# Evaluation and Improvements of Solids Removal Systems Used in Aquaculture Production

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## PROJECT OBJECTIVES

The overall goal of this project is to develop low-cost treatment technologies for the effective removal of suspended solids in aquaculture operations. The specific objectives are: (1) develop a standard protocol and set of criteria for evaluating solids removal methods from aquaculture systems; (2) utilize the protocol to evaluate several solids removal systems in current use, or with potential for use, in the western states; (3) propose and test modifications that will result in improvements in solids removal effectiveness; and (4) develop a model incorporating protocol data, economic data, and other factors to facilitate the selection of solids removal and control technologies.

## ANTICIPATED BENEFITS

The overall benefit of this collaborative research is to further refine the approaches for evaluating and developing technologies that can solve problems associated with effluent treatment. A standard protocol was developed and refined that allows for systematic analysis of aquaculture production systems. This protocol was further refined to include a simple, low-cost method for determining particle size fraction of suspended solids. Particle size directly impacts treatment capability and is largely ignored with standard measurement of total suspended solids. In addition, it is evident that many contaminants important in effluent regulations are associated with certain particle sizes. The work addresses improving certain treatment technologies or testing their application for recirculating or flow-through production systems. Drum filters, submerged surface flow (SSF) wetlands systems, and bead filters are all possible technological solutions to effluent problems. The key is a systematic approach to the actual attributes of each of these systems. This work also begins to address the difficult problems associated with treating high-volume, low-strength wastewaters generated by many raceway production systems. This area of research is extremely complex, and low-cost solutions are not always readily available. The research has made initial progress towards understanding the problems associated with flow-through raceway systems, and we acknowledge that more detailed and site-specific data is needed for these systems. We believe that it is essential for the industries dependent on these raceway technologies to explore new pathways for reducing effluent contaminants.

## PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

*Objective 1. To develop a standard protocol and set of criteria for evaluating solids removal methods from aquaculture systems*

A protocol for testing aquaculture systems was previously tested and accepted for broad application within the industry. As a further refinement to this protocol, a method for characterizing the particle size distribution (PSD) of solids in water has been proposed and tested by researchers at University of California-Davis (UCD), Arizona, and Idaho. A variety of laboratory techniques (electrozone counters, laser diffraction, etc.) can be used for PSD analysis. However, a simple and field deployable micro-sieving approach was determined to be the most appropriate analysis tool for sampling under this project. This method has been chosen because of its simplicity and minimal equipment requirements. Any laboratory with the ability to do Total Suspended Solids (TSS) analysis has the basic apparatus necessary for this test.

The method involves passing the sample through a microscreen (sieve) of a known pore size, measuring the TSS concentration of the influent and effluent, and determining the solids captured by difference. The amount captured is reported as the concentration of suspended solids (mg/L) that are larger than the nominal pore size of the sieve. This sieving process is repeated with microscreen sieves of pore sizes 30, 70, and 150 μm. The results provide a general idea of the size distribution of the particles in the sample. In this test, replicates of the original sample are passed through an individual sieve and measurements are taken, but the sample is **not** passed serially through all of the sieves.

*Objective 2. To utilize the protocol to evaluate several solids removal systems in current use, or with potential for use, in the western states*

Several systems were tested in previous years to provide data for testing the protocol. This phase of the report is essentially completed except for the new information developed for PSD analysis. Several systems were evaluated utilizing the PSD protocol. The removal of trout solids was evaluated by testing a rotating drum filter, a rotating belt filter, and off-line settling basins. Removal of tilapia solids from intensive recirculating systems was tested with floating bead filters and constructed wetlands, and saline effluent was filtered using halophytic plants. These are all systems with current applications in the western United States.

*Objective 3. To propose and test modifications to systems evaluated that will result in improvement in solids removal effectiveness*

A number of treatment systems for removing solids have been tested and data presented. These units have been applied to both recirculating and flow-through or raceway systems. Submerged surface flow (SSF) constructed wetlands have been tested to improve their removal of TSS, Chemical Oxygen Demand (COD), ammonia, and Total Phosphorus (TP) for application to treating effluents or for use in recirculating systems. These tests conducted at New Mexico State University (NMSU) examined waste control patterns generated over a 24-hour period, as well as ongoing studies conducted over several weeks. Tests were conducted on small pilot systems with tilapia densities of 0.1 to 0.3 lbs/gal. The pilot systems consisted of a conventional planted system and several unplanted systems with simple air injection systems. The tests have indicated that controlling electron couples in these multi-environment systems can impact removal efficiencies of key water quality parameters. Recent work has indicated that many SSF wetlands are oxygen limited and require additional air to aid in removal of contaminants.

The rotating drum system was found to be an effective system for removing solids and improving effluent quality when placed on the outflow of a settling basin. This is a concentrated stream of wastes that were already accumulated in the off-line settling basin. The rotating drum was not effective as an in-the-raceway filter as originally envisioned. The volumes to be treated are too great to utilize this system. The belt filter system was effective when operating, but was plagued with several mechanical problems. The equipment broke down and was eventually unusable. The bead filters were especially effective for reducing ammonia and nitrites from the recirculating systems. They were effective at re

moving solids, depending on adjustment of the operating parameters. The halophytic plants are a variation of the constructed wetland, especially suited for treating saline effluents. The plants proved useful for removing solids, nitrogen, and phosphorus. This has become more important with inland shrimp farms now in operation in Arizona.

A variety of solids removal systems have been tried or proposed for raceway aquaculture. The most promising near-term (2–5 years) research direction appears to be in the area of in-raceway rapid removal of solids. Designs in this category include the use of baffles, first explored by Boersen & Westers (1986), and the use of false bottoms, such as the designs described by Irving et al. (1992). The most promising of Irving et al.'s drawings show a false bottom installed in the quiescent zone of a raceway and under-floor plumbing used to remove the settled material. More recent (and more economically feasible) variations of these designs are currently being tested by Brannon et al. (1998).

The UC-Davis group is doing preliminary explorations of the use of induced currents to improve gravitational removal methods. Induced currents in a raceway can be accomplished with water jets or more simply with air bubble curtains. Air curtains have been used to keep waterways clear of ice and sediment, to herd fish, clear intake screens, protect harbors, contain oil spills, and direct suspended debris to collection sites (Mechrez, 1981; Pineros, 1981; Arimoto et al., 1993).

*Objective 4. To develop a model incorporating protocol data, economic data, and other factors to facilitate the selection of solids removal and control systems*

Work for the 1997–98 year has focused on enhancing the modeling of gravitational and filter-based solids removal systems. A related area of emphasis has been the development of methods to characterize aquacultural solids in ways that minimize the data collection effort while providing information that supports the modeling of particulate removal operations.

Sedimentation is the most widespread solids removal operation in aquaculture systems of the Western Region, and current modeling work is concentrated in this area. Accurate simulation of the sedimentation process must be based on the settling properties of the solids being removed. These properties may be inferred from theoretical calculations using Stokes' Law and are based on particle size, shape, and density. Alternatively, settling properties may be obtained from a settling test conducted in a small experimental column (usually no larger than 0.25 m diameter and 1.5 to 2 m tall) under standardized conditions. Settling tests are normally preferred over theoretical calculations, especially in cases in which a variety of particle shapes, sizes, and densities are present, as is the case in aquaculture waters.

The conventional column test is difficult to use with effluents from raceway culture of trout, given the very low suspended solids (SS) concentrations observed. Consequently, a newly developed column test has been implemented. An *Umwelt und Fluid Technik* (UFT) (Pisano, 1996) settling column has been fabricated, tested, and used to gather sedimentation data from a rainbow trout production facility in Southern Idaho. This procedure gives a more stable and reproducible analysis and may also be more realistic in terms of how an actual settling basin operates (Michelbach & Wohrle, 1993).

Using the modeling environment of Extend™ version 4.0 (Imagine That, Inc., San Jose, California), the sedimentation simulation model is implemented as a modular program "block." Water quality characteristics are passed to the various program blocks in the simulation. These values are manipulated during the simulation based on theoretical or empirical models of the underlying solids removal mechanisms, and of processes such as solids resuspension and decomposition. Enhancements to the basic sedimentation model include a sub-model which tracks the fate of specific constituents (other than suspended solids) in the waste stream, and accounts for solubilization or leaching (i.e., the constituent moving from the particulate state to the dissolved state). Specifically, a phosphorus capture and release submodel incorporates a settling curve based on the phosphorus (P) fractions instead of the mass fractions.

The development of the microscreen solids removal model has followed a more empirical approach than the sedimentation basin model. Performance data collected from various installations of belt and drum filters are used to calibrate various parameters in the underlying model equations. Particle size distribution provides critical information for quantifying microscreen performance, hence the current

efforts at collecting these data.

For solids removal operations that require pumping or other energy inputs, a simple economic model addressing operation and maintenance costs will be superimposed on the basic particle removal model. The economic model component will allow comparisons of solids removal systems used in aquaculture under a variety of effluent quality situations and energy and labor cost scenarios.

## USEFULNESS OF FINDINGS

The Environmental Protection Agency (EPA) is currently considering establishment of industry-wide effluent standards for aquaculture. This will impact operations nationwide, flow-through and recirculating systems alike. Regardless of species, farms may have to meet government-dictated water quality standards. The efficacy of solids removal systems and their impact on final effluent characteristics has become especially pertinent to the industry. By providing a standard methodology for comparing filtration techniques, this research has generated information that producers can use to select the most appropriate filters for their existing or proposed aquaculture operations. We feel that the drum filter, in conjunction with established off-line settling basins, will improve the effluent from a farm. The belt filter tested was inferior to the drum system tested.

The bead filter systems were effective in reducing suspended solids and ammonia levels. The open style filter required more energy input, but was easier to maintain and contributed oxygen to the system, rather than depleting oxygen like the closed style bead filters. Shrimp farms in Texas, Florida, and Arizona have come under scrutiny in the past year and will have to implement effluent treatment systems. The constructed wetland and halophyte systems tested will be the most likely candidates for treating these effluents.

One aspect of this year's research was an examination of the bacterial flora of the biofilters of several recirculating systems. An ancillary finding was that fecal coliforms are frequently present in the biofilters of both research and commercial recirculating systems. Fecal coliforms are used as a convenient indicator of human waste contamination because tests for *E. coli* and other pathogens are difficult and expensive. In a follow-up study, *E. coli* and other enteric organisms were detected, at low concentrations, in one of the commercial systems. Most aquaculture products are now being examined under HACCP plans, and these findings are likely to be repeated in other locations. Further study may be warranted to determine if the presence of fecal coliforms is indicative of contamination. Also, we should determine if the presence of *E. coli* is a fluke, or if there is some mechanism present that supports the survival of an organism that should only survive in a warmblooded animal.

The results of these studies continue to demonstrate that SSF constructed wetlands systems have promise for meeting the treatment needs for aquaculture production systems. The improvements in these systems supported by this work indicate that low-pressure, aeration injection systems can improve the performance of a SSF wetland. Removal efficiencies in the recirculating systems studied by the NMSU research group indicated that TSS, COD, ammonia, and TP can all be removed via wetland systems. Simple entrapment of soil particles appears to be the major mechanism for these improved removals; however, biological removal also played a part for the removal of nitrogen. The ability to create anoxic and aerobic environments within the SSF beds by alternating aerobic and anaerobic environments indicates that sequencing batch reactor processes can be created, and thus the potential for greater biologically based removal of TP and Total Nitrogen (TN) appears to be highly possible.

## WORK PLANNED FOR NEXT YEAR

This is the last year for this project.

## SUPPORT

| FISCAL YEAR | WRAC-USDA FUNDS | OTHER SUPPORT | | | | | TOTAL SUPPORT |
|---|---|---|---|---|---|---|---|
| | | UNIVERSITY | INDUSTRY | OTHER FEDERAL | OTHER* | TOTAL | |
| 95 | | | | 98,000 | | 98,000 | 98,000 |
| 96 | 70,500 | | | 15,000 | | 15,000 | 85,500 |
| 97 | 90,000 | | | 25,000 | | 25,000 | 105,000 |
| TOTAL | 160,500 | | | 138,000 | | 138,000 | 198,500 |

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