Particle size fractions in pond effluents

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Water in channel catfish (*Ictalurus puctatus*) ponds is usually more concentrated in nutrients, organic matter and suspended solids than are natural waters into which pond water is discharged (Boyd 1978). The concentrations of these water quality variables are greatest in late summer and early fall when rainfall and runoff are lowest and feeding wastes are highest (Schwartz and Boyd 1994). Effluents are discharged from ponds following rainfall, when ponds are partially drained for harvest and when ponds are completely drained to allow renovation of earthwork. In Alabama, storm overflow occurs every year, ponds are partially drained at 6 to 8 year intervals and ponds are completely drained after 15 to 20 years of use (Boyd *et al*. 2000).

Effluents from catfish and other aquaculture ponds can cause pollution of streams and other public waters (Schwartz and Boyd 1994). The United States Environmental Protection Agency (USEPA) has initiated a rule-making activity for aquaculture effluents. The draft rule was published on 12 September 2002 (Federal Register 2002), and the final rule, with which all states must comply, is due on 30 June 2004. It is anticipated that the effluent rule will consist primarily of best management practices (BMPs) to reduce the volume and improve the quality of effluents (Boyd and Hulcher 2001).

One BMP mentioned several times in meetings with USEPA is to require fish farmers to pass water through a sedimentation basin before final discharge into public waters. Sedimentation is one of the simplest and least expensive methods for treating effluents (Tchobanoglous and Schroedor 1985) and sedimentation has been recommended as a way of removing the high load of suspended solids from the final 20 to 30 percent of effluent when a pond is completely drained for harvest (Soek *et al*. 1995, Teichert-Coddington *et al*. 1999). However, a recent assessment of the use of sedimentation basins on Alabama catfish farms (Boyd and Queiroz 2001) raised serious concerns about their usefulness as follows:

- Large volumes of overflow occur from watershed ponds in Alabama after winter and spring rains. This effluent contains mostly finely divided clay particles and phytoplankton that may not settle rapidly. Thus, large sedimentation basins would be needed to provide enough retention time for particles to settle.
- Effluent released when ponds are partially drained to facilitate complete harvest by seining is similar to storm overflow in composition.
- Most catfish farms extend to streams or to property lines. There is often little or no space for installation of sedimentation basins.

The purpose of this study was to determine the size distribution of particles in storm overflow from catfish ponds and to estimate settling rates for these particles. Moreover, the proportion of particulate organic matter, total phosphorus, total nitrogen and biochemical oxygen demand associated with each particle size class was calculated.

Experimental Channel Catfish Ponds

Channel catfish ponds used in this study are located on the Auburn University Fisheries Research Unit (FRU), Auburn, Alabama USA. These ponds are rectangular with vertical concrete retaining walls, a water surface area of 405 m^2 and average depths of 0.9 to 1.0 m. They have earthen bottoms with highly-leached, reddish-brown soil, acidic *Ultisol,* typical of soils of the Piedmont Plateau.

Water flows to the ponds by gravity through a pipeline from a large reservoir filled with runoff from a wooded watershed. Water for filling and maintaining ponds has low total alkalinity (10 to12 mg/L) and less than 0.005 mg/L of phosphorus (Gross *et al*. 1998). Water levels were maintained about 5 to 10 cm below the tops of the standing overflow pipes to provide storage capacity and minimize the amount of water overflow during rainy days. Because native soil is acidic, liming materials are applied to ponds annually to increase alkalinity above 20 mg/Land to neutralize bottom soil acidity (Boyd 1990). The mean annual temperature is 17.5 C, with the highest mean monthly temperature of 26.5 C in August and the lowest mean temperature of 7 C in January. Annual rainfall generally averages 1,434 mm (Gross *et al* 1998).

Each pond was stocked with 400 fingerling catfish on May 11, 2000. Fingerlings had an average weight of 17 g and average length of 6 cm. The fingerlings were fed daily a commercial diet containing 28 to 32 percent crude protein at three percent of body weight, adjusted weekly for weight gain. Small pellets with 32 percent crude protein were fed until the fish reached about 100 g average weight, after which larger pellets with 28 percent crude protein were employed. Each pond had a 0.38 kW vertical pump aerator[2] that was operated from 2200 to 0600 hr daily from the middle of June until harvest in November to prevent dissolved oxygen depletion at night. Practices used for culturing catfish in the experimental ponds were similar to those used on commercial fish farms in Alabama.

Fifteen samples of storm overflow were collected from pond drains between 11 May and 24 October 2000. Raw water samples were analyzed for concentrations of total suspended solids (TSS), particulate organic matter (POM), and 5-day biochemical oxygen demand (BOD_5) by methods 2440B, 2540E and 4500PE of "Standard Methods for the Examination of Water and Wastewater" (Clesceri *et al*. 1998). Phosphorus and nitrogen fractions in samples were converted to orthophosphate and nitrate by persulfate oxidation (Gross and Boyd

1998). Total phosphorus (TP) and total nitrogen (TN) were estimated by measuring orthophosphate and nitrite in aliquots of the digest. Phosphorus was measured by the ascorbic acid method, and nitrate-nitrogen concentration was determined by ultraviolet spectrophotometry (Clesceri *et al*. 1998).

Aliquots of samples were passed through a series of six different filters with 41, 30, 20, 10 and 8 mm openings[3] and 5-mm openings[4]. These filters were prepared using short sections (10 cm) of Schedule 40 PVC pipe of 7.62 cm or 10.16 cm in diameter and attaching the fabric to the bottom of pipe sections with caulk[5]. Two sets of pipe filters were made for each mesh size in order to process samples without delay. This serial filtration procedure is illustrated as in Figure 1.

Filtrates were analyzed for the same water quality variables that were measured in the raw water. The water analysis data were used to calculate the percentages of particles that were removed by each size-class filter and the percentages of the other water quality variables associated with a particular size-class of particles.

The percentage reduction in each water quality variable by each filter was estimated as follows:

$$\text{Percentage reduction} = \frac{RW - F_s}{RW} \times 100$$

where RW = concentration of variable in raw sample (mg/L)

F_s = concentration of variable in filtrate passing filter of size = s (mg/L)

Means and standard errors were calculated for each variable for raw and serially filtered samples for 41, 30, 20, 10, 8 and 5 mm pore size filters by using Microsoft Excel (1997). Percentage removal of water quality components was calculated and the tables prepared using Microsoft Excel (1997).

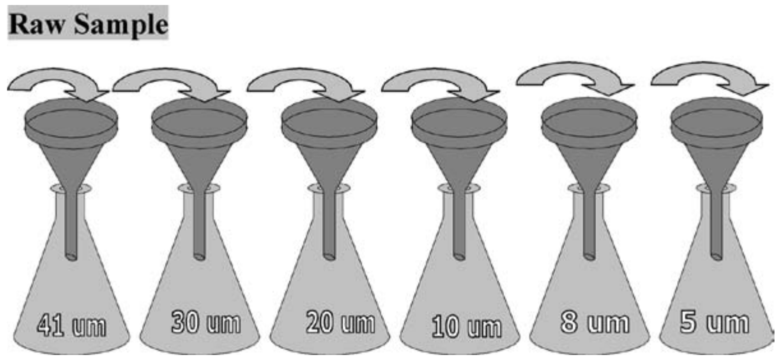

Fig. 1. Illustration of serial filtration by using 41, 30, 20, 10, 8 and 5µm pore size filters; n = 15.

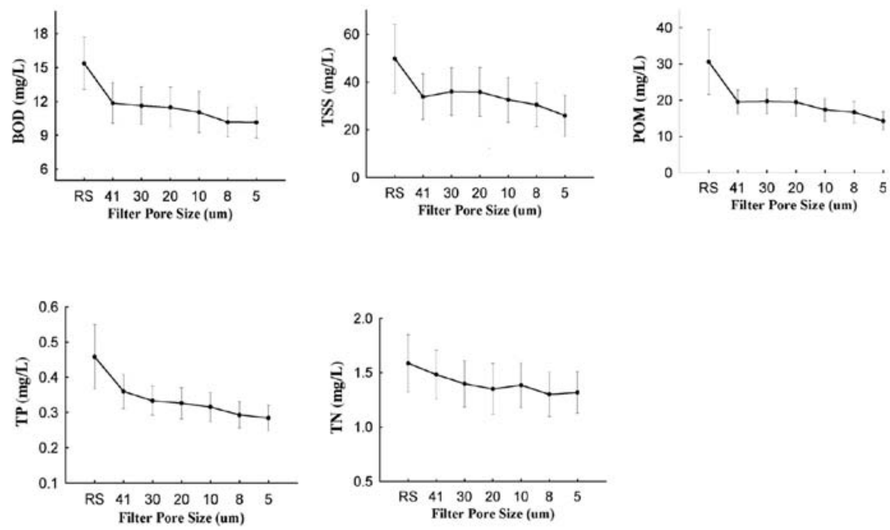

Fig. 2. Means and standard errors of selected water quality variables in raw water samples 9RS) and in filtrates of these samples passing six different filter pore sizes; n = 15. Abbreviations: BOD = biochemical oxygen demand; TSS = total suspended solids; POM = particulate organic matter; TP = total phosphorus; TN = total nitrogen.

Results

The concentrations of the water quality variables in filtrates passing the different-sized filters are presented in Figure 2. Excluding total nitrogen, there was a marked reduction in concentration of all variables in filtrates, which passed the 41 mm filter as compared to raw water, and there was a continuously but smaller removal by successively finer filters. In the case of total nitrogen, there tended to be a gradual removal with successively finer filter size.

The distribution of particles contributing to TSS was as follows: 22.5 percent, greater than 41 mm; 5.5 percent, 30 to 41 mm; 4.0 percent, 20 to 30 mm; 2.5 percent, 10 to 20 mm; 4.2 percent, 8 to 10 mm; 9.2 percent, 5 to 8 mm; 52.1 percent, less than 5mm.

The cumulative removal of particles (TSS) and of associated water quality components that would result if water was held in a basin long enough for different particle size classes to settle out are presented (Table 1). Sedimentation for a period long enough to remove 41 mm particles would reduce TSS concentration by 22.5 percent. Percentage removal of other water quality variables would be as follows: POM, 28.8 percent; TP, 21.5 percent; TN, 12.9 percent; BOD_5, 22.9 percent. If sedimentation was for a longer period to remove all particles larger than 5mm, the TSS concentration would decline by 47.9 percent, and other variables would decline as follows: POM, 51.6 percent; TP, 37.9 percent; TN, 23.5 percent; BOD_5, 51.6 percent. The removal of all variables but TN was in roughly the

Table 1. Percentage of suspended particles (total suspended solids, TSS) removed by filters of different sizes. Percentages of total phosphorus (TP), total nitrogen (TN), 5-day biochemical oxygen demand (BOD_5), and particulate organic matter (POM) removed with the TSS are provided.

Filter Pore Size (μm)	Average Percentage Removed TSS	POM	TP	TN	BOD_5
41	22.5	28.8	21.5	12.9	22.9
30	28.0	30.7	27.2	14.0	24.3
20	32.0	34.9	28.7	17.8	25.4
10	34.5	35.4	31.0	18.5	28.1
8	38.7	40.1	36.0	22.4	33.8
5	47.9	51.6	37.9	23.5	34.0

Table 2. Time (hr) necessary for mineral and organic particles of different sizes to settle 1 m at 25 C.

Filter Pore Size (μm)	Mineral Particles	Organic Particles
41	0.18	5.1
30	0.34	9.5
20	0.75	21
10	3.02	86
8	48	1,337
5	121	3,423

same percentages as the removal of TSS. This resulted because the organic particles were in a similar size range as the other particles, and much of the TP and BOD_5 are associated with organic particles (plankton and detritus). Nitrogen was not removed as efficiently as other variables because much of the total nitrogen is present in soluble organic or inorganic compounds.

Discussion

The percentage reduction in water quality variables, which would be achieved by sedimentation to remove different particles of different sizes (Table 1), shows that sedimentation would have to remove particles down to a very small size to provide much benefit. The time required to remove different-sized particles from still water can be estimated with the Stokes' Law equation (Boyd 1995). This equation is:

$$v_s = \frac{g(\rho_p - \rho_w d_p^2}{18\mu}$$

where v_s = velocity of particle (m/sec)
g = gravitation acceleration (m/sec)
ρ_p = density of particles (kg/m^3)
ρ_w = density of water (kg/m^3)
d_p = particle diameter (m)
μ = viscosity of water (kg·m/sec).

According to Boyd (1995), the particle density of organic suspended solids is around 1,050 kg/m^3 and that of mineral particles is about 2,500 kg/m^3. In channel catfish pond water, about 50 percent of the suspended particles are organic and inorganic particles make up the other 50 percent (Masuda and Boyd 1994).

For estimating the settling velocities of particles in pond water, a water temperature of 25 C was assumed. The settling velocities can be used to estimate the time required for a particle to settle a particular distance as follow:

$$\text{Settling time (hr)} = \frac{D}{(V_s)(3{,}600 \text{ sec/hr})}$$

where V_s = settling velocity (m/sec)
D = settling distance (m)

Times required for particles of different sizes to settle 1 m, a typical depth for a sedimentation basin for aquaculture application, are presented in Table 2. The time required to remove particles increases rapidly as particle size decreases. Mineral particles settle much faster than organic particles. Inorganic particles larger than 10 mm and mineral particles larger than 20 mm will settle 1 m in 24 hr. Smaller particles require a very long time to settle.

Assuming space is available for settling basins, retention times beyond a few hours would not be feasible, because pond effluents volumes can be quite large. A 1 ha pond of 1 m average depth would require an equal sized settling basin for a 24 hr retention time. A 25 year rainfall event in central Alabama would generate 40,000 m^3 of runoff from the surface and watershed of 1 ha watershed pond (Boyd and Queiroz 2001). This would require a 1 ha settling basin 1 m deep to provide a retention time of 6 hr.

Results of this study suggest that a settling time of 24 h might remove 32 percent of TSS, 34.9 percent of POM, 28.7 percent of TP, 17.8 percent of TN, and 24.5 percent of BOD_5. It will seldom be feasible to construct a settling basin to provide a 24 hr retention time for pond overflow or pond draining effluents. Moreover, the improvement in effluent quality would not be great. A requirement for settling basins for treating storm overflow and pond draining effluent does not seem feasible.

Notes

[1]Department of Fisheries and Allied Aquacultures, Auburn University, Alabama 36849 USA
[2]Air-o-lator Corporation, Kansas City, Missouri
[3]Nylon Mesh Sheets, Cole-Parmer Instrument Co
[4]Polyester filter fabric, Florida Aquaculture Supply
[5]Dow Corning〉 Silicone Sealant

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Aquaculture conference blazes new trail in Rhode Island

7th annual event draws together growers, scientists and educators

STATE HOUSE – The blazing orange, crimson and golden hues of autumn provided a festive backdrop to the 7th annual Rhode Island Aquaculture Conference, held last Thursday and Friday in West Greenwich.

More than 125 people participated in the various sessions, held at the Whispering Pines Conference Center, to discuss the status of the growing industry, develop legislative priorities for the 2004 legislative session, and to network with colleagues.

"Throughout the years, this conference has built bridges where before there were none," said Rep. Eileen S. Naughton, (D-Dist. 21), who chairs the Rhode Island Legislative Commission on Aquaculture. "It's so exciting to see shellfish growers talking with scientists, and educators mingling with equipment suppliers. That's what this conference is all about – making connections and strengthening bonds in this exciting field."

Keynote speaker Sandi McGeachy from the New Brunswick (Canada) Department of Agriculture, Fisheries and Aquaculture, kicked off the conference with a presentation on eel aquaculture in New Brunswick and Western Europe.

A report on the Rhode Island Aquaculture Initiative, given by David Alves from the Rhode Island Coastal Resources Management Council (CRMC), detailed the projects undertaken thanks to $1.5 million in funding secured by U.S. Sen. Jack Reed.

There was also a presentation and a field trip to the North Cape shellfish restoration project, which is taking place in Jerusalem. The North Cape tank barge ran aground Moonstone Beach in South Kingstown in January 1996, spilling 828,000 gallons of heating oil throughout Narragansett Bay and killing large numbers of lobsters, birds and surf clams.

With $1.5 million secured from a legal settlement, the state Department of Environmental Management (DEM) is working to restore the number of scallops, quahogs and oysters to pre-North Cape levels.

The conference wrapped up with a roundtable discussion featuring issues and ideas from neighboring states, and with a panel session determining 2004 legislative priorities for the state's aquaculture industry.

This year's event also included a special seafood reception and first-ever awards night, honoring those who have made significant strides in the industry. Dr. Robert B. Rheault, Jr. won the leadership award, while Michael T. McGiveney took home a vision award,ºand Captain Luther H. Blount received a lifetime achievement award.

"This year's conference was both informative and varied," said Dr. Michael A. Rice, who chairs the University of Rhode Island's Department of Fisheries, Animal & Veterinary Sciences. "We discussed key issues such as shellfish disease management, developing a sound financial structure for the business, and setting legislative priorities for the upcoming 2004 legislative session."

Conference-goers came from as far away as New Jersey and

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