
ANAEROBIC AMMONIUM-OXIDIZING (ANAMMOX) BACTERIA AND ASSOCIATED ACTIVITY IN FIXED-FILM BIOFILTERS OF A MARINE RECIRCULATING AQUACULTURE SYSTEM

Yossi Tal, Joy E. M. Watts, Harold J. Schreier-2006

Applied and Environmental Microbiology 72(4): 2896-2904

Abstract:
Microbial communities in the biological filter and waste sludge compartments of a marine recirculating aquaculture system were examined to determine the presence and activity of anaerobic ammonium-oxidizing (anammox) bacteria. Community DNA was extracted from aerobic and anaerobic fixed-film biofilters and the anaerobic sludge waste collection tank and was analyzed by amplifying 16S rRNA genes by PCR using anammox-selective and universal GC-clamped primers. Separation of amplified PCR products by denaturing gradient gel electrophoresis and sequencing of the different phylotypes revealed a diverse biofilter microbial community. While Planctomycetales were found in all three communities, the anaerobic denitrifying biofilters contained one clone that exhibited high levels of sequence similarity to known anammox bacteria. Fluorescence in situ hybridization studies using an anammox-specific probe confirmed the presence of anammox Planctomycetales in the microbial biofilm from the denitrifying biofilters, and anammox activity was observed in these biofilters, as detected by the ability to simultaneously consume ammonia and nitrite. To our knowledge, this is the first identification of anammox-related sequences in a marine recirculating aquaculture filtration system, and our findings provide a foundation for incorporating this important pathway for complete nitrogen removal in such systems.

(Center of Marine Biotechnology, University of Maryland Biotechnology Institute, 701 E. Pratt Street, Baltimore, Maryland 21202, USA; email of Harold J. Schreier: schreier@umbi.umd.edu)

DESIGN CRITERIA FOR RECIRCULATING, MARINE ORNAMENTAL PRODUCTION SYSTEMS

Craig A. Watson, Jeffrey E. Hill-2006

Aquacultural Engineering 34(3): 157-162
Design and Selection of Biological Filters for Freshwater and Marine Applications

Abstract:
While recirculating aquaculture systems for food animals are well defined in the literature, little information is available for the emerging production of high value marine ornamental species. These organisms typically require systems which operate within a narrow range of parameters compared to most food animals, and in addition to growth and survival issues, individual appearance of animals is critical to success. This paper is a general review of the primary design criteria parameters for the production of marine ornamental species in stable, oligotrophic, recirculating aquaculture systems.

(Tropical Aquaculture Laboratory, Department of Fisheries and Aquatic Sciences, University of Florida, 1408 24th Street SE, Ruskin, FL 33570, USA; email of Craig A. Watson : caw@ifas.ufl.edu)

WATER QUALITY REQUIREMENTS FOR REUSE SYSTEMS

John Colt-2006

Aquacultural Engineering 324(3): 143-156
Design and Selection of Biological Filters for Freshwater and Marine Applications

Abstract:
Water quality criteria for aquaculture systems have typically considered parameters such as temperature, dissolved oxygen, total gas pressure, ammonia, and nitrite. Many of the published criteria are derived for environmental protection of a wide range of species and life stages. These

criteria may not be appropriate for a single species and life stage, especially in commercial applications. The value of a given water quality criterion may depend strongly on the species, size, and culture objectives. In water reuse systems, fine solids, refractory organics, surface-active compounds, metals, and nitrate may become important. The limiting factors in very high intensity reuse systems are not entirely understood at this time. Development of more relevant water quality criteria for reuse systems will require production-scale trials. Separate water quality criteria for biofilter operation are also needed.
(Northwest Fisheries Science Center, National Marine Fisheries Service, 2725 Montlake Blvd. East, Seattle, WA 98112-2097, USA; email of J. Colt: john.colt@noaa.gov)

BIOLOGICAL FILTERS IN AQUACULTURE: TRENDS AND RESEARCH DIRECTIONS FOR FRESHWATER AND MARINE APPLICATIONS
Maria Teresa Gutierrez-Wing, Ronald F. Malone-2006
Aquacultural Engineering 34(3): 163-171
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Factors such as limitations in water quality and quantity, cost of land, limitations on water discharges, environmental impacts and diseases, are driving the aquaculture industry toward more intensive practices. This will force producers to adopt environmentally friendlier technologies. Recirculating systems, with a biofilter as the most prominent characteristic, treat internally the water contaminated with dissolved organics and ammonia and reduce the amount of water use and discharge from aquaculture operations. This paper reviews the implications of the changing use of recirculating aquaculture systems (RAS) on biofiltration research for freshwater and marine operations. Demand for cost effective biofilters will increase with the expansion of recirculating systems, both as a complement and replacement of traditional ponds. For freshwater aquaculture, emphasis should be placed in cost competitiveness, low head operations, intensification of ponds with RAS biofiltration and the evaluation of suspended growth systems. In the marine systems, an increase in demand of oligotrophic and ultraoligotrophic systems is expected, particularly in the nursery systems. Sizing and cost efficiency of biofilters for nursery operations should be addressed. Problems in marine biofilter acclimation appear to justify the development of new acclimation procedures. Biosecurity concerns, land cost and storm threats will drive nursery systems inland, where saltwater supply and disposal will force an increased water reuse. Denitrification strategies will need to be redefined and optimized for the marine nursery environment.
(Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803, USA; email of Maria Teresa Gutierrez-Wing: mgutie@lsu.edu)

BIO-FILTERS: THE NEED FOR A NEW COMPREHENSIVE APPROACH
Yoram Avnimelech-2006
Aquacultural Engineering 34(3): 172-178
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
The aquaculture industry struggles to profit in light of low product prices, increasing costs of inputs and constrains due to environmental, water and land limitations.
Intensive aquaculture systems are relevant to efficiently produce fish and shrimp. The two important limiting factors of intensive aquaculture systems are water quality and economy. An intrinsic problem of these systems is the rapid accumulation of feed residues, organic matter and toxic inorganic nitrogen species. This cannot be avoided, since fish assimilate only 20–30% of feed nutrients. The rest is excreted and typically accumulates in the water. Often, the culture water is recycled through a series of special devices (mostly biofilters of different types), investing energy and maintenance to degrade the residues. The result is that adding to the expenses of purchasing feed, significant additional expenses are devoted to degrade and remove 2/3 of it.

There is a vital need to change this vicious cycle. One example of an alternative approach is active suspension ponds (ASP), where the water treatment is based upon developing and controlling heterotrophic bacteria within the culture component. Feed nutrients are recycled, doubling the utilization of protein and raising feed utilization. Other alternatives, mostly based upon the operation of a water treatment/feed recycling component within the culture unit are discussed.
The present paper was presented in the biofilter workshop held in Honolulu, 8–11 November 2004. The main purpose of this paper was to raise new ideas and new options toward the planning and operation of intensive fish/shrimp ponds.
(Department of Environmental and Civil Engineering, Technion, Israel Institute of Technology, Haifa 32000, Israel; email of Yoram Avnimelech: agyoram@tx.technion.ac.il)

NITRIFICATION KINETICS OF BIOFILM AS AFFECTED BY WATER QUALITY FACTORS
Shulin Chen, Jian Ling, Jean-Paul Blancheton-2006
Aquacultural Engineering 34(3): 179-197
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Various types of fixed film biofilters have been used in recirculating aquaculture systems under different water quality and operating conditions. The effectiveness of the nitrification process can be evaluated by nitrification kinetics. Nitrification in the bacterial film of the biofilter involves physical, chemical and biological processes that are governed by a variety of parameters such as substrate and dissolved oxygen concentrations, organic matters, temperature, pH, alkalinity, salinity and turbulence level. The impacts of these parameters upon nitrification kinetics make predicting the performance of a biofilter for a given application an engineering challenge. Knowing the performance of a biofilter is critical for both designers and managers. This paper summarizes the current knowledge on nitrification kinetics as affected by the aforementioned factors based on literature and the results from the authors' laboratories. These factors were ranked according to their significance of impact on biofilter nitrification performance. The information presented can be used as a reference for the design and operation of biofilters in recirculating aquaculture systems.
(Department of Biological Systems Engineering, Washington State University, Pullman, WA 99164-6120, USA; email of Shulin Chen: chens@wsu.edu)

COMPARATIVE PERFORMANCE OF FIXED-FILM BIOLOGICAL FILTERS: APPLICATION OF REACTOR THEORY
Barnaby J. Watten, Philip L. Sibrell-2006
Aquacultural Engineering 34(3): 198-213
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Nitrification is classified as a two-step consecutive reaction where R1 represents the rate of formation of the intermediate product NO2-N and R2 represents the rate of formation of the final product NO3-N. The relative rates of R1 and R2 are influenced by reactor type characterized hydraulically as plug-flow, plug-flow with dispersion and mixed-flow. We develop substrate conversion models for fixed-film biofilters operating in the first-order kinetic regime based on application of chemical reactor theory. Reactor type, inlet conditions and the biofilm kinetic constants Ki (h−1) are used to predict changes in NH4-N, NO2-N, NO3-N and BOD5. The inhibiting effects of the latter on R1 and R2 were established based on the γ relation (…) where BOD5,max is the concentration that causes nitrification to cease and N is a variable relating Ki to increasing BOD5. Conversion models were incorporated in spreadsheet programs that provided steady-state concentrations of nitrogen and BOD5 at several points in a recirculating aquaculture system operating with input values for fish feed rate, reactor volume, microscreen performance, make-up and recirculating flow rates. When rate constants are standardized, spreadsheet use demonstrates plug-flow reactors provide higher rates of R1 and R2 than

mixed-flow reactors thereby reducing volume requirements for target concentrations of NH4-N and NO2-N. The benefit provided by the plug-flow reactor varies with hydraulic residence time t as well as the effective vessel dispersion number, D/μL. Both reactor types are capable of providing net increases in NO2-N during treatment but the rate of decrease in the mixed-flow case falls well behind that predicted for plug-flow operation. We show the potential for a positive net change in NO2-N increases with decreases in the dimensionless ratios K2,(R2)/K1,(R1) and [NO2-N]/[NH4-N] and when the product K1,(R1)t provides low to moderate NH4-N conversions. Maintaining high levels of the latter reduces the effective reactor utilization rate (%) defined here as (RNavg/RNmax)100 where RNavg is the mean reactive nitrogen concentration ([NH4-N] + [NO2-N]) within the reactor, and RNmax represents the feed concentration of the same. Low utilization rates provide a hedge against unexpected increases in substrate loading and reduce water pumping requirements but force use of elevated reactor volumes. Further γ effects on R1 and R2 can be reduced through use of a tanks-in-series versus a single mixed-flow reactor configuration and by improving the solids removal efficiency of microscreen treatment.
(United States Geological Survey, Leetown Science Center, 11649 Leetown Road, Kearneysville, WV 25430, USA; email of Barnaby J. Watten: barnaby_watten@usgs.gov)

LINEAR VERSUS MONOD REPRESENTATION OF AMMONIA OXIDATION RATES IN OLIGOTROPHIC RECIRCULATING AQUACULTURE SYSTEMS
Ronald F. Malone, Jon Bergeron, Chad M. Cristina-2006
Aquacultural Engineering 34(3): 214-223
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Monod kinetics are widely used to model nitrifying biofilters. However, these kinetics are incapable of representing the collapse of volumetric TAN conversion rate (VTR) under high organic loadings. Failure to recognize the underlying heterotrophic interference can lead to calibration issues as a single Monod function is applied across contrasting levels of carbon loading. This, plus an historic bias towards the analysis of peak carrying capacities leave modelers poorly prepared to serve the needs of a mariculture industry demanding oligotrophic designs for broodstock maturation and larval/fingerling production. Consequently, data was generated by a Monte Carlo technique under the assumption of heterotrophic inhibition to nitrification. The data was used to compare the accuracy of calibration of the Monod relationship using the traditional Lineweaver–Burke and Eadie–Hofstee calibration methods against direct linear regression for low substrate (mesotrophic/oligotrophic) regimes. The results indicate that a simple linear relationship with a zero intercept, calibrated on data ranging from 0.1 to 0.5 g-TAN m−3, is most suitable for the representation of the mesotrophic/oligotrophic performance of nitrifying biofilters based on a comparison of SSE for both the Monte Carlo and field data analyzed herein. Additionally, the coefficient of variation was found to be between 7 and 8% for the parameter τ, which is the slope of the linear relationship between total ammonia nitrogen (TAN) and VTR while the CV for the Monod parameters ranged between 22 and 143% for VTRmax and between 29 and 137% for the apparent half-saturation constant showing the improved stability of the linear model to that of the Monod model.
(Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803, USA; email of R. Malone: RMalone@lsu.edu)

EFFECT OF PARTICULATE ORGANIC CARBON ON HETEROTROPHIC BACTERIAL POPULATIONS AND NITRIFICATION EFFICIENCY IN BIOLOGICAL FILTERS
L. Michaud, J.P. Blancheton, V. Bruni, R. Piedrahita-2006
Aquacultural Engineering 34(3): 224-233
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:

Competition between heterotrophic and nitrifying bacteria is of major practical importance in aquaculture biofilter design and operation. This competition must be understood to minimize the negative impact of heterotrophic bacteria on an aquaculture system. On the other hand, the heterotrophic population is suspected of having a positive effect against pathogenic bacteria. Little information is available on the bacterial communities present within aquaculture systems, except for nitrifying bacteria, but a combination of traditional aquacultural engineering research methods and novel microbiological techniques offers new opportunities for the study of these communities.
The heterotrophic bacterial population activity and the nitrification efficiency of a submerged biological filter were studied for an influent TAN concentration of 2 mg/l and varying C/N ratios. The TAN removal rate was found to be 30% lower at a C/N ratio of 0.5 than at a C/N ratio of 0. For higher C/N ratios the reduction in nitrification efficiency was 50% while the attached bacterial abundance was doubled. Moreover, results confirm that abundance of sheared and attached bacteria are correlated. It is not known to what extent biofilter configuration might influence the relationship between heterotrophic and nitrifying bacteria, and further work will be carried out with moving bed and fluidized filters. A better understanding of the role of the heterotrophic bacteria in RAS will help to optimize any positive "biocontrol" effect and to minimize the microbial degradation of rearing water and the reduction of nitrification rates.
(University of Messina, Department of Animal Biology and Marine Ecology, Salita Sperone, 31-98166 Messina, Italy; email of J.P. Blancheton:jean.paul.blancheton@ifremer.fr)

DESIGN AND OPERATION OF NITRIFYING TRICKLING FILTERS IN RECIRCULATING AQUACULTURE: A REVIEW
E.H. Edinga, A. Kamstra, J.A.J. Verreth, E.A. Huisman, A. Klapwijk-2006
Aquacultural Engineering 34(3): 234-260
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
This review deals with the main mechanisms and parameters affecting design and performance of trickling filters in aquaculture. Relationships between nitrification rates and easily accessible process parameters, like bulk phase concentration of TAN, O2, organic matter (COD), nitrite, temperature, HCO3−, pH and the hydraulic loading of the trickling filter, are discussed in relation to the design and operation of such filters. Trickling filter design procedures are presented and one of them, a model describing the nitrification performance of trickling filters by plug-flow characteristics, is discussed in greater detail. Finally, practical aspects in relation to filter design and operation are presented.
(Wageningen University, Department of Animal Sciences, Wageningen Institute of Animal Sciences (WIAS), Fish Culture and Fisheries, P.O. Box 338, 6700 AH Wageningen, The Netherlands; email of Ep Eding: ep.eding@wur.nl)

PERFORMANCE AND OPERATION OF A ROTATING BIOLOGICAL CONTACTOR IN A TILAPIA RECIRCULATING AQUACULTURE SYSTEM
Brian L. Brazil
Aquacultural Engineering 34(3): 261-274
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
This paper describes the performance characteristics of an industrial-scale air-driven rotating biological contactor (RBC) installed in a recirculating aquaculture system (RAS) rearing tilapia at 28 °C. This three-staged RBC system was configured with stages 1 and 2 possessing approximately the same total surface area and stage 3 having approximately 25% smaller. The total surface area provided by the RBC equaled 13,380 m2. Ammonia removal efficiency averaged 31.5% per pass for all systems examined, which equated to an average (± standard deviation) total ammonia nitrogen (TAN) areal removal rate of 0.43 ± 0.16 g/m2/day. First-order ammonia removal rate (K1) constants for stages 1–3 were 2.4, 1.5, and 3.0 h−1, respectively. The nitrite first-order rate constants (K2) were

higher, averaging 16.2 h−1 for stage 1, 7.7 h−1 for stage 2, and 9.0 h−1 stage 3. Dissolved organic carbon (DOC) levels decreased an averaged 6.6% per pass across the RBC. Concurrently, increasing influent DOC concentrations decreased ammonia removal efficiency. With respect to dissolved gas conditioning, the RBC system reduced carbon dioxide concentrations approximately 39% as the water flowed through the vessel. The cumulative feed burden – describes the mass of food delivered to the system per unit volume of freshwater added to the system daily – ranged between 5.5 and 7.3 kg feed/m3 of freshwater; however, there was no detectable relationship between the feed loading rate and ammonia oxidation performance.
(USDA-Agricultural Research Service, National Center for Cool and Cold Water Aquaculture, Kearneysville, WV 25430, USA; email of B. Brazil: bbrazil@ncccwa.ars.usda.gov)

DESIGN AND MANAGEMENT OF CONVENTIONAL FLUIDIZED-SAND BIOFILTERS
Steven T. Summerfelt-2006
Aquacultural Engineering 34(3): 275-302
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Fluidized-sand beds are an efficient, relatively compact, and cost-competitive technology for removing dissolved wastes from recirculating aquaculture systems, especially in relatively cool or coldwater applications that require maintaining consistently low levels of ammonia and nitrite. This paper describes several types of flow injection mechanisms used in commercial fluidized-sand biofilters and provides criteria for design of flow distribution mechanisms at the bottom of the fluidized bed. This paper also summarizes the most critical aspects of sand selection, as well as methods for calculating or experimentally measuring fluidization velocities and pressure drop for a given filter sand size distribution. Estimates of nitrification rate, ammonia removal efficiency, carbon dioxide production, and oxygen consumption across fluidized-sand biofilters are also provided for various conditions. Fluidized-sand biofilter operational and management practices are also described.
(The Conservation Fund Freshwater Institute, 1098 Turner Road, Shepherdstown, WV 25443, USA; s.summerfelt@freshwaterinstitute.org)

DESIGN AND OPERATIONS OF FINE MEDIA FLUIDIZED BED BIOFILTERS FOR MEETING OLIGOTROPHIC WATER REQUIREMENTS
Dallas E. Weaver-2006
Aquacultural Engineering 34(3): 303-310
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Fine media fluidized bed biofilters (FBB) have some unique characteristics, which become very important when extremely high water quality is required. They provide greater surface area per unit volume than other fixed film biofilters and are capable of operating as a plug flow on the liquid phase and mixed flow on the biological phase type reactor. As the concentration of pollutants decreases in an aquaculture system, the removal rate per unit surface area in a biofilter decreases, hence being able to obtain very high surface areas per unit cost becomes critical. As the concentration further decreases, conventional bioreactors that are either, mixed flow biological phase and mixed flow liquid phase (i.e. moving bed type reactor), or plug flow liquid and fixed biological phase (trickling filter or submerged filter) reach the minimum substrate concentration (SMin), below which the bacteria cannot grow under steady state conditions. However, in a fine media FBB the discharge concentration can be below SMin. This allows filters to be designed and operated in commercial aquaculture settings with over 90% removal of NH3, and related biochemical oxygen demand (BOD) per pass. Fine media FBBs can be designed and operated for biological removal of 99.95% of slow biodegrading refractory organic pollutants like methyl tertiary butyl ether (MTBE) in a single pass with discharge concentrations <1 ppb (inlet 2000 ppb, 20 min contact time, SMin = 20 ppb). The details of how and

why these high performances at low concentrations are possible and why this oligotrophic water quality is desirable for maturation and larva rearing will be discussed.
(Scientific Hatcheries, 8152 Evelyn Cr., Huntington Beach, CA 92646, USA; Deweaver@surfcity.net)

NITRIFICATION PERFORMANCE OF A PROPELLER-WASHED BEAD CLARIFIER SUPPORTING A FLUIDIZED SAND BIOFILTER IN A RECIRCULATING WARMWATER FISH SYSTEM
Tim Pfeiffer, Ron Malone-2006
Aquacultural Engineering 34(3): 311-321
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
A propeller-wash bead filter (PWBF) and a fluidized sand filter (FSF) on a 28 m3 recirculating system stocked with tilapia maintained favorable water quality at five different feed rates, ranging from 0.9 to 4.5 kg feed per day. TAN removal rates ranged up to about 200 g TAN/m3 of media per day for each of the units. Peak rates of 244 g TAN/m3 of media per day were observed when the recirculating flow was boosted by 20%. Roughly 75% of the removal was accomplished by the fluidized sand filter an observation that is consistent with the difference between the fluidized sand filter volume (0.92 m3) and the bead filter media volume (0.28 m3). The bead filter's primary function was clarification. At the highest daily feed load, over 570 g dry weight of solids were removed during each daily bead filter backwashing event. A 20% increase in flow, at the same daily feed rate, improved solids removal to over 670 g dry weight per bead filter backwash event. The PWBF and FSF combination provided suitable water quality for fish production; however, further increases in feed loading were limited by carbon dioxide buildup and oxygen limitations.
(USDA Agricultural Research Service, Sustainable Marine Aquaculture Systems, 5600 U.S. Highway 1 North, Fort Pierce, FL 34946, USA; email of Tim Pfeiffer: tpfeiffer@spa.ars.usda.gov)

DESIGN AND OPERATIONS OF THE KALDNES MOVING BED BIOFILM REACTORS
Bjorn Rusten, Bjørnar Eikebrokk, Yngve Ulgenes, Eivind Lygren-2006
Aquacultural Engineering 34(3): 322-331
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
The moving bed biofilm reactor (MBBR) was developed in Norway in the late 1980s and early 1990s. It is covered by several patents and has been a huge success world-wide for treatment of municipal and industrial wastewaters. In addition, MBBRs have been successfully used for biological treatment of drinking water as well as for water treatment in fish farms. The MBBRs use plastic biofilm carriers of a unique design, to maximize the active biofilm surface area in the reactors. Reactors have insignificant headloss, no need for periodic backwashing and no susceptibility for clogging. This paper describes the fundamentals of the MBBR. It has a major emphasis on nitrification with the type of biofilm carrier used in fish farms, but briefly touches upon removal of organic matter and denitrification. Major factors influencing the nitrification rates in MBBRs are discussed in detail. Results from small-scale MBBR tests, as well as from commercially operated MBBRs at full scale fish farms are presented. The data are from both freshwater and marine applications.
(Aquateam—Norwegian Water Technology Centre, P.O. Box 6875, Rodelokka, N-0504 Oslo, Norway; email of Bjorn Rusten: bjorn.rusten@aquateam.no)

APPLICATION OF MICROBEAD BIOLOGICAL FILTERS
Michael B. Timmons, John L. Holder, James M. Ebeling-2006

Aquacultural Engineering 34(3): 332-343
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
The application of floating microbead filters to aquaculture is reviewed and discussed. The microbead filter is distinctly different from the more commonly used floating bead filters that are used today. Conventional bead filters work in pressured vessels and use a media that is only slightly buoyant. The required mass of beads for the volume required make the media a relatively expensive component of a floating bead filter in contrast to sand or microbead media that is much less expensive on a per volume basis. Microbead filters use polystyrene beads (microbead) that are 1–3 mm in diameter (floating bead filters use media approximately 3 mm in diameter also). Microbead have an overall bulk density of 16 kg/m3 and a specific surface area of 3936 m2/m3 (for 1 mm beads). This material can be obtained commercially in bulk for roughly US$ 4 kg−1 of material. Biological filters that use microbeads for their nitrifying substrate can be thought of as a trickling bio-filter in terms of how the flow distribution and collection mechanics are designed and operated. For design purposes, microbead filters can be assumed to nitrify approximately 1.2 kg of TAN/m3 of media per day for warm water systems with influent ammonia–nitrogen levels from 2 to 3 mg/l. For cool water applications, rates should be assumed to be 50% of warm water rates or use rates similar to those used for fluidized sand beds. Designs and results in several applications are presented. Microbead filters have been used successfully by several commercial growers after being first introduced in the mid 1990s. Effects of capitalization for equipment and buildings upon production costs is discussed and presented in graphical form.
(Biological & Environmental Engineering, Cornell University, Ithaca, NY 14853, USA; email of Michael B. Timmons:mbt3@cornell.edu)

PHOTOSYNTHETIC SUSPENDED-GROWTH SYSTEMS IN AQUACULTURE
John A. Hargreaves-2006
Aquacultural Engineering 34(3): 344-363
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Standardized evaluation and rating of biofilters for aquaculture should be assessed in the context of the economic efficiency of ecological services (waste assimilation, nutrient recycling, and internal food production) provided by earthen ponds, and the availability and cost of land, water, and electrical energy resources required to support particular classes of production systems. In photosynthetic suspended-growth systems, water quality control is achieved by a combination of natural and mechanical processes. Natural processes include photosynthesis of oxygen, algal nutrient uptake, coupled nitrification–denitrification, and organic matter oxidation; mechanical processes include aeration and water circulation. Ammonia is controlled by a combination of phytoplankton uptake, nitrification, and immobilization by bacteria. Unlike biofilters for recirculating aquaculture systems, unit processes are combined and are an integral part of the culture unit. The important design and operational considerations for photosynthetic suspended-growth systems include temperature effects, aeration and mixing, quantity and quality of loaded organic matter, and fish water quality tolerance limits. The principle advantages of photosynthetic suspended-growth systems are lower capital costs relative to other recirculating aquaculture systems and increased control over stock management relative to conventional static ponds. The main disadvantage is the relatively low degree of control over water quality and phytoplankton density, metabolism, and community composition relative to other recirculating aquaculture systems. Examples of photosynthetic suspended-growth systems include semi-intensive ponds, intensively aerated outdoor lined ponds, combined intensive–extensive ponds, partitioned aquaculture systems, greenwater tanks, greenwater tanks with solids removal, and greenwater recirculating aquaculture systems.
(Louisiana State University Agricultural Center, Aquaculture Research Station, 2410 Ben Hur Road, Baton Rouge, LA 70808, USA; jhargreaves@agcenter.lsu.edu)

DENITRIFICATION IN RECIRCULATING SYSTEMS: THEORY AND APPLICATIONS
Jaap van Rijn, Yossi Tal, Harold J. Schreier-2006
Aquacultural Engineering 34(3): 364-376
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
Profitability of recirculating systems depends in part on the ability to manage nutrient wastes. Nitrogenous wastes in these systems can be eliminated through nitrifying and denitrifying biofilters. While nitrifying filters are incorporated in most recirculating systems according to well-established protocols, denitrifying filters are still under development. By means of denitrification, oxidized inorganic nitrogen compounds, such as nitrite and nitrate are reduced to elemental nitrogen (N2). The process is conducted by facultative anaerobic microorganisms with electron donors derived from either organic (heterotrophic denitrification) or inorganic sources (autotrophic denitrification). In recirculating systems and traditional wastewater treatment plants, heterotrophic denitrification often is applied using external electron and carbon donors (e.g. carbohydrates, organic alcohols) or endogenous organic donors originating from the waste. In addition to nitrate removal, denitrifying organisms are associated with other processes relevant to water quality control in aquaculture systems. Denitrification raises the alkalinity and, hence, replenishes some of the inorganic carbon lost through nitrification. Organic carbon discharge from recirculating systems is reduced when endogenous carbon sources originating from the fish waste are used to fuel denitrification. In addition to the carbon cycle, denitrifiers also are associated with sulfur and phosphorus cycles in recirculating systems. Orthophosphate uptake by some denitrifiers takes place in excess of their metabolic requirements and may result in a considerable reduction of orthophosphate from the culture water. Finally, autotrophic denitrifiers may prevent the accumulation of toxic sulfide resulting from sulfate reduction in marine recirculating systems. Information on nitrate removal in recirculating systems is limited to studies with small-scale experimental systems. Packed bed reactors supplemented with external carbon sources are used most widely for nitrate removal in these systems. Although studies on the application of denitrification in freshwater and marine recirculating systems were initiated some thirty years ago, a unifying concept for the design and operation of denitrifying biofilters in recirculating systems is lacking.
(Department of Animal Sciences, Faculty of Agricultural, Food and Environmental Quality Sciences, The Hebrew University of Jerusalem, P.O. Box 12, Rehovot 76100, Israel; email of Jaap van Rijn: vanrijn@agri.huji.ac.il)

REPORTING STANDARDS FOR BIOFILTER PERFORMANCE STUDIES
John Colt, Jonathan Lamoureux, Richard Patterson, Gary Rogers-2006
Aquacultural Engineering 34(3): 377-388
Design and Selection of Biological Filters for Freshwater and Marine Applications
Abstract:
The development of standardized rating and design procedures for biological filters will require that filter performance be evaluated and reported in a standardized manner. This article recommends draft reporting standards for biofilter performance studies. It is important that critical parameters are defined and reported in a standard manner, both in terms of definition, variable names, and units. Depending on the type and scale of an experiment, reporting of certain parameters will be either mandatory or optional. Basic principles of experimental design, statistical analysis, and randomization must be followed. Experimental protocols are recommended to ensure the accuracy of measured or computed parameters. The development of this reporting standard is being organized through the Standards and Reporting Committee of the Aquaculture Engineering Society (AES). It is anticipated that a revised version of these standards will be incorporated into the Guide to Authors for Aquacultural Engineering.
(Northwest Fisheries Science Center, National Marine Fisheries Service, 2725 Montlake Blvd. East, Seattle, WA 98112-2097, USA; email of John Colt: john.colt@noaa.gov)

RATING FIXED FILM NITRIFYING BIOFILTERS USED IN RECIRCULATING AQUACULTURE SYSTEMS

Ronald F. Malone, Timothy J. Pfeiffer-2006

Aquacultural Engineering 34(3): 389-402
Design and Selection of Biological Filters for Freshwater and Marine Applications

Abstract:
Predicting the performance of biofilters is an engineering challenge that is critical to both designers and managers. The task is complicated by the wide variety of water quality expectations and environmental conditions displayed by a recirculating aquaculture system (RAS). A myriad of biofilters designs have been generated reflecting approaches of engineers attempting to maximize specific surface area and oxygen transfer within the context of a biofilm management strategy. A rating strategy is presented for biofilters to facilitate the identification of appropriate matches between biofiltration formats and RAS applications. As a foundation, a previously proposed RAS classification system based upon salinity, temperature and trophic levels is upgraded to create 17 systems classifications. A biofilter classification system identifies seven combinations of trophic level and pH which should be sufficient to serve the RAS demands. Temperature and salinity are neglected as a means of simplifying the approach. An experimental methodology based upon chemical feeds is proposed to represent the steady-state RAS performance of the biofilters. Data is summarized by linear analysis of filter performance for concentration ranges below 1.0 g TAN m−3 and simple averaging is proposed for higher trophic levels. Input from the aquacultural engineering community and RAS aquaculturists is required to further refine the approach prior to endorsement.

(Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803, USA; email of R. Malone: rmalone@lsu.edu)

STANDARDIZED EVALUATION AND RATING OF BIOFILTERS. II. MANUFACTURER'S AND USER'S PERSPECTIVE

Douglas G. Drennan II, K.C. Hosler, , Mark Francis, Dallas Weaver, Ed Aneshansley, Gregory Beckman, Chandler H. Johnson, Chad M. Cristina-2006

Aquacultural Engineering 34(3): 403-416
Design and Selection of Biological Filters for Freshwater and Marine Applications

Abstract:
As manufacturers of biofilters we feel that it is important that our customers have a standardized set of criteria that can be used to compare the many different commercially available biofilters on the market today. The purpose of this paper is to show how a variety of manufacturers size their own filters, establish commonalities between the methods and suggest, to the engineering community, the needs of the industry that are required to develop a uniform sizing criteria. Similarities in sizing methodologies include standard information supplied by the consumer (system volume, feed rate, etc.) as well as those estimated by the manufacturer (TAN production, and hydraulic requirements). Differences in sizing methodology include the use of in situ nitrification and system flushing. From the various examples of biofilter sizing, it is clear that manufacturers use a sizing methodology based on either an areal or volumetric TAN conversion rate (ATR or VTR). As manufacturers, we should be able to publish ATR or VTR for each of three trophic levels (oligotrophic, mesotrophic and eutrophic) with appropriate correction factors for water temperature and salinity. A standardized labeling system that would allow system designers to accurately and rapidly determine which biofilter(s) meet their needs is proposed. We leave it to the engineering community to devise a standardized scheme by which VTR values could be determined to facilitate this comparison.

(Aquaculture Systems Technologies, LLC & Aquaculture Supply, LLC, New Orleans, LA 70121, USA; email of Douglas G. Drennan: Douglas@beadfilters.com)

SPAWNING INDUCTION IN KUTUM RUTILUS FRISII KUTUM (KAMENSKII, 1901) USING CARP PITUITARY EXTRACT OR GNRH ANALOGUE COMBINED WITH METOCLOPRAMIDE

Salar Dorafshan, Fatemeh Paykan Heyrati-2006

Aquaculture Research 37(8):

Abstract:

Kutum Rutilus frisii kutum (Kamenskii, 1901), Cyprinidae is an endemic fish of the Caspian Sea. Iranian Fisheries Organization (Shilat) produce up to 200 million fry (1–2 g body weight (b.w.)) to restock the Caspian Sea population annually. Some of these fry are produced by spawning induction in broodfish by carp pituitary extract (CPE). The objective of this study was to assay the effectiveness of the gonadotropin releasing hormone analogue (d-Ala6, Pro9-Net GnRH) alone or in combination with metoclopramide (MET), a dopamine antagonist, on the percentage of ovulated females, latency period, ovulation index and fertilization success. The following hormone treatments were tested: single injection of 2 mg kg1 b.w. of CPE as a positive control, GnRHa alone 20 and 40 μg kg1 b.w. and combination of GnRHa and MET as follows: 5 μg+2.5 mg, 10 μg+ 5 mg and 20 μg+10 mg kg1 b.w. Negative control group was injected with 0.7% saline. The percentage of ovulated females, ovulation index and fertilization success were 90%, 71.3±1.24%, 68.4±2.3%, respectively, in the group treated with GnRHa+MET at a dose of 20 μg+10 mg kg1 b.w. and were significantly higher than those in the positive control (60%, 64.5±0.23%, 69.1±4.5%) ($P<0.05$). However, the latency period in this group was longer than that in the positive control ($P<0.05$). Only 20% and 40% fish ovulated in groups that received 20 or 40 μg kg1 b.w. GnRHa. No fish ovulated in the negative control.

(Department of Fisheries, College of Natural Resources and Marine Sciences, Tarbiat Modarres University, Noor, 46414-356, Mazandaran, Iran; email of S Dorafshan: dorafshan@modares.ac.ir)

BIOCHEMICAL AND TECHNICAL OBSERVATIONS SUPPORTING THE USE OF COPEPODS AS LIVE FEED ORGANISMS IN MARINE LARVICULTURE

Guillaume Drillet, Niels O G Jørgensen, Thomas F Sørensen, Hans Ramløv, Benni W Hansen-2006

Aquaculture Research 37(8): 756

Abstract:

The use of live prey is still necessary for a large number of raised fish species. Small sized rotifers are usually used as live preys during the first days of feeding in small mouth fish. An alternative to this is the use of copepods as prey for first feeding. In this study, the sizes, weight and biochemical contents of two copepods and one rotifer species raised on similar algal food conditions were compared. Rotifers contained a higher proportion of essential amino acids in the free amino acid (FAA) fraction (43%) than copepods (30–32%). However, rotifers had lower levels of important fatty acids like DHA (7% compared with 23–32% in copepods) and their DHA/EPA ratio was lower than that in copepods (0.54 compared with 1.35–1.63 in copepods). The FAA pattern of the preys tended to be species-specific and its implications from an aquaculture point of view is discussed. In contrast, the-protein bound amino acids tended to be very conservative among the studied organisms. The second part of the work is focused on 'the price' of hatching in Acartia tonsa eggs before or after cold storage at 3°C. The fatty acid contents in A. tonsa tended to decrease with the storage time. It also decreased with hatching of the nauplii, but its proportion compared with the dry weight remained constant.

(Department of Life Sciences and Chemistry, Roskilde University, Universitetsvej 1, PO Box 260, DK-4000, Roskilde, Denmark; email of B W Hansen bhansen@ruc.dk)

USE OF BIOMASS OF THE MARINE MICROALGA ISOCHRYSIS GALBANA IN THE NUTRITION OF GOLDFISH (CARASSIUS AURATUS) LARVAE AS SOURCE OF PROTEIN AND VITAMINS

Paula Coutinho, Paulo Rema, Ana Otero, Oscar Pereira, Jaime Fábregas-2006

Aquaculture Research 37(8): 793-

Abstract:
The effect of the replacement of fish protein hidrolizate and vitamin premix by freeze-dried biomass of the marine microalga Isochrysis galbana in the feed for goldfish (Carassius auratus) larvae was tested. Larvae (3.4±0.7 mg) were fed with three experimental microparticulated diets that differ from each other in the percentage of replacement of fish protein hidrolizate (25% or 100%) or vitamin premix by I. galbana biomass. The control diet and the diet containing microalgae biomass as a substitute of 25% of fish protein hidrolizate (MP25) presented the highest survival, being almost 100%, with no significant differences between them. Survival in diets in which 100% of fish protein hidrolizate (MP100) or vitamin premix (MV) had been substituted by microalgal biomass was 78% and 66% respectively. Growth, measured as weight, was lower than with the control diet in all treatments in which microalgal biomass was included, with lowest results being obtained with the MP100 diet. Differences between treatments and control were lower when growth was measured as length. The harvesting and processing microalgae biomass is crucial to maintain the nutritive value and could be the cause for the obtained results.
(Departamento de Microbiología y Parasitología, Facultad de Farmacia, University of Santiago de Compostela, 15782 Santiago de Compostela, Spain; email of P Coutinho: coutinho@usc.es)

EFFECTS OF ASCORBIC ACID ENRICHMENT BY IMMERSION OF RAINBOW TROUT (ONCORHYNCHUS MYKISS, WALBAUM 1792) EGGS AND EMBRYOS
Bahram Falahatkar,, Konrad Dabrowski, Murat Arslan, Jacques Rinchard-2006
Aquaculture Research 37(8): 834
Abstract:
This study was conducted to examine the effects of different forms and concentrations of ascorbic acid (vitamin C), and different enrichment times (24 and 48 h post ovulation) on egg, embryo and alevin ascorbate concentrations and survival of rainbow trout (enrichment was at the ova stage). In experiments 1 and 2, fertilized eggs were immersed in water containing ascorbate at 0 (control), 100, 1000 mg L1 l-ascorbic acid (AA) and 2000 mg L1 l-ascorbyl monophosphate (AP). In experiment 3, 0 (control), 500 and 1000 mg L1 AA neutralized (N) with NaOH, 1000 mg L1 AA non-neutralized (NN), 1000 and 2000 mg L1 AP immersions were used. The mean total ascorbic acid (TAA) and dehydroascorbic acid (DHA) concentrations were measured before fertilization, at 3 and 24 h after fertilization, at the eyed stage, and in hatched alevins. We observed significant differences in TAA concentration at different immersion levels at 3 and 24 h after fertilization. Survival decreased significantly depending on the level of vitamin C, pH of the solutions and immersion time. We suggest that when broodstock rainbow trout do not have enough vitamin C in their ovaries, immersion of eggs in 1000 mg L1 of neutralized AA may be useful.
(The School of Environment and Natural Resources, The Ohio State University, Columbus, OH 43210, USA; email of K Dabrowski: dabrowski.1@osu.edu)
