CHAPTER 6

WATER USE, WASTEWATER CHARACTERIZATION, AND POLLUTANTS OF CONCERN

6.1 WATER USE BY SYSTEM TYPE

The quantity of water required for aquatic animal production (AAP) depends on the type of production system and the facility's management practices. For AAP facilities, water is required to replace evaporative and seepage losses, to replenish oxygen, and to flush wastes from the system. Most AAP facilities are constructed to allow the operators at least some control over the water supply to the production units. There are a wide array of production systems, many unique in their layout and design. The unique characteristics of an individual system often take advantage of site-specific water supply characteristics.

Sources of culture water for AAP facilities include groundwater, springs, surface water, rainwater, municipal water, and seawater (Lawson, 1995). Many of these water sources require either the filtration or purification of before use (Wheaton, 1977a). Common problems with source water include insufficient dissolved oxygen (DO), heavy solids loads, and biological contaminants such as predator fish and insects.

Source water treatment systems are designed specifically to treat specific contaminants or problems with the source water before it is added to the culture system. Source water problems are usually specific to the water source. Groundwater lacks oxygen but is usually free of other pollutants and therefore only needs aeration before use. Surface waters may contain one or more of a variety of contaminants including solids loads, wild fish, parasites, waterborne predators, and disease organisms. Surface waters are often filtered with fine mesh screens to remove these contaminants before use (Wheaton, 1977a). The following subsections describe typical water use by production system type.

6.1.1 Pond Systems

The type of water supply for a pond system is primarily a function of the type of pond. Levee ponds are built with berms above grade to exclude surface water and allow the operator almost complete control of the water that enters the pond. Rainwater falling directly onto the surface of the pond and interior slopes of the berms is the only uncontrolled input of water to levee ponds; all other water is pumped or piped into the ponds.

Watershed ponds are constructed to capture water from a contributing watershed during storm events. Ideally, watershed ponds are constructed so that the contributing watershed provides good-quality water (free of sediment and other pollutants) and sufficient quantities of water to maintain adequate volumes throughout the year. The pond operator does not usually have much control over the runoff into the pond. Water is sometimes pumped or piped into watershed ponds to maintain pond volumes.

Depression ponds are constructed below grade, and most take advantage of groundwater seepage to maintain water levels in the pond. Depression ponds capture direct rainfall and some runoff, depending on the topography of the surrounding landscape. Water is sometimes pumped or piped into depression ponds to maintain pond volumes.

For many ponds the water supply is one or more wells located on-site at a facility. Some facilities rely on pumped or free-flowing water from surface water bodies such as lakes, streams, or coastal waters. Those relying on surface waters, however, must be careful not to introduce undesirable species or organisms into the culture ponds. To prevent this, water might need to be screened or filtered as it is pumped into the pond. Rainwater falling directly on the pond is also captured and can be a source for maintaining water levels, but most commercial AAP ponds cannot be filled with rainfall alone because rainfall events are sporadic.

Pond systems initially require a large supply of water to fill the ponds and then smaller amounts of water to regulate the water levels and compensate for seepage and evaporation. For example, a 10-acre pond with an average depth of 4 feet holds about 13 million gallons of water. Adding 3 inches of water to compensate for evaporation requires about 815,000 gallons of water in a 10-acre pond. Generally, ponds are drained infrequently; therefore, after initially filling the ponds, operators typically do not use large volumes of additional water. For those systems that rely on well water, water conservation and rainwater capture are important management tools to minimize pumping costs.

Pond system sizes vary depending on the species and lifestage (fingerlings versus food-size) raised and among facilities producing the same species. Typical pond sizes for catfish production vary from 7 to 15 acres of surface area and from 3 to 5 feet in depth (Hargreaves et al., 2002). Striped bass are cultured in ponds with an average size of 2 to 4 acres as fingerlings and then moved to growout ponds with 5 to 10 acres of surface area and a maximum depth of 6 feet (Hodson and Jarvis, 1990). Crawfish production ponds typically range in size from 10 to 20 acres (LSU, 1999).

Water use in pond systems varies based on the size and draining frequency of the pond. For example, a 10-acre catfish pond with a depth of 4 feet would contain about 13 million gallons of water, but the water would be used for an average of 6 years before being discharged (Boyd et al., 2000). Striped bass, shrimp, and crawfish production ponds are drained annually. Crawfish ponds usually are managed to a depth of about 8 to 10 inches of water, but water is exchanged throughout the harvest season (LSU, 1999). Water exchange can increase the water use in crawfish ponds to 651,800 gallons/acre/year (Lutz, 2001).

6.1.2 Flow-through Systems

Flow-through systems rely on a steady water supply to provide a continuous flow of water for production. As such, flow-through systems do not consume water but only flow water through production units for a relatively short period of time, typically less than an hour. The water is used to provide DO and to flush wastes from the system, producing a high volume of continuous discharge. Most flow-through systems use well, spring, or stream water as a source of production water. These sources are chosen to provide a constant flow with relatively little variation in rate, temperature, or quality.

Flow-through systems require high volumes of water. Water requirements for single-pass raceways can be as high as 30,000 to 42,000 gallons/pound production; however, this requirement can be reduced to 6,600 gallons/pound production using serial raceways (Hargreaves et al., 2002). Facilities with flow-through systems are found throughout the United States, wherever consistent quantity and quality of water are available. Flow-through systems are the primary method used to grow salmonid species such as rainbow trout. These species require high-quality coldwater with high levels of DO. Flow-through systems are therefore located where water is abundant, allowing farmers to efficiently produce these types of fish.

6.1.3 Recirculating Systems

Recirculating systems do not require large volumes of water because the culture water is continuously filtered and reused before it is discharged. System water volumes include the volume of the production units, filters, and reservoirs. The production water treatment process is designed to minimize water requirements, which leads to small-volume, concentrated waste streams as well as makeup water overflow. Waste streams from recirculating systems are typically a small but continuous flowing effluent. (Refer to Chapter 4, Section 4.2.3 for more information about internal treatment processes used in recirculating systems.) Facility operators typically rely on a supply of pumped groundwater from on-site wells or municipal water supplies. Most systems add makeup water (about 5% to 10% of the system volume each day) to dilute the production water and to account for evaporation, solids removal, and other losses. A recirculating production system operating at 10% added makeup water per day, may complete one water exchange every 10 days; a flow-through production system, on the other hand, might complete more than 100 volume exchanges per day (Orellana, 1992).

6.1.4 Net Pen Systems

Net pen systems rely on the water quality of the site at which the net pens are located. Open systems like net pen facilities can implement fewer practices than closed or semi-closed systems to control water quality parameters such as temperature, pH, and DO. Net pens and cages rely on tides and currents to provide a constant supply of high-quality water to the cultured animals and to flush wastes out of the system. The systems may be located along a shore or pier or may be anchored and floating offshore or in an embayment. Strict siting requirements typically restrict the number of units at a given site to ensure sufficient flushing to distribute wastes and prevent degradation of the bottom near the net pens.

6.1.5 Other Production Systems: Alligators

Alligator production systems use water primarily to provide resting pools and to clean the holding areas where alligators are kept. The amount of water used varies greatly between facilities depending on the cleaning frequency, pool depth, and water recirculating practices practiced at the facility. Water use estimates for the alligator industry varied between 0.5 and 2 gallons/alligator/day (Pardue et al., 1994; Shirley, 2002, personal communication).

6.2 WASTEWATER CHARACTERISTICS

Concentrated aquatic animal production (CAAP) facilities produce a variety of pollutants that may be harmful to the aquatic environment when discharged in significant quantities. The most significant of these pollutants are nutrients (nitrogen and phosphorus), total suspended solids (TSS), and biochemical oxygen demand (BOD). Each of these pollutants causes a variety of impacts on water quality or ecology in different bodies of water. Each type of production system produces different quantities and qualities of effluents, which are determined by the following:

- Amount and type of feed used for production
- Volume and frequency of discharge
- In-system treatment processes (including natural processes)
- Other inputs to the process water (such as drugs or pesticides).

The following subsections describe some of the production system wastewater characteristics.

6.2.1 Pond Systems

Characteristics of effluent from pond systems are influenced by the culture practices used to raise different species and the type of pond used. The composition of pond effluents during water exchange, overflow after heavy rains, and initial stages of pond draining is similar to that of pond water (Boyd and Tucker, 1998). Pond systems are unique because they are capable of assimilating wastes within the pond. Over time, natural processes within the pond lower the concentrations of nitrogen, phosphorus, and organic material. If water is retained in catfish ponds over a long enough period of time, biological, chemical, and physical processes remove some of the waste generated by fish. Some of the organic matter from phytoplankton production and fish waste is oxidized in the natural process of microbial decomposition (JSA, 2000). Total nitrogen (TN) levels in catfish pond waters are lowered as nitrogen is lost from the water column as organic matter when nitrogen particulates decompose on the bottom of the pond. Nitrogen is also lost from the water as a gas through denitrification and volatilization. Finally, total phosphorus (TP) concentrations in the water are lowered as phosphorus is lost to the pond bottom soils as particulate organic phosphorus and precipitates of calcium phosphates.

6.2.1.1 Catfish

In catfish ponds, the most important constituents of potential effluents are nitrogen, phosphorus, organic matter, and settleable solids (SS) (JSA, 2000). These materials are a direct or indirect product of feeds added to the ponds to promote rapid fish growth. Inorganic nutrients in fish waste stimulate the growth of phytoplankton, which, in turn, stimulate the production of more organic matter through photosynthesis. For both watershed and levee ponds, nitrogen and phosphorus compounds and organic matter are present in the pond water throughout the growout period, and they represent potential pollutants if discharged.

Table 6.2–1 shows effluent loadings for TSS, 5-day biochemical oxygen demand (BOD_5), TN, and TP from channel catfish ponds in Alabama. These data illustrate the influence of draining frequency on annualized effluent loadings. For example, TSS loads from levee foodfish production ponds, which are drained an average of once per 6.5 years, are about an order of magnitude lower than TSS loads from levee fry and fingerling ponds, which are drained once per year. Annual effluent loads in watershed ponds are about four times lower in the less frequently drained foodfish ponds than in fry and fingerling ponds.

Table 6.2–1. Mass Discharge of TSS, BOD_5, TN, and TP from Channel Catfish Farms in Alabama

Pond Type	*Source of Effluent*	*TSS (lb/ac/yr)*	*BOD_5 (lb/ac/yr)*	*TN (lb/ac/yr)*	*TP (lb/ac/yr)*
Fry and Fingerling Ponds Annual Draining					
Levee ponds	Overflow	58	7.9	4.5	0.48
	Partial drawdown	823	112.3	75.3	2.98
	Final drawdown	3,062	94.8	1.8	4.73
	Total	3,943	214.7	108.3	8.19
Watershed ponds	Overflow	232	31.5	9.82	1.94
	Partial drawdown	822	112.2	75.2	2.98
	Final drawdown	3,062	94.8	28.5	4.74
	Total	4,116	238.5	113.5	9.66
Foodfish Production Ponds Average 6 years Between Drainings					
Levee ponds	Overflow	58	7.8	4.5	0.48
	Partial drawdown	123	16.9	6.1	0.45
	Final drawdown	204	6.3	19.0	0.31
	Total	385	31	29.6	1.24
Watershed ponds	Overflow	738	50.9	15.8	3.15
	Partial drawdown	123	16.9	6.1	0.45
	Final drawdown	204	6.3	19.0	0.31
	Total	1,065	74.1	40.9	3.91

Source: Boyd et al., 2000.

6.2.1.2 Hybrid Striped Bass

Effluents from hybrid striped bass ponds are similar to catfish pond effluents; however, hybrid striped bass facilities typically drain their ponds more frequently because they must be drained and completely harvested before restocking. To avoid draining the ponds, some farmers treat the ponds with a piscicide (a pesticide, such as Rotenone, used to kill fish) to eliminate remaining fish before restocking. Ponds are usually drained annually or biennially, depending on stocking size and production management.

In a study in South Carolina (Tucker, 1998), water samples were collected and analyzed from 20 commercial hybrid striped bass ponds (Table 6.2–2). To provide a broad representation of the industry, researchers included large and small operations, as well as ponds from both the coastal plain and piedmont areas of the state. Most of the commercial ponds sampled were freshwater ponds, but some saltwater ponds were also represented in the study. Water samples were collected from the surface and the bottom of each pond. Overall, the quality of effluents from hybrid striped bass ponds varied greatly from pond to pond. Concentrations of suspended solids, TN (including total ammonia), and BOD were the parameters that were most elevated relative to the source water and could potentially have the greatest impact on receiving bodies of water.

Table 6.2–2. Means and Ranges for Selected Water Quality Variables from Hybrid Striped Bass Ponds in South Carolina

Variable	*Mean*	*Range*
Suspended solids (mg/L)	49	0–370
Volatile suspended solids (mg/L)	29	0–135
BOD (mg/L)	11.5	1.4–64.4
Kjeldahl nitrogen (mg/L)	7.1	0–97.0
Total ammonia (mg N/L)	0.95	0.02–7.29
Nitrite (mg N/L)	0.07	0–2.94
Nitrate (mg N/L)	0.36	0–4.61
TP (mg P/L)	0.31	0–1.9
Soluble reactive phosphorus (mg P/L)	0.02	0–0.18

Source: Tucker, 1998.

6.2.1.3 Penaeid Shrimp

There is some evidence to suggest that effluent characteristics for marine shrimp ponds are similar to effluent characteristics for catfish farms (Table 6.2–3), but that the final portion of effluent from marine shrimp ponds is higher in pollutant concentrations by 20% to 30% (Boyd and Tucker, 1998). For example, total annual TSS for shrimp ponds is about 5,000 pounds/acre and for catfish fingerling ponds about 4,000 pounds/acre. When shrimp ponds are drained for harvest, the effluent is almost identical in composition to pond water until about 80% of the pond volume has been released (Boyd, 2000). During the draining of the final 20% of the pond volume, concentrations of BOD_5, TSS, and other substances increase because of sediment resuspension caused by harvest activities, crowding of agitated shrimp, and shallow and rapidly flowing water. The average BOD_5 and TSS concentrations often are about 50 and 1,000 milligrams/liter, respectively (Boyd, 2000).

Although catfish ponds and shrimp ponds might have similar effluent characteristics, shrimp ponds are drained more frequently than food-size catfish ponds to facilitate harvest; therefore, the volume of water discharged from a shrimp farm is typically higher than the volume of water discharged from a catfish farm. Shrimp farms in the United States have responded to state regulatory concerns regarding the discharge of solids during draining and harvesting. In Texas, shrimp farms use drainage canals and large sedimentation basins to hold water on the farm and reuse the water in other ponds to minimize TSS in effluents. Most Texas facilities try to discharge during the winter, after harvests are complete and solids have had maximum time to settle (Tetra Tech, 2002b).

Table 6.2–3. Average Concentrations and Loads of BOD_5 and TSS in a Typical Shrimp Farming Pond with a Water Exchange of 2% per day

Type of Effluent	*Concentration (mg/L)*		*Load (lb/ac)*	
	BOD_5	*TSS*	*BOD_5*	*TSS*
Water exchange	5	100	107	2,142
Draining (first 80%)	10	150	71	1,071
Final draining	50	1,000	89	1,785
Total	–	–	267	4,998

Source: Boyd, 2000.

South Carolina shrimp farmers also try to reuse water, when possible. Some South Carolina shrimp farms are holding water in harvested ponds and growing clams and other shellfish. The "treated" water is then slowly discharged after the shellfish are harvested (Whetstone, 2002 personal communication).

6.2.1.4 Other Species

Tilapia ponds are drained to harvest fish, to adjust fish inventories, or to repair ponds. At the start of pond draining for harvest, pond water effluent characteristics can be expected to be similar to production water characteristics. However, fish harvest by seining stirs up sediments at the bottom of the pond. In fertilized tilapia ponds, sediments are likely to contain significant quantities of nitrogen and phosphorus. As draining and seining continue, effluent water quality can be expected to deteriorate (Tucker, 1998).

Although there are few data on ornamental fish farm effluent characteristics in the literature, the impact from water discharged from ornamental fish production facilities is likely to be minimal. Assuming the average size of a growout pond is 2,152 square feet with approximately 80,000 gallons of water, ornamental culture facilities typically discharge the volume of one pond, or less, per year (Watson, 2002 personal communication). There are also very few data available on water quality in commercial baitfish ponds or on effluents from these ponds. Baitfish production uses low biomass stocking densities. The combination of low biomass and reduced feed input before draining makes it likely that baitfish effluents will have lower solids concentrations than effluents from catfish ponds (Stone et al., n.d.).

There is limited information about the quality of water discharged from crawfish ponds for either rotational ponds or permanent ponds. Crawfish production relies on the forage-based system for feeding, so unlike other AAP systems that rely on pelleted feed, feed management practices will not significantly affect water quality because the feed input is so low. Also, although DO levels are a concern, particularly as vegetation decays, crawfish farmers routinely check levels and use best management practices (BMPs) and technologies, such as mechanical aeration, to maintain appropriate DO levels. Very few data are available on water quality within commercial ponds for other finfish production or on effluents from these ponds; however, the effluent is likely to be similar to the effluent from hybrid striped bass ponds.

6.2.2 Flow-through Systems

Effluents from flow-through systems can be characterized as continuous, high-volume flows containing low pollutant concentrations. Effluents from flow-through systems are affected by whether a facility is in normal operation or whether the tanks or raceways are being cleaned. Waste levels can be considerably higher during cleaning events (Hinshaw and Fornshell, 2002; Kendra, 1991).

Boardman et al. (1998) conducted a study after surveys conducted in 1995 and 1996 by the Virginia Department of Environmental Quality (VDEQ) revealed that the benthic aquatic life of receiving waters was adversely affected by discharges from several freshwater trout farms. Three trout farms in Virginia were selected to represent fish farms throughout the state. This study was part of a larger project to identify practical treatment options that would improve water quality both within the facilities and in their discharges to receiving streams.

After initial sampling and documentation of facility practices, researchers and representatives from VDEQ discovered that although pollutants from the farms fell under permit regulation limits, adverse effects were still being observed in receiving waters. Each of the farms was monitored from September 1997 through April 1998, and water samples were measured for DO, temperature, pH, SS, TSS, total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), BOD_5, and dissolved organic carbon (DOC).

Sampling and monitoring at all three sites revealed that little change in water quality between influents and effluents occurred during normal conditions at each facility (Table 6.2–4). The average concentrations of each regulated parameters (DO, BOD_5, TSS, SS, and ammonia-nitrogen (NH_3-N)) were below their regulatory limit at each facility; however, raceway water quality declined during heavy facility activity like feeding, harvesting, and cleaning. During these activities, fish swimming rapidly or employees walking in the water would stir up solids that had settled to the bottom. During a 5-day intensive study, high TSS values were correlated with feeding events. TKN and ortho-phosphate (OP) concentrations also increased during feeding and harvesting activities. Overall, most samples taken during this study had relatively low solids concentrations, but high flows through these facilities increased the total mass loadings.

Table 6.2–4. Water Quality Data for Three Trout Farms in Virginia

Parameter	***FARM A***			***FARM B***			***FARM C***		
	Inlet	***Within Farm***	***Outlet***	***Inlet***	***Within Farm***	***Outlet***	***Inlet***	***Within Farm***	***Outlet***
Flow (mgd)	1.03–1.54[a] (*1.18*)[b]			4.26–9.43 (*6.39*)			9.74–10.99 (*10.54*)		
DO (mg/L)	9.2–14.2 (*10.6*)	3.2–13.3 (*7.0*)	5.7–9.5 (*8.5*)	8.2–11.5 (*10.5*)	5.8–10.8 (8.6)	6.8–9.6 (*7.9*)	9.4–10.6 (*10.5*)	4.8–9.7 (*7.6*)	7.2–9.4 (*8.1*)
Temperature (ºC)	10.5–13 (*12.2*)	11.5–15 (*13*)	11–15.5 (*12.9*)	6–12.5 (*9.7*)	6–14 (*9.1*)	5–16.5 (*11.4*)	8.5–13.5 (*10.5*)	8–14 (*11.0*)	8.5–14 (*10.4*)
pH (SU)	7.1–7.4 (*7.3*)	7.0–7.4 (*7.2*)	7.3–7.8 (*7.5*)	7.3–7.6 (*7.5*)	7.2–7.6 (*7.4*)	6.9	7.3	7.1–7.6 (*7.3*)	7.8
TSS (mg/L)	0–1.1 (*0.2*)	0–30.4 (*3.9*)	0.8–6 (*3.2*)	0–1.8 (*0.5*)	0–43.7 (*5.3*)	1.5–7.5 (*3.9*)	0–1.5 (*0.3*)	0–28 (*7.1*)	4.1–62 (*6.1*)[c]
SS (mg/L)	ND[d]		0–0.04 (*0.02*)	ND		0.01–0.08 (*0.04*)	ND		0.04–0.08 (*0.07*)
BOD$_5$ (mg/L)	0–1.25 (*0.7*)	0.5–3.9 (*1.5*)	0.96–1.9 (*1.3*)	0–1.4 (*0.5*)	0.3–7.2 (*2.1*)	0.6–2.4 (*1.2*)	0–2.0 (*1.1*)	0.4–7.5 (*2.5*)	0.5–1.8 (*1.3*)
DOC (mg/L)	0.93–4.11 (*2.1*)	0.9–7.9 (*2.9*)	1.5–2.4 (*1.9*)	0.91–2.56 (*1.6*)	1.2–8.1 (*2.7*)	1.2–3.1 (*1.9*)	1.1–2.7 (*2.0*)	1.1–11.1 (*2.4*)	1.5–3.8 (*2.3*)
NH$_3$-N (mg/L)	0.6	0.2–1.1 (*0.5*)	0.5–0.6 (*0.6*)	0.2	0.06–1.1 (*0.5*)	0.45	0.03	0.03–2.2 (*0.4*)	0.02–0.17 (*0.1*)

[a] When available the range of values has been reported

[b] The average is indicated using italics.

[c] Two outliers were discarded for calculation of mean.

[d] ND: Non-detect

Source: Boardman et al., 1998.

Table 6.2−5 describes the water quality data for two flow-through systems sampled as part of EPA's data collection efforts at CAAP facilities.

Table 6.2–5. Flow-through Sampling Data

Parameter	***Facility A***			***Facility B***		
	Inlet	***OLSB[d] Effluent***	***Bulk Water Discharge***	***Inlet***	***OLSB Effluent***	***Final Effluent***
BOD (mg/L)	ND (4)[a]	56.0–185.0[b] (*125.70*)[c]	3.50–4.20 (*3.85*)	ND (2)	13	ND (2)
Flow (mgd)	192.4	0.914	91.4	2.481–2.777	0.017	2.481–2.777
pH (SU)	7.98–8.14 (*8.05*)	6.11–6.58 (*6.43*)	7.50–7.83 (*7.72*)	7.73–8.06 (*7.93*)	7.27	7.93–8.19 (*8.03*)
TP (mg/L)	0.7–0.25 (*0.14*)	8.32–11.10 (*9.81*)	0.15–0.25 (*0.21*)	0.02–0.03 (*0.03*)	0.36	0.03–0.07 (*0.05*)
TSS (mg/L)	ND (4)	44.0–78.0 (*63.0*)	ND (4)	ND (4)	38	ND (4)

[a] ND: Non-detect, the minimum level is listed in parenthesis.
[b] When available the range of values has been reported.
[c] The average is indicated using italics.
[d] OLSB=Offline settling basin
Source: Tetra Tech, 2001a; Tetra Tech 2002a.

6.2.3 Recirculating Systems

Recirculating systems have internal water treatment components that process water continuously to remove waste and maintain adequate water quality. Overall, recirculating systems produce a lower volume of effluent than flow-through systems. The effluent from recirculating systems usually has a relatively high solids concentration in the form of sludge. The sludge is then processed into two streams—a more concentrated sludge and a less concentrated effluent (Chen et al., 2002). Once solids are removed from the system, sludge management is usually the focus of effluent treatment in recirculating systems.

In a study describing the waste treatment system for a large recirculating facility in North Carolina, Chen et al. (2002) characterize effluent at various points in the system (Table 6.2–6). Approximately 40% of the solid waste produced by this particular facility is collected in the sludge collector and composted. The remaining 60% of the solids are treated with two serial primary settlers (septic tanks) and then a polishing pond (receiving pond). Table 6.2–7 describes the water quality data for one recirculating system sampled as part of EPA’s data collection efforts at CAAP facilities.

Table 6.2–6. Water Quality Characteristics of Effluent at Various Points in the Waste Treatment System of Recirculating Aquaculture Systems at the North Carolina State University Fish Barn[a]

Parameter	*TKN (mg/L)*	*NH_3-N (mg/L)*	*NO_2-N (mg/L)*	*NO_3-N (mg/L)*	*TP (mg/L)*	*PO_4-P (mg/L)*	*COD (mg/L)*	*TS (%)*	*TSS (mg/L)*
Primary settling 1 inflow	50.3	2.96	5.35	109.0	28.6	5.98	1043	0.22	752
Primary settling 2 inflow	47.5	2.42	31.17	78.5	22.7	11.50	690	0.18	364
Septic tank 2 outflow	37.7	3.42	44.00	36.4	17.6	12.20	409	0.16	205
Receiving pond effluent	8.94	0.12	1.93	8.2	4.95	3.68	153	0.11	44

[a] Results are from sampling conducted 4 weeks after startup of the waste handling system. Flow from the system into the receiving pond for the sampling period was 15.5 cubic meter/day.

Source: Chen et al., 2002.

Note: NO_2-N = nitrite-nitrogen; NO_3-N = nitrate-nitrogen, PO_4-P = phosphate-phosphorous, COD = chemical oxygen demand, TS = total solids

6.2.4 Net Pen Systems

Although net pen systems do not generate a waste stream like other production systems, waste from the system can adversely affect water quality. The release of nutrients, reductions in concentrations of DO, and the accumulation of sediments under the pens or cages can affect the local environment through eutrophication and degradation of benthic communities (Stickney, 2002).

Table 6.2–7. Recirculating System Sampling Data

Parameter	*Facility C*	
	Inlet	*Discharge*
BOD (mg/L)	ND (2)[a]	35.0–48.0[b] (*42.0*)[c]
Flow (mgd)	0.22	0.22
pH (SU)	7.8	6.97–7.25 (*7.15*)
TP (mg/L)	ND (0.01)	8.58–10.50 (*9.32*)
TSS (mg/L)	ND (4)	26.0–60.0 (*42.80*)

[a] ND: Non-detect, the minimum level is listed in parenthesis.

[b] When available the range of values has been reported.

[c] The average is indicated using italics.

Source: Tetra Tech, 2001b.

6.2.5 Other Production Systems: Alligators

Wastewater from alligator production facilities is generated during the cleaning of production pens and when discharges are released from the building heating system. Wastewater characteristics from alligator farms are analogous to those of strong municipal wastewater (Pardue et al., 1994). Values for alligator farm wastewater constituents are shown in Table 6.2–8.

Table 6.2–8. Alligator Wastewater Characteristics

Parameter	***Concentration (mg/L)***
BOD_5	452
Total solids	379
Volatile solids	219
TP	11
Ammonia	78
Nitrate	5
TKN	153
pH	6.9 (SU)

Source: Pardue et al., 1994.

6.3 WATER CONSERVATION MEASURES

6.3.1 Pond Systems

Pond systems provide many opportunities to conserve water. Water conservation practices can be grouped into structural conservation measures and management conservation measures. Structural conservation measures are those measures that can be installed at the time the production pond is constructed or added at a later date. Structural water conservation measures include seepage reduction, building watershed ponds with watershed-to-pond area ratios of 10 or less, and maintaining vegetated levees. Ongoing management water conservation measures include maintaining storage volume, harvesting without draining, and reducing or eliminating water flushing (Hargreaves et al., 2002).

6.3.2 Flow-through Systems

Flow-through systems do not consume or hold water for long periods. Typically water in a flow-through system is in a production unit for less than an hour. The opportunities to use lower volumes of water in flow-through systems are usually limited and can involve substantial expense. Often, more fish can be grown in a flow-through system with a fixed inflow of water through increased stocking densities in production raceways, with additional oxygenation of the production water. Water use can also be maximized through the use of multi-pass serial raceways or tanks, which use re-oxygenated water passing through multiple raising units prior to discharge. Using water more efficiently allows flow-through system operators to reduce water use from high rates of 30,000 to 42,000 gallons/pound to much lower rates of 6,600 gallons/pound.

Facilities reusing multi-pass serial raceways must use active or passive aeration systems in order to maintain adequate DO concentrations in the culture water. Facilities with sufficient hydraulic head between raceways often use passive or gravity aeration systems to increase the air-water interface thereby increasing the DO content of the culture water (Wheaton, 1977b).

Facilities with insufficient head to passively aerate must use mechanical aeration systems to increase the DO content of the culture water. Mechanical aeration systems include liquid oxygenation systems and diffuser aerators. Liquid oxygen systems operate by adding liquid oxygen below the surface of the culture water. 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, 1977b).

6.3.3 Recirculating Systems

Recirculating systems are designed to conserve water by raising fish in small volumes of water, treating the water to remove waste products, and then reusing it (Rakocy et al., 1992). Normal stocking densities in recirculating systems vary from 0.5 to over 1 pound/gallon of culture water (Losordo and Timmons, 1994). Opportunities to conserve water in recirculating systems include operating all filter systems as efficiently as possible, increasing stocking densities, and reducing daily makeup water to less than 10%. These practices would not amount to significant reductions in water use and might not be achievable in most recirculating systems.

6.3.4 Other Production Systems: Alligators

Water conservation measures at alligator production systems have focused on reusing or recirculating cleaning water. Each alligator holding pen contains a shallow pool that accumulates waste products and must be cleaned regularly to remove the wastes and ensure good skin quality for the alligators. The pen-cleaning process takes place daily or every other day and causes the loss of a large amount of heated water (Delos Reyes, Jr. et al., 1996). Properly operating recirculating systems can reduce daily loss of heated water to as little as 5% (Delos Reyes, Jr. et al., 1996), but these systems are not commonly used in alligator production (Pardue et al., 1994; Shirley, 2002, personal communication).

6.4 POLLUTANTS OF CONCERN

6.4.1 Characterization of Pollutants of Concern

Four sources of data were reviewed to provide an initial assessment of the pollutants of concern (POC): (1) data from a sampling event at a flow-through facility; (2) data from a sampling event at a recirculating facility; (3) discharge monitoring report (DMR) data submitted to EPA from the EPA Regions; and (4) Permit Compliance System (PCS) data from an EPA database.

EPA used several criteria to identify the list of POCs. For the sampling data, the identification criteria were as follows: (1) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 5 times the minimum level (ML) (ML is the level at which an analytical system gives recognizable signals and an acceptable calibration point); (2) raw wastewaters with analytes that had three or more reported values with an average concentration greater than 10 times the ML; and (3) treated effluents with analytes that had at least one reported value with an average concentration greater than 5 times the ML. The results for determining POCs are presented in Appendix C.

The first two criteria were applied to the same data (e.g., a raw wastewater from a sampling event) and were used as a measure to determine how a more stringent criterion (> 5 ML) contrasted with a less stringent criterion (> 10 ML) in determining an analyte as a pollutant of concern. In almost all cases, both criteria (> 5 ML and > 10 ML) produced the same results.

For the PCS and DMR data sets, the original data were first associated with a system type as defined by National Permit Discharge Elimination System (NPDES) permit information. Parameters with measurements in the DMR and PCS data without a value or with a value of zero were excluded from the data sets and assumed to be nondetectable. All other data were summarized by system type and analyte, with an analysis for the average sampling value, the maximum sampling value, the minimum sampling value, and the number of samples taken.

The PCS and DMR data, composed mainly of state and federal facilities and large commercial facilities that have NPDES permits, represent the best available information. One limitation of the data is the lack of information on pond systems. Generally, the pollutants identified in the DMR or PCS database are included in the list of POCs provided below.

The POCs that are currently indicated for the CAAP industry, based on the available data, include the following: conventional and nonconventional pollutants (ammonia, BOD, chemical oxygen demand (COD), chlorine, nitrate, nitrite, oil and grease, OP, pH, SS, TKN, TP, and TSS), metals (aluminum, barium, boron, copper, iron, manganese, selenium, and zinc), microbiologicals (*Aeromonas*, fecal *streptococcus*, and total coliforms), organic chemicals, and hexanoic acid.

6.4.2 Methodology for Selection of Regulated Pollutants

EPA selects the pollutants for regulation based on the POCs identified for each subcategory. Generally, a pollutant or pollutant parameter is considered a POC if it was detected in the untreated process wastewater at five times the minimum level in more than 10% of samples. The ML is a metric of the sensitivity of the analytic testing procedure to measure for a pollutant or pollutant parameter.

Monitoring for all POCs is not necessary to ensure that CAAP wastewater pollution is adequately controlled because many of the pollutants originate from similar sources (the feed), are associated with the solids, and are treated with the same pollutant removal technologies and similar mechanisms. Therefore, monitoring for one pollutant as a surrogate or indicator of several others can be sufficient in some cases.

Regulated pollutants are pollutants for which EPA establishes numerical effluent limitations and standards. EPA evaluated a POC for regulation in a subcategory using the following criteria:

- Not considered a volatile compound.
- Effectively treated by the selected treatment technology option.
- Detected in the untreated wastewater at treatable levels in a significant number of samples, e.g., generally five times the minimum level in more than 10% of the raw wastewater samples.

6.5 POLLUTANTS AND POLLUTANT LOADINGS

CAAP facility effluents can have high concentrations of nutrients, suspended solids, and BOD and low levels of DO. When discharged into receiving waters, effluents with high levels of suspended solids can cause turbidity, which can reduce light available for photosynthesis. Low DO levels can affect estuarine organisms in the receiving waters, and excessive nutrients can accelerate plankton growth, resulting in die-offs and increased BOD in receiving waters.

6.5.1 Sediments and Solids

Solids are the largest pollutant loading generated in CAAP facilities. Most pond systems, however, are managed to capture and hold solids in the pond, where the solids naturally degrade. Proper management of flow-through and recirculating systems captures most of the generated solids, which must then be properly disposed of. Many CAAP facilities with NPDES permits must control and monitor their discharge levels of solids. In Idaho, NPDES permits specify average monthly and maximum daily TSS limits that vary according to production and system treatment technology (USEPA, 2002).

Although some solids from CAAP facilities are land-applied, other solids leave the facility in the effluent stream and can have a detrimental effect on the environment. Suspended solids can degrade aquatic ecosystems by increasing turbidity and reducing the depth to which sunlight can penetrate, which decreases photosynthetic activity and oxygen production by plants and phytoplankton. If sunlight is completely blocked from bottom-dwelling plants, the plants stop producing oxygen and die. As the plants decompose, bacteria use up more of the oxygen and decrease DO levels further. Subsequently, low DO can cause fish kills. Decreased growth of aquatic plants also affects a variety of aquatic life that use the plants as habitat. Increased suspended solids can also increase the temperature of surface water because the particles absorb heat from the sunlight. Higher temperatures result in lower levels of DO because warmwater holds less DO than coldwater.

Suspended particles can abrade and damage fish gills, increasing the risk of infection and disease. They can also cause a shift toward more sediment-tolerant species, reduce filtering efficiency for zooplankton in lakes and estuaries, carry nutrients and metals, adversely affect aquatic insects that are at the base of the food chain (Schueler and Holland, 2000), and may harm fish development (Colt and Tomasso, 2001). Suspended particles reduce visibility for sight feeders and disrupt migration by interfering with a fish's ability to navigate using chemical signals (USEPA, 2000). Finally, suspended particles cause a loss of sensitive or threatened fish species when turbidity exceeds 25 nephelometric turbidity units (NTUs) and a decline in sunfish, bass, chub, and catfish when monthly turbidity exceeds 100 NTUs (Schueler and Holland, 2000).

As sediment settles, it can smother fish eggs and bottom-dwelling organisms, interrupt the reproduction of aquatic species, destroy habitat for benthic organisms (USEPA, 2000) and fish spawning areas, and contribute to the decline of freshwater mussels and sensitive or threatened darters and dace. Deposited sediments also increase sediment oxygen demand, which can deplete DO in lakes or streams (Schueler and Holland, 2000).

Increased levels of suspended solids and nutrients have very different effects on aquatic plants. High levels of suspended solids can kill off desirable species, while elevated nutrient levels can cause too many plants to grow. In either situation, an ecosystem can be drastically altered by increases in these pollutants. As a result, it is important to maintain a balance in the levels of suspended solids and nutrients reaching waterbodies to reduce such drastic impacts on aquatic plants.

6.5.2 Nutrients

The two major nutrients found in CAAP discharges are nitrogen and phosphorus. Nitrogen from CAAP facilities is typically discharged nitrate, nitrite, ammonia, and organic nitrogen. Most of the nitrogen from these facilities is in the form of ammonia, which is not usually found at toxic levels in CAAP discharges. Some facilities with ponds and recirculating systems might also have high levels of nitrite. Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This decomposition consumes oxygen, reducing DO levels and adversely affecting aquatic life. Phosphorus is discharged from CAAP facilities in both the solid and dissolved forms. The dissolved form, however, poses the most immediate risk because it is available to plants.

Excess nutrients in receiving waters can lead to nutrient overenrichment which can then result in overgrowth of plants, murky water, low DO, fish kills, and depletion of desirable flora and fauna. In addition, the increase in algae and turbidity in drinking water supplies heightens the need to chlorinate drinking water. Chlorination, in turn, leads to higher levels of disinfection by-products that have been shown to increase the risk of cancer. Excessive amounts of nutrients can also stimulate the activity of microbes, such as *Pfiesteria piscicida* that may be harmful to human health (Grubbs, 2001).

6.5.2.1 Nitrogen

In CAAP facilities nitrogen can take many forms, although it is discharged mainly in the forms of ammonia, nitrate, and organic nitrogen. Organic nitrogen decomposes in aquatic environments into ammonia and nitrate. This decomposition consumes oxygen, potentially reducing DO levels and adversely affecting aquatic life. Ammonia can be directly toxic to aquatic life, affecting hatching and growth rates of fish. For example, when levels of un-ionized ammonia exceed 0.0125–0.025 milligrams/liter, growth rates of rainbow trout are reduced and damage to liver, kidney, and gill tissue may occur (IDEQ, n.d.). The proportion of total ammonia in the un-ionized form can vary with temperature and pH levels (IDEQ, n.d.). However, ammonia is not usually found at toxic levels in CAAP discharges.

Ammonia and nitrate may both be used by plants as a source of energy. However, the species of nitrogen available is largely dependent upon environmental conditions (e.g., availability of oxygen). Ammonia tends to bind to sediments and may be less available for plant uptake than nitrate, and large quantities of ammonia may be toxic to plants (Schlesinger, 1997). Nitrate is soluble in water and does not bind to particles, making them highly mobile (Kaufman and Franz, 1993). As a result, elevated levels of nitrate may cause increased plant and algae growth, particularly in estuarine or marine environments where nitrogen is generally a limiting nutrient. Nitrate is not usually found at toxic levels in CAAP effluents.

Some facilities with ponds and recirculating systems might have high levels of nitrite. High concentrations of nitrite can produce “brown blood disease” in fish. In this disease, the blood is unable to carry enough oxygen, leading to respiratory distress (Boyd and Tucker, 1998). As a result, fish may die of suffocation. However, according to EPA sampling data and technical literature, nitrite concentrations in CAAP facility effluents generally do not approach toxic levels.

6.5.2.2 Phosphorus

CAAP facilities release phosphorus in both the solid and dissolved forms. Although the solid form is generally unavailable, chemically some phosphorus may be slowly released from the solid form. However, the dissolved form is readily available and it poses the most immediate risk to the environment. Plants and bacteria require phosphorus in the dissolved form, generally as OP, for their nutrition (Henry and Heinke, 1996). The principle concerns associated with phosphorus in freshwater aquatic systems, however, are algal blooms and increased eutrophication (Hinshaw and Fornshell, 2002), which is an increase in levels of production in a water body (Wetzel, 2001). Eutrophication may result in decreased DO levels as bacteria decompose dead algae, consuming oxygen in the process. When DO concentrations fall below the levels required for metabolic requirements of aquatic biota, both lethal (e.g., fish kills) and sublethal effects can occur.

6.5.3 Organic Compounds and Biochemical Oxygen Demand

Organic matter is discharged from CAAP facilities primarily from feces and uneaten feed. Elevated levels of organic compounds contribute to eutrophication and oxygen depletion. This occurs because oxygen is consumed when microorganisms decompose organic matter. BOD is used to measure the amount of oxygen consumed by microorganisms when they decompose the organic matter in a waterbody. The greater the BOD, the greater the degree of pollution and the less oxygen available. When a sufficient level of oxygen is not available, aquatic species become stressed and might not eat well. Their susceptibility to diseases can increase dramatically, and some species might even die. Even small reductions in DO can lead to reduced growth rates for sensitive species.

6.5.4 Metals

Metals may be present in CAAP wastewaters for various reasons. They might be used as feed additives, occur in sanitation products, or result from deterioration of CAAP machinery and equipment. Many metals are toxic to algae, aquatic invertebrates, and fish. Although metals can serve useful purposes in CAAP operations, most metals retain their toxicity once they are discharged into receiving waters. EPA observed that many of the treatment systems used in the CAAP industry to remove solids provide substantial reductions of most metals. Because most of the metals are present in particulate form or bind to solid particles, they can be adequately controlled by controlling solids.

6.6 OTHER MATERIALS

CAAP facility effluents may also contain other materials, pathogens, drugs, chemicals, and pesticides. There is little evidence to suggest that the accumulation of wastes from net pen facilities is a source of human or environmental pathogens (Nash, 2003). Non-native species, if introduced to an area, have the potential to become invasive, outcompeting and threatening the survival of the native species. There is also the potential that introducing non-native species may introduce diseases against which native populations have no natural defenses. Potentially non-native species associated with CAAP facilities include Atlantic salmon, grass carp, shrimp, and tilapia (depending on the location of the facility).

Drugs, which include medicated feed, are added to the production facility to maintain or restore animal health, and they can be subsequently released into the waters of the United States. Some pesticides, such as copper sulfate, are used at CAAP facilities to remove algae and subsequently might be discharged to waters of the United States. More detailed information about pathogens, non-native species, and drugs/chemicals, as well as a discussion of their environmental impacts, is available in Chapter 7 of the Economic and Environmental Impact Analysis.

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