feed management are development of feeding regimes, based on the weight of the cultured species, and regular observation of feeding activities to ensure that the feed is consumed. This practice is advantageous because it decreases the costs associated with excess feed that is not consumed by the cultured species. Excess feed can degrade the quality of the production water by adding excess nutrients to the system. Facilities should also handle and store feed with care to prevent the breakdown of feed into fine particles. If fines are present in the feed, they should be removed and disposed of properly.

In pond systems, solids from the excess feed usually settle out and are naturally processed, along with feces from the aquatic animals. Although most of the dissolved and solids fractions from the uneaten feed are treated in the pond, some of the constituents can be released when water overflows from the pond or during draining. Too much excess feed can overwhelm natural processes in the pond and result in the discharge of higher pollutant loads.

There are a variety of practices that can be used to minimize wasted feed and optimize feed uptake by the aquatic animals. Facilities should use high-quality feed consistent with the nutritional needs of the cultured species to maximize feed consumption and conversion. The facility operator should know the feed requirements of the cultured species to accurately determine daily feed amounts. Facilities should use information including size of fish, water temperature, projected growth rates, and biomass in the system to determine appropriate feeding rates (Westers, 1995). Facilities should also store feed properly to maintain the nutrient quality and minimize humidity to prevent growth of molds or bacteria on feed.

In addition to the above practices, feed management practices for net pen facilities should monitor feeding rates using technologies such as underwater photography. Excess feed is the primary source of sediment accumulation beneath net pens, which can have an adverse effect on the benthic community.

7.2.2 Best Management Practices Plan

The BMP plan describes and documents management activities that are implemented at the CAAP facility to reduce the discharge of pollutants, including solids generated from feeding the aquatic animals. The BMP plan also documents practices and management activities such as those associated with the storage and use of drugs and pesticides, management and maintenance of solids containment systems, maintenance of the structural integrity of various system components, and any activities associated with feed management. Additionally, BMP plans include descriptions of record-keeping activities and training sessions for employees. The overall goal of the BMP plan is to document planning and implementation of operation and management activities that a facility uses to control the discharge of solids, nutrients, and chemicals such as drugs and pesticides. The BMP plan also shows regulatory authorities how facility personnel are preventing the accidental discharge of stored materials, trash, and dead aquatic animals.

7.2.3 Health Screening

During normal operations, health screening involves the periodic sampling of the cultured species, which are screened for diseases, parasites, and body weight. Health screening can be done periodically and involves using small seines, cast nets, or dip nets to collect a random sample. The samples are visually inspected for diseases and parasites, then weighed and returned to the culture system.

Health screening allows for the early detection of certain diseases and parasites, such as columnaris or trichodina, which would otherwise not be detected until the outbreak had spread through the cultured population. Most states have diagnostic services available to assist in screening aquatic animals and identifying potential problems. Measuring weight allows producers to evaluate general health, determine how well the crop is performing, and continually update feeding regimes so that the most efficient feed rates are used. Health screening can also reduce the use of medicated feeds by identifying diseases early in their development before catastrophic outbreaks occur.

7.2.4 Inventory Control

Inventory control refers to the ongoing management of the amount of aquatic animal biomass in a culture system. Accurate record-keeping and regular sampling to determine the average size of cultured species are important tools for estimating the amount of biomass in the production system. Higher biomass requires higher feed inputs, which could potentially lower the water quality by adding nutrients and reducing levels of dissolved oxygen (DO). Production systems with high biomass are subject to reduced growth rates, lower feed conversion ratios, and increased pollutant loadings from metabolic wastes. Information collected as part of inventory control helps the facility to develop cost-effective feeding regimes to promote optimal water quality.

7.2.5 Mortality Removal

Mortality of the cultured species in small numbers is a common occurrence in CAAP systems. Many of the mortalities float to the surface of the culture water and can be collected by hand or with nets. Mortality removal requires at least daily inspection of each culture unit to check for the presence of mortalities. Changes in operations should not be required because most producers complete at least one daily inspection of all production operations.

The timely removal of mortalities helps to prevent the spread of some diseases. Quickly removing mortalities before they start to decompose also reduces the introduction of excess nutrients into the system. There are no known disadvantages to the timely removal of mortalities; however, when facilities have large numbers of mortalities, removal might be more costly and require seines and crews similar to those used during harvest.

7.2.6 Net Cleaning

The regular cleaning of production nets helps to ensure the constant flow of water through the production area of the net pens. As the nets sit in the culture area, marine organisms attach to and grow on the nets, reducing the area of the openings. This reduction in area reduces the water flow through the net pens and the amount of DO available. Lack of water exchange due to a reduced open net area also increases the buildup of metabolic waste in the system.

7.2.7 Pond Discharge Management

The most significant determinant for effluent quality in pond systems appears to be frequency and duration of pond drainings. The longer the time interval between drainings, the lower the wastewater volume and pollutant loads being discharged primarily because of fewer discharge events.

Pond systems are characterized as systems with infrequent discharges of water that have been treated by natural processes in the pond. There are two types of discharge from ponds: unintentional discharges due to overflow events and intentional discharges related to production practices such as harvesting.

Intentional discharges vary in frequency with the type of pond, the species being produced, and operator preferences. Water may be intentionally discharged from ponds to facilitate harvests or to improve the quality of the water in the pond by flushing or exchanging the water with new water additions.

Discharge management applies practices to reduce the volume of water discharged and to improve the quality of water through in-pond processes. By managing the frequency of discharge and holding water between crops, natural processes in the pond can assimilate wastes in the system. Other practices and technologies, such as aeration and feed management, also enhance water quality in the system.

Reusing water for multiple crops reduces the effluent volume. Effluent volume can also be reduced by draining ponds only when necessary. When possible, facilities can construct ponds that do not have to be drained for harvest. Facilities may harvest fish by seining without partially or completely draining the pond unless it is necessary to harvest in deep ponds, restock, or repair pond earthwork.

Facilities may also design new ponds with structures that allow the ponds to be drained near the surface instead of from the bottom to improve the quality of the water drained. (Water from the bottom of the pond has more solids.) If necessary, facilities may install a swivel-type drain that can take in water from the surface and be lowered to completely drain the pond.

When ponds must be drained completely, it is recommended that the final 20% to 25% of the pond volume be discharged into a settling basin or held for 2 to 3 days to minimize suspended solids and then discharged slowly.

7.2.8 Rainwater Management

Ponds can be managed to capture and store precipitation and minimize the need for expensive pumped groundwater or surface water. By maintaining pond depths between 6 to 12 inches below the height of the overflow structure, about 160,000 to 325,000 gallons of storage capacity per surface acre of pond is available to capture direct rainfall and runoff from the pond walls. When more water is stored, less water is released through overflows and smaller amounts of potential pollutants are released. Capturing rainfall and reducing the amount of overflow reduces the need for pumping additional water into a pond to compensate for water lost to evaporation and infiltration. The capture of rainfall also reduces the amount of pollutants released into the waterways by extending the natural treatment processes that take place in the pond. This practice of preventing overflow by capturing rainwater is a common practice in many sectors within pond operations such as the catfish and baitfish industry. An additional benefit of this practice is that less energy is required for operating the facility.

For watershed ponds in larger watersheds, excess flows can be diverted away from the ponds. Diversions can be designed to provide sufficient water for the management of the pond and crop of fish while diverting excess water away from the pond. With less water flowing through the ponds during large runoff events, the overflow volume is reduced (Boyd et al., 2000).

There are little, if any, costs for this practice. The cost of energy and pump maintenance will be saved if water is not pumped into ponds to maintain water levels. The cost of adding more capacity by extending the height of drain structures should include pond design evaluations, materials to modify the structure, and labor to perform the modifications.

7.2.9 Siting

Siting is the preimplementation planning that should take place to ensure that a net pen system is located in an area of adequate flow. Net pens placed in areas without sufficient tidal flushing have an increased probability of sedimentation beneath the pens. Net pens should also be located in areas where they are protected from storm events and do not become a hazard to navigation.

7.2.10 Secondary Containment (Escape Control)

Secondary containment involves the use of a second set of containment netting around a net pen system. The secondary containment netting should be positioned to capture any fish that might escape the primary containment netting due to damage to the net pen system, which could occur because of a storm event or other structural failure.

Influent screening is also applicable to all systems using ambient water sources for culture water. Influent screening can prevent the escapement of the cultured animals into source water. Screening also ensures the removal of organisms such as wild fish and insects that can significantly reduce production through predation.

Many facilities also screen effluents to guard against the escapement of the cultured species into the receiving waters. Effluent screening may include the use of metal grates or screens with mesh sizes small enough to exclude the cultured species from the effluent stream or the use of disinfection techniques such as ozonation or UV disinfection to kill any of the cultured species before they are discharged to a receiving waterbody.

7.2.11 Solids Removal BMP Plan

A facility’s solids removal BMP plan includes components designed to minimize the discharge of solids from the facility. The CAAP facility would provide written documentation of a solids removal BMP plan and keep necessary records to establish and implement the plan.

Evaluating and planning site-specific activities to control the release of solids from aquatic animal production (AAP) facilities is a practice currently required in several EPA regions as part of individual and general National Pollutant Discharge Elimination System (NPDES) permits (e.g., shrimp pond facilities in Texas, net pens in Maine, and flow-through facilities in Washington and Idaho). BMP plans in these permits require the facility operators to develop a management plan for handling removed solids and preventing excess feed from entering the system. The BMP plan also ensures planning for proper operation and maintenance of equipment, especially treatment control technologies.

7.2.12 Drug and Pesticide BMP Plan

The purpose of the drug and pesticide BMP plan is to document the proper use and storage of specific drugs and pesticides in the production facility (e.g., amount of the drugs and pesticides used, proper storage of chemicals, and proper identification of the disease or problem and selection of proper chemical). The plan also addresses practices to minimize the accidental spillage or release of drugs and pesticides. The CAAP facility is expected to provide written documentation of a BMP plan and keep necessary records to establish and implement the plan as well as to report use of investigational new animal drugs and extralabel drug use. Again, this tool is intended to be flexible; individual facilities are able to comply with the regulations by designing plans that address the unique needs of their facilities.

7.3 WASTEWATER TREATMENT TECHNOLOGIES

7.3.1 Aeration

Some discharges from ponds, especially those from bottom waters, might be low in DO or have sufficient biochemical oxygen demand (BOD) to be problematic in receiving waters. When DO is a problem, aeration of pond discharges can be used to increase DO levels and prevent receiving water problems. Discharges from ponds can be aerated by using mechanical or passive aeration devices before they are discharged into a receiving water body. For relatively shallow ponds that are easily mixed, aerating the pond to meet fish culture needs should be sufficient to prevent problematic discharges.

Mechanical aeration devices include paddlewheel aerators and other surface aerators that create surface agitation. Surface agitation increases the surface area available for oxygen transfer. For deeper ponds, aeration of the discharge as it leaves the pond might be more practical and efficient. Passive aeration systems use the energy generated by falling water to increase the air-water surface area. Passive aeration systems take many forms, including waterfalls, rotating brushes, and splash boards. Mechanical aeration devices used for effluent treatment should undergo the same inspection and maintenance procedures implemented for aeration devices used in production areas. Passive aeration devices should be inspected regularly to remove debris and ensure correct function of the device.

Mechanical aeration can be integrated at most pond production facilities because the facilities already own the necessary equipment to aerate the pond. Passive aeration systems require no energy inputs and have low maintenance inputs once they have been constructed. Passive aeration systems can also be used to convey discharges to the receiving water body, thus reducing the potential for erosion along earthen conveyance systems.

Facilities with multi-pass serial raceways use active or passive aeration systems to maintain adequate DO concentrations in the culture water. Those facilities with sufficient hydraulic head between raceways tend to use passive or gravity aeration systems to increase the air-water interface, which in turn increases the DO content of the culture water (Wheaton, 1977).

Facilities with insufficient head between raceways use mechanical aeration systems to increase DO in the culture water. Recirculating systems also use mechanical aeration systems. Mechanical aeration systems include liquid oxygenation systems and diffuser aerators. Liquid oxygen systems add oxygen to the culture water under pressure to increase the efficiency of oxygenation. Diffuser aerators inject air or pure oxygen below the culture waters surface in the form of bubbles. As the bubbles pass through the water column, oxygen is transferred across the air-water interface (Wheaton, 1977).

Disadvantages of mechanical aeration systems include the energy and labor resources required to operate and maintain the aeration devices. Mechanical aerators should be operated and sited carefully to minimize the generation of suspended solids in the effluent.

7.3.2 Biological Treatment

Biological treatment involves the use of microorganisms to remove dissolved nutrients from a discharge (Henry and Heinke, 1996). Organic and nitrogenous compounds in the discharge can serve as nutrients for rapid microbial growth under aerobic (with oxygen) or anaerobic (with little or no oxygen) conditions. Biological treatment systems can convert approximately one-third of the colloidal and dissolved organic matter to stable end products and convert the remaining two-thirds into microbial cells, which can be removed through gravity separation.

Biological treatment operations are contained in tanks, lagoons, or filter systems. Most biological treatment systems are aerobic, meaning that they require free oxygen to maintain the microbial biomass necessary for effective treatment. Oxygen is usually supplied through diffusers in the bottom of the containment structure. In addition to providing oxygen, the diffusers ensure mixing of the discharge in the containment structure. After treatment, the discharge usually flows to polishing treatment operations before being discharged. Excess biomass from the containment structure is drained from the containment structure or captured in a settling device after the treated discharge leaves the biological treatment unit.

Biological treatment systems must have a constant supply of nutrient-rich water to keep the microorganism growth at its maximum potential. Aerobic biological systems also require supplemental oxygen systems to supply oxygen to the treatment system. In addition, biological systems in northern climates must be insulated from extremely cold conditions to remain effective throughout the winter. Biological treatment systems provide for the rapid conversion and removal of organic and nitrogenous pollutants in a small treatment volume. Biological treatment units also help to remove both fine and coarse solids as the discharge is settled.

Disadvantages of biological treatment systems include the cost associated with the continuous operation of these systems. Biological treatment systems are most effective when operated 24 hours/day and 365 days/year. Systems that are not operated continuously have reduced efficiency because of changes in nutrient loads to the microbial biomass. Biological treatment systems also generate a consolidated waste stream consisting of excess microbial biomass, which must be properly disposed. Operation and maintenance costs vary with the process used.

7.3.3 Constructed Wetlands

Constructed wetland treatment systems consist of shallow pools constructed on non-wetland sites with water at depths of usually less than 2 feet (Metcalf and Eddy, 1991; USEPA, 1996). Constructed wetlands provide substrate for specific emergent vegetation types such as cattail, bulrush, and reeds.

Constructed wetlands are designed to treat discharges through physical, chemical, and biological processes. The vegetation causes the discharge to flow slowly in a more serpentine manner, increasing the likelihood of solids settling. The vegetation also aids in the absorption of potential pollutants through plant and bacterial uptake, and it increases the oxygen level in the discharge flowing through it. Constructed wetland treatment systems can be designed to provide several different benefits, including treatment of the discharge through biological and chemical processes, temporary storage of discharges, recharge of aquifers, and reduction in discharge volume to receiving water bodies.

Constructed wetland treatment systems are most commonly used to provide a polishing or finishing step for discharge treatment operations. Newly constructed systems often require significant replanting of vegetation and backfilling of erosion damage. Once the system is operating properly, it should be inspected regularly to remove dead or fallen vegetation, check for erosion and channelization, and monitor sedimentation levels. Periodic harvest and proper disposal of the vegetation can also increase nutrient removal.

Constructed wetlands that have collected large amounts of sediment should be refurbished to ensure proper removal efficiencies and protect against the resuspension of collected solids. The section of the constructed wetland being refurbished should be taken offline for a period long enough to allow the removal of solids and regrowth of emergent vegetation. Solids removed from the wetland should either be land applied at agronomic rates or disposed using other sludge disposal methods.

Constructed wetlands have varying success in CAAP operations. Wetlands require large areas for treatment of relatively small volumes of water; therefore, facilities with limited available land for expansion are not able to use constructed wetlands. In many parts of the United States, constructed wetlands have seasonal differences in pollutant removal efficiencies. For example, in colder climates, constructed wetlands might discharge some dissolved nutrients during the colder season and become a sink for these pollutants during warmer months.

7.3.4 Injection Wells

Deep well injection is a wastewater disposal method by which wastewater is injected into a geologic layer beneath the earth’s surface. EPA categorizes injection wells into five classes, based on the type of well and the waste disposed of. Class I and Class V wells are the only wells that may be used by CAAP facilities. Because of the costs associated with drilling and maintaining Class I wells, EPA assumes that most injection wells used by the

CAAP industry are Class V wells. Class V injection wells are defined as shallow wells such as septic systems and drywells used to place nonhazardous fluids directly below the land surface (USEPA, 2002b). Class V wells include technologically advanced wastewater treatment systems and simple waste disposal systems, such as septic systems and cesspools. These wells are usually shallow and depend on gravity to “inject” wastes below the earth’s surface. Because Class V wells may be hydraulically connected to drinking water aquifers, they should be closely monitored to avoid contamination (USEPA, 2002a).

Class I injection wells are defined as municipal or industrial injection wells that inject wastewater below the lower most underground source of drinking water (USWD). To qualify as a USWD, the aquifer or part of it must or be able to supply a public water system (PWS) or contain water with less than 10,000 milligrams/liter of total dissolved solids, and not be exempted by EPA or state authorities from protection as a source of drinking water (USEPA, 2001).

7.3.5 Disinfection

Disinfection is a process by which disease-causing organisms are destroyed or rendered inactive. Most disinfection systems work in one of the following four ways: (1) damage to the cell wall, (2) alteration of the cell permeability, (3) alteration of the colloidal nature of the protoplasm, or (4) inhibition of enzyme activity (Henry and Heinke, 1996; Metcalf and Eddy, 1991).

Disinfection is often accomplished using bactericidal agents. The most common agents are chlorine, ozone (O_3), ultraviolet (UV) radiation, or disinfection with UV light. Chlorination, the use of chlorine, is the most common method of disinfection used in the United States. Applications of high concentrations of chlorine and ozone are used to disinfect the discharge stream. UV radiation disinfects by penetrating the cell wall of pathogens with UV light and completely destroying the cell or rendering it unable to reproduce.

Each disinfection system has specific operational factors related to its successful use, which might limit its appeal. Chlorine systems must have a chlorine contact time of 15 to 30 minutes, after which the discharge must in general be dechlorinated prior to discharge, depending on facility location and permit requirements. Chlorine systems may create byproducts, such as trihalomethanes, which are known carcinogens. Finally, the contact chamber must be cleaned on a regular schedule. Ozonation has limitations as well. Ozone must be generated on-site because its volatility does not allow it to be transported. On-site generation requires expensive equipment. UV radiation systems might have only limited value to dischargers without adequate total suspended solids (TSS) removal because the effectiveness of UV radiation systems decreases when solids in the discharge block the light. This system also requires expensive equipment with high maintenance costs to keep the system clean and replace UV bulbs.

Disinfection systems are beneficial because they render CAAP effluents free from active pathogenic organisms, regardless of their source. In addition, ozonation increases the DO content of the discharge stream and destroys certain organic compounds.

7.3.6 Flocculation/Coagulation Tank

Flocculation or coagulation tanks are used to improve the treatability of wastewater and to remove grease and scum from wastewater (Metcalf and Eddy, 1991). The purpose of wastewater flocculation is to cluster fine matter to facilitate its removal. These clusters are often referred to as “flocs.” The flocculation of wastewater by mechanical or air agitation increases the removal of suspended solids and BOD in primary settling facilities. For mechanical and air agitation, the energy input is commonly decreased so that the initially formed flocs will not be broken as they leave the flocculation facilities. Disadvantages associated with flocculation/coagulation tanks include high costs for maintenance and energy use.

7.3.7 Filters

A number of different filtration systems are available to treat CAAP effluents, including microscreen filters, multimedia filters, and sand filters. Filters are used to remove solids and associated pollutants from the wastewater stream. Because small-diameter solids and associated nutrients contained in CAAP industry effluents might be difficult to remove using only conventional (gravity) solids settling wastewater treatment operations, the use of filtration systems can efficiently increase the removal of these solids.

7.3.7.1 Microscreen Filters

Microscreen filters are commonly used filtration systems that consist of a synthetic screen of specific pore size that is used to remove solids from the effluent stream. Typical pore sizes for microscreen filters vary from 60 to 100 microns. Most microscreen filters operate by pumping the wastewater stream across the filter. Water passes through the screen and the solids are trapped on the surface of the screen, where they can later be flushed off to a solids holding unit for further treatment.

7.3.7.2 Multimedia Filters

Multimedia filters are pressurized or non-pressurized treatment units that contain filter media of at least two different materials. Wastewater flow is directed through a series of media (e.g., gravel and sand) using the coarse, larger sized media first to facilitate the removal of larger solids, then smaller sized media that are progressively less porous. At periodic intervals the flow of wastewater is stopped and the filters are backwashed (cleaned) by forcing clean water through the filter in the direction opposite the wastewater flow. The procedure removes the collected solids from the filter media and directs waste to either an additional treatment unit or to a solids holding structure.

7.3.7.3 Sand Filters

Sand filters can be pressurized or nonpressurized treatment units that contain sand. Sand filters are typically shallow beds of sand (24 to 30 inches) with a surface distribution system and an underdrain system (Metcalf and Eddy, 1991). The effluent is applied to the surface of the sand bed and the treated liquid is collected in the underdrain system. Most sand filters are buried underground.

7.3.8 Hydroponics

Hydroponics is a process in which fine solids and nutrients in discharges are removed through the culture of aquatic or terrestrial plants (Metcalf and Eddy, 1991; Van Gorder, 2001). After a concentrated waste has been screened to remove coarse solids, it is diverted through the hydroponics system. A hydroponics system functions by suspending the root system of a plant species in the discharge stream to allow for the uptake of nutrients and removal of fine solids. After the plants grow to their maximum size, they are harvested and replaced with new plants that will more effectively absorb nutrients.

Operational factors associated with hydroponic systems include the need for a constant supply of a nutrient-rich discharge to the hydroponics operation for the cultured plants, the harvesting of the cultured aquatic plants, and disposal of any unused biomass. Constant nutrient-rich discharge requirements make hydroponic systems most applicable to recirculating and flow-through production systems. The constant harvesting or removal of biomass requires the dedication of labor resources to these tasks. Hydroponic systems that use aquatic plants, such as water hyacinth, duckweed, or pennywort, to treat discharges must develop composting plans because the biomass generated by these species has no commercial value.

Limitations of hydroponic systems for intensive CAAP systems include the size of the hydroponics system needed to effectively treat the discharge stream and climatic conditions. A small intensive CAAP operation can provide sufficient nutrients for a large-scale hydroponics operation; however, a large hydroponic treatment in northern climates is limited by the infrastructure inputs needed to operate the system year-round. Most hydroponically grown plants cannot effectively grow year-round without being located inside a greenhouse. Also, it can be very difficult to control the nutrient content of effluents to meet the specific nutrient needs of the cultured plants.

Advantages of hydroponic systems include the removal of nutrients, such as phosphorus and ammonia, and economic benefits through the sale of crops such as lettuce.

7.3.9 Infiltration/Percolation Pond

Infiltration/percolation ponds allow for the simultaneous treatment and disposal of discharges by allowing them to gradually infiltrate the soils surrounding the basin. These ponds are constructed in soils with high hydraulic conductivity, allowing for the rapid infiltration of the wastewater into the soil (USEPA, 1996). Infiltration/percolation basins are designed with flat bottoms and without drainage structures. Evaporation is not considered to significantly increase the effectiveness of these basins.

Infiltration/percolation systems have few operational factors once they have been constructed. Before the ponds are constructed, soil tests must be conducted to ensure that the soils will have sufficient infiltration rates. Once operational, the basins should be inspected monthly to monitor water levels, check for soils accumulation, and determine whether any erosion of the banks has occurred. In some cases, it might be necessary to remove sediment and debris, and to till the basin bottom to preserve functionality.

All solids removed as part of an operation and maintenance program or in conjunction with a refurbishing effort should be treated in the same manner as solids from primary settling operations. The solids can be either be land applied at agronomic rates or disposed using other sludge disposal methods.

The primary advantage of these systems is the low operation and maintenance costs associated with their operation. Very few equipment or labor inputs are required after the construction of the systems; periodic brief inspection of the basin should be the only required operational task. Additional benefits of infiltration/percolation basins include the recharge of groundwater aquifers located below the basins and the absence of a discharge to a receiving water body.

Disadvantages of these systems include space availability for the basin and requirements for specific soil types with high hydraulic conductivities. Infiltration systems require a large surface area to successfully treat and dispose of large volumes of discharge. Another limitation of these systems is their long-term viability. Studies have shown the functional life of these systems is 5 to 10 years.

7.3.10 Oxidation Lagoons (Primary and Secondary)

Oxidation lagoons, also known as stabilization ponds, are usually earthen, relatively shallow wastewater treatment units used for the separation of solids and treatment of soluble organic wastes (Metcalf and Eddy, 1991). The basins are cleaned of solids as needed, which may be as long as once every 20 years. Oxidation ponds are used extensively in the wastewater treatment industry and are commonly used by the alligator industry for the treatment of wastewater generated during pen cleaning.

Oxidation lagoons are usually classified as aerobic, anaerobic, or aerobic-anaerobic (facultative) according to the nature of the biological activity in the pond. Aerobic and facultative lagoons require that oxygen be added to all or parts of the lagoon constantly; therefore, in order to reduce costs, most lagoons in the alligator industry are operated as anaerobic lagoons.

The primary advantages of oxidation lagoons for treatment of wastewater are the relative low costs of designing, constructing, and operating oxidation lagoons; the low technology requirements for the operators; and the demonstrated effectiveness of their use in treating similar effluents. Oxidation lagoons can also be operated without a discharge to surface waters through land application by spray irrigating water from the lagoon to prevent overflows.

Disadvantages of oxidation lagoons include the need to clean out accumulated solids; the potential odor emitted from the lagoon under normal operating conditions and during solids removal; and the inability of the lagoons to remove small-sized particles. The lagoon is designed to hold a fixed volume of solids and must be cleaned when the solids volume exceeds the design volume. Accumulated solids must be removed and properly disposed of through land application or other sludge disposal methods. Odors are a constant nuisance, and several methods are available to treat particularly bad odor problems. These solutions, however, tend to be costly and require additional equipment and operational resources.

7.3.11 Quiescent Zones

Quiescent zones are used in raceway flow-through systems where the last approximately 10% of the raceway serves as a settling area for solids. It is important to note that flow-through system raceways are typically sized according to loading densities (e.g., 3 to 5 pounds of fish per cubic foot), but the flow rate of water through the system drives the production levels in a particular raceway. Thus, EPA evaluated the impacts of placing quiescent zones in the lower 10% of raceways and found no adverse impacts on the production capacity of a facility (Hochheimer and Westers, 2002). The goal of quiescent zones and other in-system solids collection practices is to reduce the total suspended solids (and associated pollutants) in the effluent. Quiescent zone pollutant reductions were based on information supplied by industry representatives (Hinshaw, 2002, personal communication; Tetra Tech, 2002).

Quiescent zones usually are constructed with a wire mesh screen that extends from the bottom of the raceway to above the maximum water height to prohibit the cultured species from entering the quiescent zone. The reduction in the turbulence usually caused by the swimming action of the cultured species allows the solids to settle in the quiescent zone. Then the collected solids are available to be efficiently removed from the system. The quiescent zones are usually cleaned on a regular schedule, typically once per week in medium to large systems (Tetra Tech, 2002), to remove the settled solids. The Idaho BMP manual (IDEQ, n.d.) recommends minimal quiescent zone cleaning of once per month in upper raceways and twice per month in lower units. The settled solids must be removed regularly to prevent breakdown of particles and leaching of pollutants such as nutrients and BOD.

Quiescent zones placed at the bottom or end of each raising unit or raceway allow for the settling of pollutants, mainly solids, before the pollutants are discharged to other production units (when water is serially reused in several raising units) or receiving waters.

Quiescent zones increase labor inputs because of the regular removal of collected solids and maintenance of screens that exclude the culture species. Cleaning of the quiescent zones also creates a highly concentrated waste stream that should be treated before it is discharged into a receiving water body.

7.3.12 Sedimentation Basins

Sedimentation basins, also known as settling basins, settling ponds, sedimentation ponds, and sedimentation lagoons, separate solids from water using gravity settling of the heavier solid particles (Metcalf and Eddy, 1991). In the simplest form of sedimentation, particles that are heavier than water settle to the bottom of a tank or basin. Facilities with high levels of production and feeding rates clean the basins as often as once per month. Facilities with lower feeding rates clean less often, but at a minimum of once per year. Sedimentation basins are used extensively in the wastewater treatment industry and are commonly found in many flow-through aquatic animal production facilities. Most sedimentation basins are used to produce a clarified effluent (for solids removal), but some sedimentation basins remove water from solids to produce a more concentrated sludge. Both of these practices are used and are important in CAAP systems.

Settling in sedimentation basins occurs when the horizontal velocity of a particle entering the basin is less than the vertical (settling) velocity in the tank. When designing a sedimentation basin, settling properties of an effluent are determined, particularly the settling velocities, and the basins are sized to accommodate the expected flow through the basin. The length of the sedimentation basin and the detention time can be calculated so that particles will settle to the bottom of the basin.

Other design factors include the effects of inlet and outlet turbulence, short-circuiting of flows within the basin, solids accumulation in the basin, and velocity gradients caused by disturbances in the basin (such as those from solids removal equipment).

Proper design, construction, and operation of the sedimentation basin are essential for the efficient removal of solids. The basin must be cleaned at proper intervals to ensure the solids are removed at the designed efficiency.

The primary advantages of sedimentation basins for removing suspended solids from effluents from aquatic animal production systems are the relative low cost of designing, constructing, and operating sedimentation basins; the low technology requirements for the operators; and the demonstrated effectiveness of their use in treating similar effluents. In many CAAP systems, most of the solids from feces and uneaten feed are of sufficient size to settle efficiently in most moderately sized sedimentation basins. Many of the pollutants from CAAP operations can be partly or wholly removed with the solids captured in a sedimentation basin.

Disadvantages of a sedimentation basin include the need to clean out accumulated solids, the potential odor emitted from the basin under normal operating conditions, the odor produced by solids removed from the basin, and the inability of the basin to remove small-sized particles. Accumulated solids must be periodically removed and properly disposed of through land application or other sludge disposal methods. Odors are a constant nuisance, and several methods are available to treat particularly bad odor problems. These solutions, however, tend to be costly and require additional equipment and operational resources. System operators should attempt to minimize the breakdown of particles (into smaller sizes) to maintain or increase the efficiency of sedimentation basins. Existing CAAP systems might have limited available space for the installation of properly sized sedimentation basins.

Sedimentation basins do not function well in colder climates, where they are likely to freeze. The viscosity of water increases as its temperature decreases, which results in a decrease of the settling velocity of solids in the wastewater stream. Sedimentation basins designed for colder climates should include a safety factor to account for the longer detention times and inlet and outlet pipes should be located underwater to reduce the likelihood of freezing (Metcalf and Eddy, 1991).

7.3.13 Vegetated Ditches

A vegetated ditch is an excavated ditch that serves as a discharge conveyance, treatment, and storage system (USEPA, 1996). The vegetation layer aids in treating the discharge and reduces the susceptibility of the ditch banks and bottom to erosion. The length and width of the ditch are designed to allow for the slowing and temporary storage of the discharge as it flows toward the receiving water body. The walls of the ditch are excavated at an angle that supports the growth of a dense vegetation layer to enhance sedimentation and ensure against erosion.

Vegetated ditches are effective for treating wastewater discharges from CAAP facilities. They reduce the velocity of discharged water, which induces the settling of solids and associated pollutants by gravity. The vegetation ditch essentially traps pollutants such as suspended solids, settleable solids, and BOD and prevents them from being discharged into receiving waters. Depending on the porosity of the soil, a vegetated ditch might also allow wastewater to infiltrate the underlying soil as it flows along the channel.

Few operational factors are associated with using vegetated ditches. The main component of effective operation is proper design and construction of the ditch to ensure adequate vegetation and prevent scouring flows. Infiltration/percolation rates are a function of soil porosity and increase if the ditch is constructed in an area of high soil porosity. Vegetated ditches need to be maintained periodically to remove accumulated sediment for proper disposal and to maintain vegetation. Periodic harvest and proper disposal of the vegetation can also increase nutrient removal.

Disadvantages of vegetated ditches include lack of control over the treatment of the discharge. Furthermore, vegetated ditches have no backup system in the event of extremely high flow or during times when the vegetation needs to be reestablished.

7.3.14 Publicly Owned Treatment Works

Publicly owned treatment works (POTWs) are wastewater treatment plants that are constructed and owned by a municipal government for the purpose of treating municipal and industrial wastewater from homes and businesses within its borders and/or surrounding areas. A facility that discharges to a POTW is considered to be an “indirect” discharger because the facility’s wastewater is directed to a POTW for treatment before being discharged to surface water. Some CAAP facilities are indirect dischargers.

7.3.15 Solids Handling and Disposal

7.3.15.1 Dewatering

Dewatering is the physical process used to reduce the moisture content of sludge to make it easier to handle for transport, or prior to composting or incineration of the sludge. Several techniques are used to dewater sludge; some rely on natural evaporation, whereas others use mechanically assisted physical means such as filtration, squeezing, capillary action, vacuum withdrawal, and centrifugal separation (Metcalf and Eddy, 1991).

7.3.15.2 Composting

Composting is a process by which organic material undergoes biological degradation to a stable end product (Metcalf and Eddy, 1991). Approximately 20% to 30% of the volatile solids are converted to carbon dioxide and water. As the organic material in the sludge decomposes, the compost heats to temperatures in the range of 120 to 160 ºF, and pathogenic organisms are destroyed.

7.3.15.3 Land Application

Land application is the most common sludge disposal method in the CAAP industry (Chen et al., 2002). Land application of sludge is defined as the spreading of sludge on or just below the soil surface (Metcalf and Eddy, 1991). Application methods include using sprinklers and tank trucks to apply the sludge directly to the land. Sludge may be applied to agricultural land, forested land, disturbed land, and dedicated land disposal sites. In all of these cases, the land application is designed with the objective of providing further sludge treatment (Metcalf and Eddy, 1991). Sunlight, soil microorganisms, and dryness combine to destroy pathogens and other toxic organic substances present in sludge.

7.3.15.4 Storage Tanks and Lagoons

Manure, or sludge, from CAAP facilities has to be properly treated and disposed of. Storage tanks or storage lagoons are used to store untreated wastewater until the water can be treated or to store treated wastewater until it can be reused by the production system. Holding tanks, storage tanks, and surge tanks are used throughout the CAAP industry to hold untreated or treated wastewater.

7.4 TREATMENT TECHNOLOGIES OBSERVED AT EPA SITE VISITS

Table 7.4–1 describes the treatment technologies observed at the CAAP facilities that EPA visited as part of the Agency's data collection efforts.

Table 7.4–1. Aquatic Animal Production Site Visit Summary

State	*Species*	*Production System*	*Treatment Technologies*
AL	Catfish	Ponds	Storage of runoff in reservoir, water management, erosion control, proper ditch construction
AL	Catfish	Ponds	Water management, erosion control, proper ditch construction
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control, drainage to natural wetland
AL	Catfish	Ponds	Water management, riprap on pond banks, erosion control, stairstep watershed ponds
AR	Baitfish	Ponds	Water management, erosion control

State	***Species***	***Production System***	***Treatment Technologies***
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control
AR	Baitfish	Ponds	Water management, erosion control
CA	Salmon, steelhead	Flow-through	Settling pond
CA	Trout	Flow-through	No treatment
CA	Trout	Flow-through	Settling pond, constructed wetland
CA	Trout, salmon, steelhead	Flow-through	Infiltration pond
FL	Ornamentals	Flow-through tanks, low flow rate	Infiltration ditches
FL	Ornamentals	Ponds	Infiltration ditches
FL	Ornamentals	Ponds	Infiltration ditches
FL	Ornamentals	Ponds	Infiltration ditches
FL	Ornamentals	Ponds, recirculating systems	Infiltration ditches
FL	Ornamentals	Recirculating, flow-through tanks w/ low flow rate	Infiltration ditches
HI	Ornamentals	Flow-through	In-pond treatment
HI	Ornamentals, seaweed	Flow-through	Infiltration ditches
HI	Shrimp	Flow-through	In-pond treatment
HI	Shrimp	Flow-through	Settling ponds
HI	Shrimp, ornamentals, mullett, milkfish, red snapper	Flow-through	Infiltration ditches
HI	Tilapia, Chinese catfish	Net pen in pond	In-pond treatment
ID	Catfish, tilapia, alligators	Flow-through	Quiescent zone, gravel ditches, linear clarifiers, OLSB, full-flow settling
ID	Salmon/trout	Flow-through, recirculating	Biological treatment, linear clarifiers
ID	Tilapia	Flow-through, recirculating	Biological treatment ponds, full-flow settling
ID	Trout	Flow-through	Quiescent zones with OLSB
ID	Trout	Flow-through	Quiescent zones with OLSB
ID	Trout	Flow-through	Quiescent zones with OLSB
ID	Trout	Flow-through	Quiescent zones with OLSB
ID	Trout	Ponds, flow-through	Quiescent zones with OLSB
LA	Alligators	Other—alligator huts	2-stage lagoon
LA	Crawfish	Ponds	In-pond treatment

State	**Species**	**Production System**	**Treatment Technologies**
LA	Crawfish	Ponds	In-pond treatment
LA	Crawfish	Ponds	In-pond treatment
LA	Hybrid striped bass	Ponds	In-pond treatment
LA	Tilapia	Recirculating system	Land application of solids
MA	Hybrid striped bass	Recirculating system	Primary settling, biological treatment, microscreen, ozonation, indirect discharge
MA	Tilapia	Recirculating	Plant production, constructed wetland
MD	Multiple	Recirculating system	Sand filters
ME	Brook trout, lake trout, splake	Flow-through	Settling pond
ME	Brook trout, landlocked salmon (coho, chinook)	Flow-through	Settling ponds
ME	Lobster	Other - pounds	None
ME	Salmon	Flow-through	Microscreen filters
ME	Salmon	Flow-through	Settling ponds
ME	Salmon	Net pens	Feed management, active feed monitoring
ME	Salmon, mussels	Net pens, off-bottom hanging culture (mussels)	Feed management, active feed monitoring
ME	Salmon - native endangered species	Flow-through	Settling ponds
ME	Salmon - native endangered species	Flow-through	Settling ponds
MI	Landlocked salmon	Flow-through	OLSB, quiescent zone, polishing pond
MI	Rainbow trout, brown trout	Flow-through	OLSB, quiescent zone, polishing pond
MN	Tilapia	Recirculating system	Lagoon, indirect discharge, composting
MO	Various warmwater species (including bluegill, catfish, paddlefish)	Ponds	Erosion control, water management, riprap
MS	Catfish	Ponds	In-pond treatment
MS	Catfish	Ponds	In-pond treatment
MS	Catfish	Ponds	In-pond treatment
NC	Crawfish	Ponds	In-pond treatment
NC	Hybrid striped bass, crawfish	Ponds	In-pond treatment
NC	Tilapia	Recirculating system	Solids particle trap
NC	Trout	Flow-through	Quiescent zones with OLSB
NC	Trout	Flow-through	Quiescent zones with OLSB
NC	Yellow perch, crab	Ponds, tanks	Settling pond

State	***Species***	***Production System***	***Treatment Technologies***
	shedding, catfish		
NH	Marine species	Recirculating	Microscreen filter, solids settling tank, UV
NY	Tilapia	Recirculating	Holding pond—indirect discharge
PA	Hybrid striped bass	Flow-through	Full-flow settling
PA	Trout	Flow-through	Full flow settling
PA	Trout	Flow-through	OLSB
PA	Trout	Flow-through	Quiescent zone, OLSB, full-flow settling basin
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent, constructed wetland
TX	Shrimp	Ponds	Erosion control, water management, reuse, disease management, screening of effluent, constructed wetland
UT	Trout	Flow-through	Quiescent zones, microscreen filter
VA	Tilapia, hybrid striped bass, yellow perch	Recirculating system	Indirect discharger to POTW
VT	Trout	Flow-through	Formalin detention pond, package plant for aerobic digestion for solids and phosphorus removal, chemical addition for phosphorus removal, full-flow polishing pond
WA	Molluscan shellfish - oysters	Flow-through, bottom culture	None
WA	Salmon	Flow-through, recirculating	Full-flow settling ponds in series
WA	Salmon	Net pens	Feed management
WA	Salmon	Net pens	Feed management
WA	Salmon	Net pens	Feed management
WI	Baitfish, various species of sport fish	Ponds	Erosion control, water management, discharge control (bottom drawing)
WI	Rainbow trout	Flow-through, earthen raceways	Riprap, erosion control, settling ponds, in pond settling

Note: OLSB = Offline settling basin.

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