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Biological filters in aquaculture: Trends and research directions for freshwater and marine applications

Maria Teresa Gutierrez-Wing, Ronald F. Malone *

Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA 70803, USA

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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.

Keywords: Aquaculture; Biofilters; Recirculation; Nitrification

1. Introduction

Over the last two decades, aquaculture has gone through major changes, growing from small-scale homestead-level activities to large-scale commercial farming, exceeding landings from capture fisheries in many areas (National Research Council, 1992; NACA/FAO, 2001). While output from capture fisheries grew at annual average rate of 1.2%, output from aquaculture (excluding aquatic plants) grew at a rate of 9.1%. The latter is a faster rate than any other animal food producing systems such as fisheries and terrestrial farmed meat (FAO, 2003). This growth is expected to continue as the population grows and the per capita consumption of seafood increases while

* Corresponding author. Tel.: +1 225 5788666; fax: +1 225 7675233.
E-mail addresses: mgutie@lsu.edu (M.T. Gutierrez-Wing), rmalone@lsu.edu (R.F. Malone).

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other protein sources consumption decreases. As an example, fish consumption per capita increased 24% from 1970 to 1998, legumes increased 13% as egg and meat consumption had a net decrease (USDA/ERS, 1999).

The need to increase aquacultural production is driving the industry toward more intensive practices. Some of the factors that influence this trend are: limitations in quality and quantity of water, availability and cost of land, limitations on water discharges and environmental impacts. Recirculating technologies help minimize these issues. A recirculating aquaculture facility reduces water demands and discharges by reconditioning of water (Goldburg et al., 2001). Better food conversions are achievable with a recirculating aquaculture system (RAS) which means less waste is generated by the feed (Lorsordo et al., 1998). In recent years, there has been a growing concern over the impacts of aquaculture operations (Buschmann et al., 1996; Harache, 2002; Naylor et al., 2000; Cranford et al., 2003; Johnson et al., 2004). It is estimated that 85% of phosphorus, 80–88% of carbon, 52–95% of nitrogen (Wu, 1995) and 60% of mass feed input in aquaculture will end up as particulate matter, dissolved chemicals, or gases (Masser et al., 1999). Increasing regulatory pressure focusing on discharges to natural water bodies will force producers to adopt methods that are environmentally friendlier (White et al., 2004). RAS technology can reduce the effluent waste stream by a factor of 500–1000 (Chen et al., 1997; Timmons et al., 2001). Thus, recirculating technologies may allow existing operations to upgrade and expand and comply with future regulations.

Recirculating systems have been identified as one of the two main research areas in aquaculture (NOAA, 2001) and one of the proposed research areas for the European Union (Martin, 2002). The most prominent characteristic of these production systems is the presence of a biofilter, which reflects a commitment to internally treat water contaminated by dissolved organics and ammonia rather than discharge them, as in the case of net-pens and flow-through systems, or to treat them extensively as in the case of pond production. This paper reviews the implications of the changing use of recirculating systems on biofiltration technologies for freshwater and marine systems with the intention of assisting researchers and biotechnologists in selection of research topics.

2. Freshwater

The feasibility of raising freshwater species to market size in recirculating systems has been demonstrated (Broussard and Simco, 1976; Buckling et al., 1993). RAS systems have the advantage of temperature control which opens the door for year around production (Lazur and Britt, 1997; Funge-Smith and Phillips, 2001). Recirculation can be an economic alternative when energy costs associated with temperature control and pumping requirements are otherwise high. Buckling et al. (1993) working in an ornamental fish production facility calculated that the average RAS savings in energy for heating and pumping was US$ 0.96 per pound of fish produced. Seasonality of tilapia production from southern ponds was a major factor encouraging the development of RAS tilapia production in the United States. The catfish and eel production facilities found in the Netherlands also exist, in part, because of the heating advantages presented by RAS systems (Bovendeur et al., 1987; Kamstra et al., 1998).

Water use issues are also rapidly becoming a strong factor driving the adoption of recirculating technologies. Varadi (2000) discusses the increasing pressures being placed upon the world's freshwater supplies. Major recirculating developments being undertaken in support of hybrid striped bass production in the deserts of California in the western United States (Carlberg et al., 2003) and similar work in Israel are being driven by underlying water resource issues (Barak and van Rijn, 2000). Additionally, urbanization brings with it increased water use demands. The ornamental fish industry in relatively wet Florida is experiencing severe water use restrictions as a result of the population growth in the Orlando-Tamps area. Asano et al. (2003) describes an even more severe water resource threat to Hawaii's ornamental fish industry which is prompting an examination of RAS technologies. Likewise, water use and the underlying competition with urban areas for this limited resource has driven a major recirculating thrust supporting cold water production in the Northeast regions of the United States (Heinen et al., 1996). Schuster and Stelz (1998) also frame their description of cold water trout recirculation designs in terms of water conservation. Water resource limitations increasingly are becoming a major factor in prompting RAS adoption.