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Demonstration of the Use of the Air-lift Pump and Lignocellulosics Materials in Recirculation Aquaculture Systems

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Project Summary

The growth of the aquaculture industry in the next twenty years represents a significant new market opportunity for electrical utilities. Recirculation aquaculture -- consisting of circulating water from the culture tank, through a waste filtration system, and back to the culture tank -- is an especially energy intensive system. If growth of recirculation aquaculture is to be based upon the most efficient available technology, then utilities will need to take an active role in providing technical information to the public.

This proposal calls for the construction of an intermediate scale recirculation aquaculture system as a precursor to develop design standards for a commercial-size system. The system will demonstrate the energy efficiency in the use of air-lift pumps over conventional electrical pumps. Air-lift pumps should be a standard in design of recirculation aquaculture systems; however, there exists biasness against use of the air-lift pump. This is due to the combination of market forces and engineering designs that do not maximize its performance capabilities.

The system will also employ a unique filtration system employing lignocellulosic fibers as an alternative media for the growth of nitrifying bacteria, and as a secondary sedimentation system for the removal of residual suspended solids. Lignocellulosics materials will increase energy efficiency through increase fish production over conventional filtration designs.

People or Organizations who will Benefit:

- existing aquaculturists who are looking for opportunities to become more profitable by reducing consumption of electrical power and increasing fish yields by reducing suspended solids in the culture tank;
- prospective quaculturists who are seeking technical information for design of new recirculation systems;
- utilities who wish to supply the electrical power needs of this industry based upon the use of the most efficient technology;
- commercial suppliers of waste or bi-product lignocellulosics; and
- the public, who will pay less for the fish produced with less energy and whose environment will be minimally affected by the power required to produce it.

Objectives:

- To develop design specifications for the use of air-lift pumps for commercial-size recirculation aquaculture systems.
- To develop design specifications for lignocellulosics as a media in a conventional biofiltration system in a commercial-size recirculation system.
- To develop design specification for the use of lignocellulosics as a secondary sedimentation system in a commercial-size aquaculture system
- To provide the utility industry with technical information that will be used to promote the efficient use of electrical power by the aquaculture industry.

Contributions to Increased Energy Efficiency:

The project has two components that will increase energy efficiency in intensive aquaculture. First, less energy (per unit of fish produced) will be required to circulate water through the filtration system. Second, the reduction of residual suspended solids in the culture tank will allow more intensive fish culture, through increased feeding per unit volume of water per day.

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Anticipated Benefits of the Project:

The research team has previously demonstrated the use of the air-lift pump and lignocellulosics in a small-scale, pilot recirculation fish culture system. This project will apply these same systems to a medium-scale aquaculture system that will be approximately ten times the size (in terms of culture tank volume). Successful completion of this project will provide the design parameters for application of a commercial-size systems – a further scaling of between 5 to 10 times.

Future Research using Lignocellulosics Materials:

Removing ammonia by direct ion exchange represents an alternative to biofiltration for water recirculation systems. Ion exchangers examined to date consist of resins or naturally occurring zeolites (e.g., Clinoptilolite) which can be recharged. One drawback to these systems is that the downtime required for recharging necessitates the installation of at least two parallel systems, thereby adding to capital costs. Several researchers have reported success with rechargeable ion exchangers on a pilot scale, but currently it remains questionable if these filters will be economically feasible in large commercial aquaculture production systems because of their expense and complexity of use and regeneration.

An alternative to removing ammonia from water recirculation systems that has not been explored is the use of simple, disposable ion exchange filters made from inexpensive lignocellulosic fibers. Lignocellulosics possess natural sorption potential; however, the capacity is generally low. Researchers at the FPL are leaders in the study of modified lignocellulosics for environmental remediation, as well as commercial and industrial applications. Modifications consist of enlarging the surface area of the fiber altering of the surface chemistry to create more active sites for sorption of ions. Modification techniques include physical, biological and chemical processes.

The Fish Culture System

The fish culture system consists of a 6-ft. diamenter tank (located inside enclosure) and two filtration boxes.
A second system is located in the foreground, on the opposite side of the staircase.

The Filter Box: Design

The filtration boxes are made of wood. The internal measurements are 96"x25.5"x48". Five rods were install to provide support for the lateral load along the length of the box. A sealent is applied to the inside of the box. Twelve air lines are spaced throughout the length of the box. Slots were made in thebox for 12 baffles and 12 filters.

The Filter Box: Air Lines

Each air line is connected to a horizontal pipe located at the bottom of the box. Small diameter holes were dilled along the top of each pipe.

The Filter Box: Air Supply

The air tubes are connected to an air manifold located along the outside wall of the box. Air flow to each of the air tubes can be controlled using needle valves.

The Filter Box: Operation

An acrylic baffle is placed on the upstream side of each air tube, and a filter is placed on the down stream side. The bottom 1. 5 inches of the baffle is open. Water flows into the chamber from the bottom, and mixes with air from the tube. A localized air-lift occurs, providing energy to assist in pushing the water through the filter. The air bubbles also facilitate oxygen flow into the water and stripping of carbon dioxide from the water.

Fish Tank

The fish tank is made of fiberglass and has a capacity of 800 gallons. Approximately 700 gallons is maintained in the tank for the rearing of fish.

Air-Lift Pump (System #1, Tubes)

Water is pumped through the filtration system using air. Adjacent to the tank is one of two air-lift pump systems designed for this project. Water discharged from the second filter box is lifted using a series of four air-lift tubes. Water enters the tubes from the bottom and passes through a chamber where air is mixed. The change in the density of the water, together with the physical design of the tubes, results in the water being lifted up. When it reaches the top of the tank, the water exists the tube through a T-section and discharges into the tank.

The hoizontal pipe located above the air-lift tubes is an air manifold that supplies air to the individual air chambers. The air manifold also supplies air to an aerator located in the tank (not shown). Air is supplied to the air manifold via the large clear plastic hoze located to the left of the air-lift tubes.

Air-lift Pump (System #2, Weir)

A second method of pumping the water uses fixed weirs in a 2-stage process. The last two air lines in each box are placed in front of polyethylene weirs. A chamber is created by placing a piece of acrylic immediately in from of the air tube. The bottom 1.5 inches of the acrylic sheet is open, allowing water to enter the chamber. The water is then immediately mixed with water. The change is density of the air-water mixture, combined with the physical parameters of the chamber, results in the water being lifted. Each of the lifts is two inches. Water is lifted a minimum of 4 inches per box and 8 inches through the filtration system. At he end of the second box, the water level is high enough to be able to return to the fish tank via gravity only. No further pumping is required.

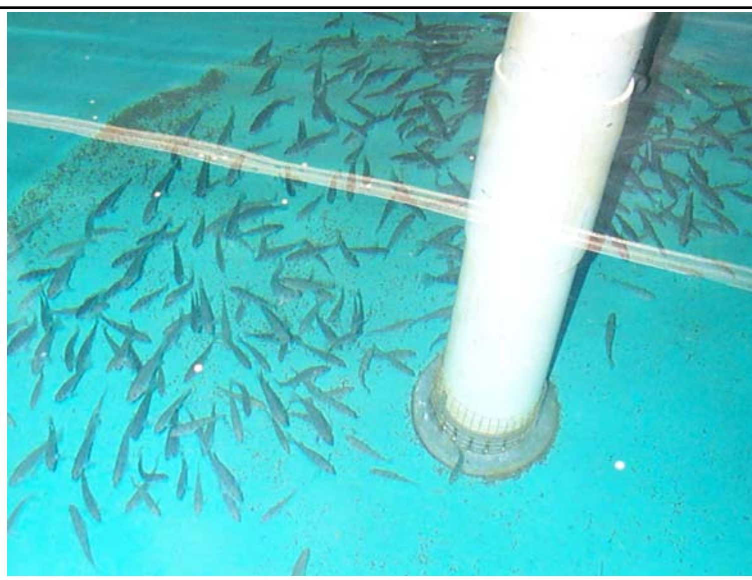
Air-lift Pump (System #3, Fish Tank Aerator)

An air-lift pump is used for supplemental aeration in the fish tank, and as an emergency aerator during power outages.

The design of the air-lift pump is similar to the design of the air-lift used in the air-lift tubes; however, the main function is to aerate the water. Water pumped through the air-lift helps to maintain a uniform oxygen level throughout the tank.

Natural Fiber Filter Mat

Filters are composed of fiberized juniper chips. Odbek Industries prepared the fiber into filter mats. The filter mat on the left has not been placed into the water. The filter on the right was taken out of the water after three weeks of exposure.



Culturing Yellow Perch Fingerlings

1300 yellow perch fingerlings will be stocked in each of the two tanks. They will be raised to a weight of one-third pound, totaling approximately 400 pounds of fish per tank. Improved water quality using natural fiber filters will allow greater densities of fish to be cultured.

Bench Scale System (1):

A prototype fish culture system was design and tested from 1997-99, consisting of a 235 gallon fish tank, sedimentation tank using natural fiber filters, and biofiltration box using various natural fiber materials as filter media. Pumping, aeration and degassification was conducted using airlift pump tubes.

Bench Scale System (2):

Ninety (90) Tilapia were grown to an average weight of 2 pounds or approximately 0.5 pounds of fish per gallon of water. This density is to be exceeded in the current fish culture system. Low suspended solids in the culture water is essential to maintaining optimum fish growth and to control disease.