

## BIOFILTRATION FOR RECIRCULATING FINFISH CULTURE SYSTEMS

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The interest in using recirculating water systems in the rearing of finfish has increased tremendously over the last decade. Since total ammonia nitrogen (TAN), nitrite, biochemical oxygen demand (BOD), and total suspended solids (TSS) buildup in recirculating systems are the major limiting factors optimizing recirculating system efficiency, biofiltration technology of some type must be employed.

The type of biological processes used in the treatment of recirculating system waters is called "fixed film" filtration. The bacteria, which remain "fixed" to the media surface in a thin film, draw dissolved wastes, oxygen, and other required nutrients from the passing water (Spotte, 1979; Wheaton; 1977). The rate at which the critical nitrifying bacteria assimilate and process waste is controlled by a wide variety of factors (Table 1).

TABLE 1                      FACTORS EFFECTING NITRIFYING BACTERIA PERFORMANCE

<u>FACTOR</u>	<u>IMPORTANCE</u>
TEMPERATURE	OPTIMUM GROWTH IN 25-30 C RANGE
pH	OPTIMUM pH RANGE 7.5-8.0 BELOW 7.0 SEVERELY INHIBITS NITRIFIERS ABOVE 8.0 AMMONIA TOXICITY TO ANIMALS
DISSOLVED OXYGEN	INHIBITION OF NITRIFIERS OCCURS AT LESS THAN 3.0 mg/l
ALKALINITY	INHIBITION OF NITRIFIERS OCCURS BELOW 100 mg/l AS CaCO <sub>3</sub>
OTHER	NITRIFIERS SENSITIVE TO WIDE VARIETY OF ANTIBIOTICS AND METAL IONS.

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The critical characteristics of concern in the design of biofiltration units are listed in Table 2 below.

TABLE 2      CRITICAL BIOFILTER DESIGN CRITERIA

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- \*      SPECIFIC SURFACE AREA
  - \*      POROSITY (% VOIDS)
  - \*      BIOMASS REMOVAL MECHANISM
  - \*      OXYGEN DELIVERY (GRAMS OXYGEN PER HOUR)
  - \*      HEADLOSS
  - \*      MECHANICAL RELIABILITY
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The total suspended solids (TSS) and biochemical oxygen demand (BOD) excreted from finfish is six to eight times that excreted by crabs or crawfish (Wimberly, 1990). Due to this higher excretion, solids removal becomes critical in optimizing biofiltration operations. Most of the BOD of the waste excreted by fish is associated with the solids. Wimberly (1990) found that the BOD<sub>5</sub> of the excreted wastes was reduced by 76% if the solids were completely removed. Total Ammonia Nitrogen (TAN) is not reduced by solids capture; however, rapid removal of the solids minimizes the waste load on biofilters.

There are six fixed film biofiltration processes that have been used in intensive finfish recirculating systems. These biofilters, as well as some of the advantages and disadvantages of each, are listed in Table 3.

The bead biofiltration units utilizing low-density polyethylene (LDPE) pelletized feedstock as a filter media were developed to overcome the limitations of the other fixed film biofiltration technologies. The LDPE media is utilized in an upflow, pressurized biofilter configuration.

The rapid removal of the solids by use of multiple backwashes improved the carrying capacity of the bead biofilters by a factor of four over upflow sand biofilters. Figure 1 shows the filtration cycle for a 20 cubic foot model. The

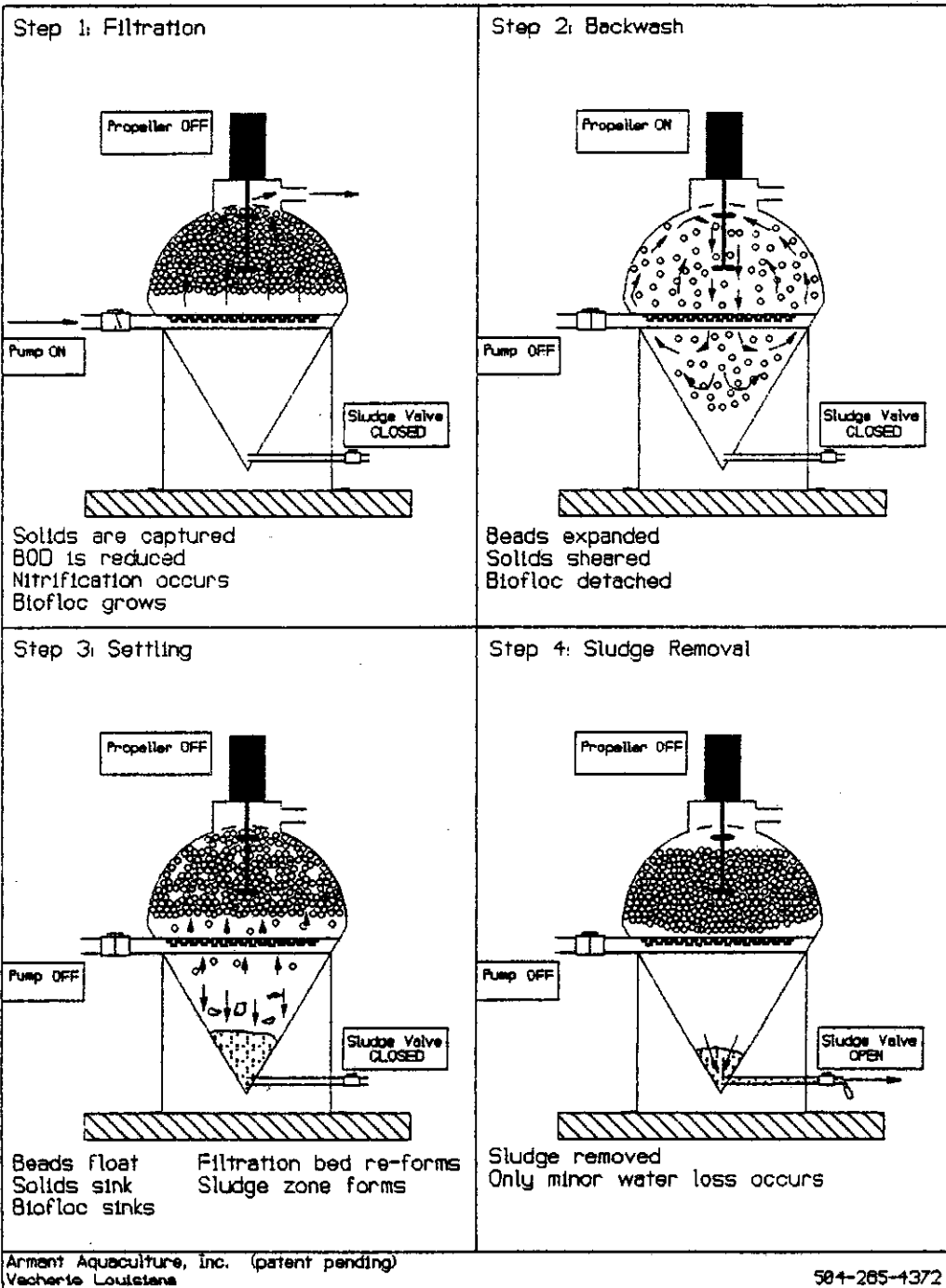


TABLE 3 FIXED FILM BIOFILTRATION PROCESSES

<u>PROCESS</u>	<u>ADVANTAGES</u>	<u>DISADVANTAGES</u>
TRICKLING FILTER	EASY TO OPERATE NITRIFICATION	LARGE VOLUME, NO SOLIDS REMOVAL
RBC	OXYGENATION NITRIFICATION	NO SOLIDS REMOVAL, LOW SURFACE AREA PER UNIT VOLUME, RELIABILITY
FLUIDIZED BED	HIGH TREATMENT CAPACITY	PUMPING DEMANDS, NO SOLIDS REMOVAL
UPFLOW SAND	SOLIDS REMOVAL	HIGH WATER LOSS, BACKWASH PUMP SIZE
RAPID SAND	SOLIDS REMOVAL NITRIFICATION	WATER LOSS, GELS UNDER HIGH SOLIDS LOADS
BEAD FILTER	SOLIDS REMOVAL NITRIFICATION NO WATER LOSS	PUMPING DEMANDS

sequence of events is filtration, backwash, settling, and sludge removal. The water loss problem is eliminated by use of the low density media, which after being backwashed floats back up while the solids and excess bacteria settle to the bottom of the filter. The settled out solids and bacteria can then be taken out of the system as a concentrated sludge. With a high specific surface area the bead filter has high rates of nitrification in combination with good solids removal, unlike the trickling filter or RBC.

The authors have collected data from a variety of demonstration facilities and experimental units to determine the nitrification capacity of the units. These results, Table 4, show that in addition to the excellent solids capture capability, the bead filters provide for nitrification rates comparable to the other units tested. The high specific surface area (319 to 375 FT<sup>2</sup>/FT<sup>3</sup>) and frequent filter cleaning contribute to the nitrification performance.

# VOLUMETRIC OXIDATION RATES

## SUBSTRATE LIMITED

<u>FILTER TYPE</u>	<u>TAN OXIDATION</u>	<u>NITRITE OXIDATION</u>
LSU COARSE SAND UFSF	20.69	27.34
LSU COARSE SAND FBF	11.43	19.3
LSU BEAD FILTER	8.05	4.54
MP&L BEAD FILTER	7.78	4.08
MP&L RBC (BIO-DEK)	0.77	1.37

RATES IN (GRAMS PER FT<sup>3</sup>)

## REFERENCES

- Cooley, P.E. 1979. "Nitrification of Fish-Hatchery Reuse Water Utilizing Low-Density Polyethylene Beads as a Fixed-Film Media Type". M.S. Thesis, University of Idaho, Moscow, Idaho.
- Lewis, W.M. and R.C. Heidinger. 1981. Tank Culture of Striped Bass Production Manual. Illinois Striped Bass Project IDC FF-26-R, Fisheries Research Laboratory, Southern Illinois University, Carbondale, Illinois.
- Spotte, S. 1979. Fish and Invertebrate Culture - Water Management in Closed Systems. Wiley-Interscience, New York, New York.
- Wheaton, F.W. 1977. Aquacultural Engineering. Wiley-Interscience, New York, New York.
- Wimberly, D.M. 1990. "Development and Evaluation of a Low Density Media Biofiltration Unit For Use in Recirculating Finish Culture Systems". M.S. Thesis, Louisiana State

## ONGOING RESEARCH

Last year, several of the ten cubic foot prop-washed bead biofilters (PBF-10) were installed in laboratories or demonstration facilities. Three were on recirculating finfish culture systems. Two are at the North Carolina State University "Fish Barn" project. The third PBF-10 was employed at the "AQUATANK" project in Greenville, Mississippi.

The "AQUATANK" project was a collaborative project with a consortium consisting of Mississippi Power & Light Co., Fish Management, Inc., Mississippi Delta Community College, and Mississippi State University attempting to raise channel catfish (*Ictalurus punctatus*). The 10,000 gallon system held a maximum of 3500-4000 pounds of catfish at the end of May 1991. The PBF-10 was added primarily for solids removal but provided additional nitrification. The project provided a performance comparison between a prop wash PBF-10 and a RBC.

In October 1991, a Workshop entitled "Design of High Density Aquaculture Systems Intensive Finfish Recirculating Systems", jointly sponsored by LSU Department of Civil Engineering, Louisiana Sea Grant, the National Sea Grant, U. S. Fish and Wildlife Service, and the U. S. Department of Agriculture, was held. This workshop brought together the leading engineers, scientists, and economists involved in recirculating aquaculture systems to discuss current state of the art technologies and determine future research directions. The agenda, included presentation of position papers on the participants areas of expertise and then debates on the presented positions. The proceedings of the workshop will be published in an edition of the World Aquaculture Society Journal.

There are three ongoing evaluation programs involving low density media biofilters in finfish culture applications. The bead biofilters were developed in a cooperative arrangement with Armant Aquaculture, Inc. of Vacharie, Louisiana. The prop-washed bead biofilters are manufactured solely by Armant Aquaculture, Inc. under a pending patent; however, the literature (Cooley, 1979, Lewis and Heidinger, 1981) provides illustrations of other washing systems.

The first effort is the Civil Engineering Aquatic Systems Laboratory (CEASL) with a 15 cubic foot PBF-15, a three cubic foot prop washed filter (PBF-3), several prototypes utilizing a bubblewash backwash system, and several 0.05 cubic foot research filters. There two research associates and several graduate students doing treatment system integration and filter optimization studies. The optimization studies are on biofilter design parameters including; backwash frequency, specific surface area, and porosity.

The second effort is the comparison testing at N. C. State, under Dr. Tom Losordo of the Department of Agricultural Engineering and Zoology. This

program is in its second year of testing with the low-density bead biofilters chosen for use in combination with RBCs for raising tilapia. Dr. Losordo's work focuses on the economics of intensive recirculating systems.

The third evaluation effort is at the Louisiana State University School of Veterinary Medicine's Aquatic Disease Laboratory. This effort is directed by Dr. Ron Thune and consists of two prop wash PBF-1.5 and six prototype 1.5 cubic foot, bubble backwashed filters (BBF-1.5). These systems are being used to raise catfish fingerlings for disease and vaccine studies.

Additionally, in the upcoming year, evaluations of bead filter performance on alligator rearing (Louisiana), soft shell crab shedding (Louisiana), soft shell crawfish systems (Louisiana), shrimp maturation (Texas), tropical fish rearing (California), clams (Georgia), and seafood processing wastes (Louisiana) are anticipated.

It is hoped that these units will lay the foundation for more cost effective recirculating systems.

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