Innovative use of intermediate bulk containers as fluidized bed biofilters in a recirculating aquaculture system

Elizabeth A. Kastl[1], Brian Fletcher[2], Cody Treft[2], Jill M. Voorhees[3*], Michael E. Barnes[3]

[1]Department of Engineering, Benedictine College, USA
[2]Department of Game, Fish and Parks, Cleghorn Springs State Fish Hatchery, USA
[3]Department of Game, Fish, and Parks, McNenny State Fish Hatchery, USA

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Abstract

The increased use of Recirculating Aquaculture Systems (RAS) makes the development of cost-effective components essential. This paper describes the innovative use of widely available Intermediate Bulk Containers (IBC) as part of a fluidized bed biofilter. Four, 946.4-L IBC units, with tops removed, were filled with K1 style media to approximately 92% media-to-IBC total volume. A regenerative blower to push 2,718 L/min of air at a pressure of 12.46 kPa through two diffusers to fluidize the bed in each IBC unit. Flow rates through the entire system was 303 L/min, or approximately 75 L/min through each IBC unit. The biofilter was evaluated in two trials during rearing of larval walleye (*Sander vitreus*). Trial one included 640,000 larval walleye, temperatures ranged from 17.5°C to 23.6°C, ammonia levels reaching 0.59 mg/L, feeding rate of 12.4 kg/day, and pH of 7.5. Trial two included 480,000 larval walleye, temperatures ranged from 17.5°C to 22.5°C, ammonia levels reaching 0.70 mg/L, feeding rate of 14.9 kg/day, and pH of 7.2. Based on these results and additional rearing experiences, this Fluidized Bed Biofilter is suitable for production level rearing of fish in RAS.

Keywords: Recirculating aquaculture; RAS; Biofilters; Inexpensive

Introduction

The use of Recirculating Aquaculture Systems (RAS) to produce fish is rapidly growing worldwide [1]. In RAS, water is continually recycled, while being purified through filtration and other processes [2,3]. RAS units include mechanical filters to remove fish waste and other solids [4,5], biofilters to oxidize ammonia to nitrate [6,7], carbon dioxide strippers [8,9], equipment to add oxygen [10], heaters or coolers for temperature control [11], and ultraviolet radiation for microbial control [12,13].

Detoxification and removal of ammonia waste produced by fish is a primary concern in RAS [14]. Ammonia is toxic to fish. Even at low concentrations it causes stress, damage to gills and other tissues, decreased growth, and increased susceptibility to bacterial infections [14]. To eliminate ammonia, biofilters provide surface area for colonization by Nitrosomonas and other ammonia-oxidizing bacteria, as well as Nitrobacter and other nitrite-oxidizing bacteria [9,15]. As the water flows through the biofilters, these bacteria oxidize the ammonia first to nitrite and then from nitrite to nitrate [16]. The amount of ammonia oxidized is proportional to the surface area available for bacterial growth [17]. Bead filters and fluidized bed biofilters are the two primary types of biofilters, with the amount of ammonia oxidized proportional to the surface area available for bacterial growth [17].

Bead filters function both as mechanical filters to remove solid waste and as biofilters to convert ammonia to nitrate [15,18]. However, the solid waste in biofilters decreases oxygen availability, thereby limiting its biofiltration capabilities. Fluidized bed biofilters use aeration to create a moving bed with the media that allows unpurified water more contact with the denitrifying bacteria in a relatively-small volumetric space, as well as more oxygen availability to the bacteria [16]. Compared to 22 other filters, fluidized bed biofilters dramatically improve biofiltration effectiveness [19].

Commercially-available fluidized bed biofilters can be relatively expensive and cost-effective designs are needed. This paper describes an innovative fluidized bed biofilter system designed and fabricated at Cleghorn Springs Fish Hatchery, Rapid City, South Dakota USA.

Design

The fluidized bed biofilter system used four, 946.4-L, Intermediate Bulk Container (IBC) units (109 cm long × 107 cm wide × 105 cm high) (Figures 1 and 2). The top section of each unit was removed to allow access to the inside of the biofilter and for atmospheric gas exchange (Figure 3). Each IBC unit contained K1 style media (Global Aquaculture Supply, Vista, California USA) (Figure 4). The media-to-total-volume ratio of the units was approximately 92%. The high percentage of media-to-total-volume allowed for largest amount of media as possible to be placed within each of the IBC units to maximize the surface area for bacterial colonization. The total size of the entire fluidized bed biofilter (all four IBC combined) is approximately 2.6 m long by 3.0 m wide by 2.6 m tall.

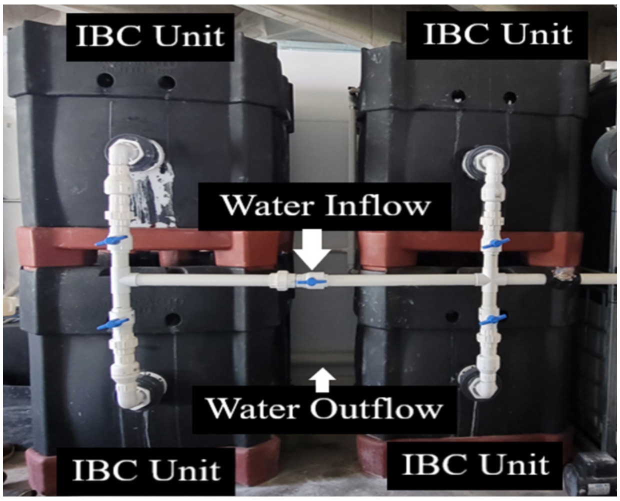


Figure 1. *Photograph of Cleghorn Springs State Fish Hatchery IBC fluidized bed filter system used in RAS for larval walleye (Sander vitreus)*

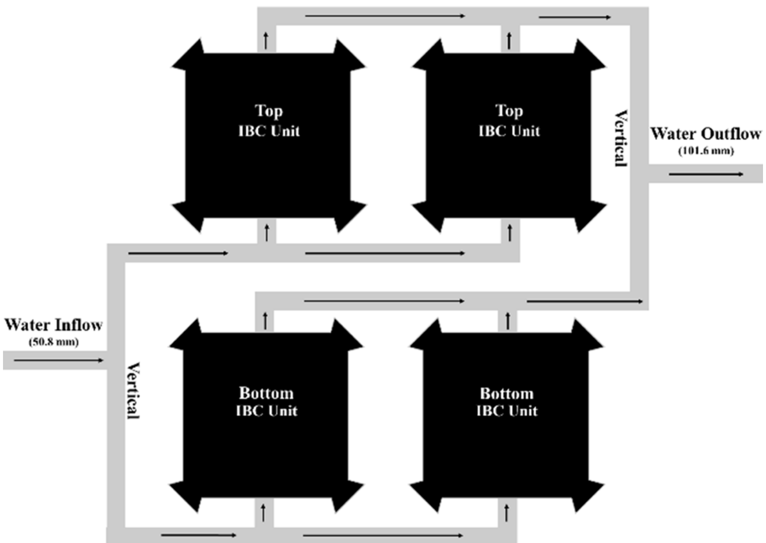


Figure 2. *Water flow diagram of IBC units fluidized bed filtration system*

Each IBC unit had two aeration devices to fluidize the bed of media. Air was blown through each of these devices by a regenerative blower at 2,718 L/min at a pressure of 12.46 kPa. The air flows to each IBC unit through a piping network (Figure 5). The air runs from the blower through 38.1 mm diameter Polyvinylchloride (PVC) pipe to an elbow which transitions to 25.4 mm suction line connected to an L-shaped 25.4 mm diameter PVC pipe before finally connecting to 19.1 mm aerators (Course Bubble Diffuser, Pure Stream Inc, Walton, Kentucky USA) stabilized with cross bars (Figure 6). Uniform mixing in the unit occurs when air blown from the aerators moves the water up through the media and out towards the walls of the IBC unit. The flow rate of air into the diffusers is adjusted using a valve to create a controlled rolling motion of the material which adequately mixes and fluidizes the bed but does not eject media and water out of the IBC units.

In the overall RAS, water from the tanks is first pumped through a mechanical drum filter and then pumped into the bottom of the IBC units. It flows upwards through the media allowing the bacteria to consume the ammonia and nitrite to form nitrate. The media is not lost in the outflow of the water due to a filter present on the outflow pipe (Figure 7). The flow rate in the entire system is approximately 303 L/min, with the flow rate into and out of each unit at approximately 75 L/min. The height of water and media in each IBC unit is approximately 737 mm.

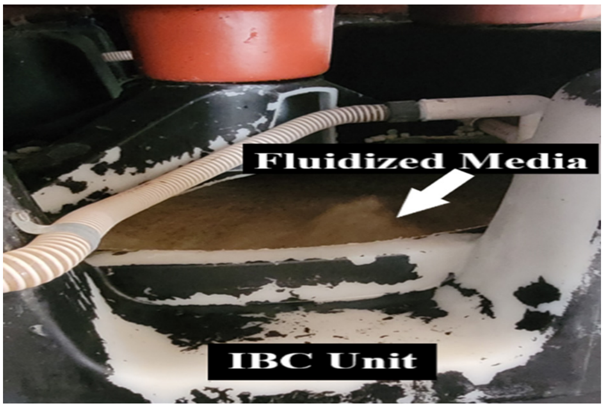
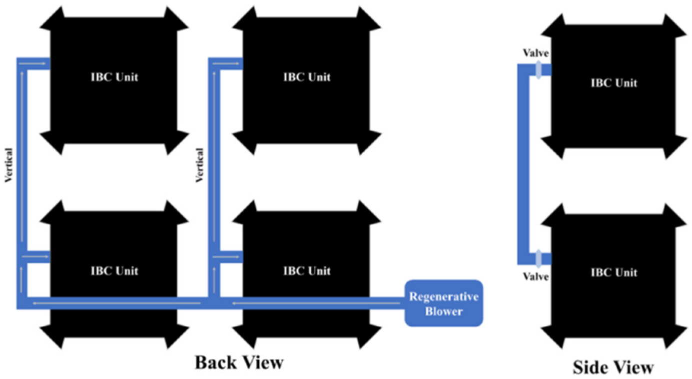


Figure 3. *IBC unit photo showing access through top for access inside of the biofilter and for atmospheric gas exchange*

Figure 4. *Photo of K1 style media used in fluidized bed biofilter system. This media allows maximum surface area for maximum bacterial growth to convert ammonia to nitrate*

Figure 5. *Diagrams of view from behind (left) and side (right) to show air flow through the IBC units fluidized bed biofilter system*



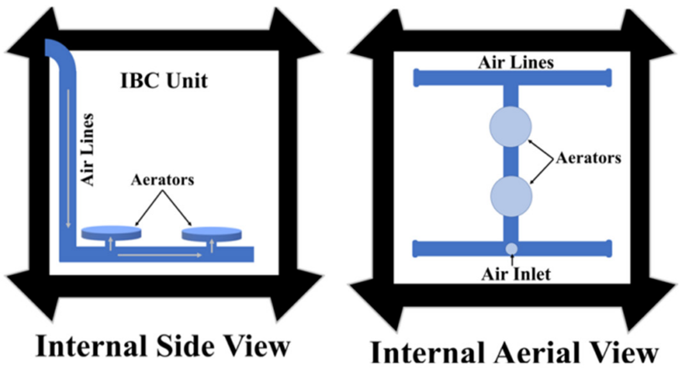


Figure 6. *Diagrams of internal side (left) and aerial (right) view of aerators used to mix media in the IBC units of the fluidized bed biofilter system*

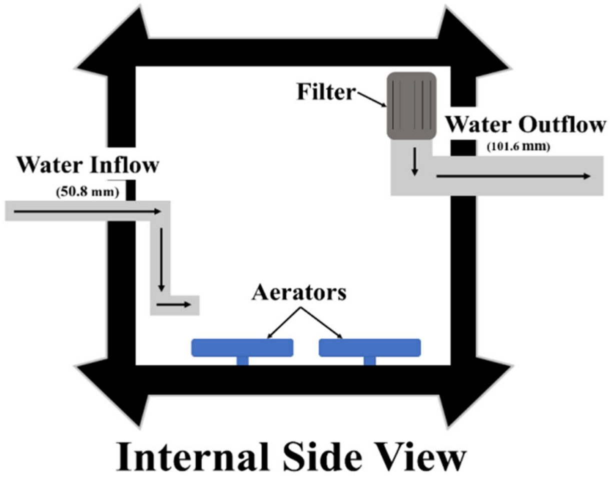


Figure 7. *Diagram of internal plumbing of IBC units in the fluidized bed biofiltration system*

Evaluation

The IBC unit fluidized bed biofilter was evaluated during two larval walleye (*Sander vitreus*) trials at Cleghorn Springs Fish Hatchery, Rapid City, South Dakota USA. The first trial initially had 640,000 walleye fry in the system at a density of 57.1 fry/L of water and had a temperature range of 17.5°C to 23.6°C. At 17 days of post-hatch the final feed ration was 12.4 kg/day, with the system reaching an ammonia level of 0.59 mg/L and a pH of 7.5 (Table 1). The second trial initially had 480,000 fry in the system at a density of 42.8 fry/L of water and had a temperature range of 17.5°C to 22.5°C. At 18 days post-hatch the final feed ration was 14.9 kg/day, with the system reaching an ammonia level of 0.702 mg/L and a pH of 7.2 (Table 2). Ammonia curves were similar for each trial (Figures 8 and 9). When pH is higher there is a greater concentration of unionized ammonia, which is more toxic, so with a decrease in pH there is more ionized ammonia in the system, which is not as toxic to fish [20].

Table 1. *Trial one temperature, daily feed amounts, ammonia, and daily average pH for 6,40,000 larval walleye (Sander vitreus) reared in a RAS using an IBC fluidized bed biofiltration system*

Days Post Hatch	Temperature (°C)	Feed Total (kg)	Ammonia (mg/L)	Average pH
1	17.5	2.56	---	7.85
2	18.05	2.56	---	7.82
3	19.17	2.56	0.097	7.8
4	19.17	2.56	---	7.62
5	19.17	2.56	---	7.6
6	19.72	3.2	0.176	7.7
7	19.72	3.52	0.152	7.58
8	19.72	5.12	0.202	7.4
9	20.28	5.76	0.233	7.15
10	21.39	6.4	0.162	7.22
11	21.94	9.28	0.281	7.31
12	21.94	9.28	0.383	7.2
13	22.5	10.54	0.356	7.38
14	22.5	12.09	0.402	7.3
15	23.06	12.09	0.536	7.46
16	23.06	11.408	0.579	7.58
17	23.61	12.4	0.59	7.5

Table 2. *Trial two temperatures, daily food amount, ammonia, and average daily pH for 4,80,000 larval walleye (Sander vitreus) reared in a RAS using an IBC fluidized bed biofiltration system*

Days Post Hatch	Temperature (°C)	Feed Total (kg)	Ammonia (mg/L)	Average pH
1	17.5	1.92	---	---
2	17.5	1.92	0.101	8.1
3	18.05	2.88	0.126	8.1
4	18.61	3.36	0.08	8.07
5	19.72	3.36	0.11	8.03
6	19.72	3.6	0.13	8
7	19.72	4.32	0.154	7.9
8	20.28	4.8	0.157	7.85
9	20.28	5.76	0.16	7.84
10	20.28	6.72	0.177	7.79
11	20.28	7.68	0.175	---
12	21.39	9.12	0.229	7.53
13	21.94	10.56	0.299	7.4
14	22.5	11.52	0.394	7.31
15	22.5	12.48	0.433	7.3
16	22.5	12.48	0.55	7.3
17	22.5	13.44	0.614	---
18	22.5	14.88	0.702	7.2

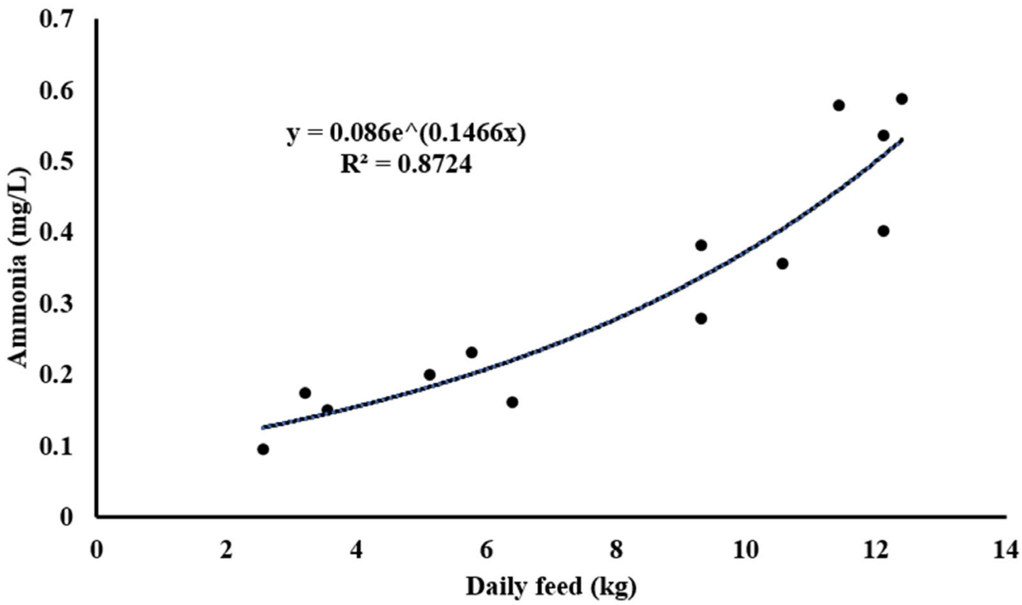


Figure 8. *Ammonia in RAS with an IBC fluidized bed biofilter in relation to the amount of food fed per day in the system while rearing 6,40,000 larval walleye (Sander vitreus)*

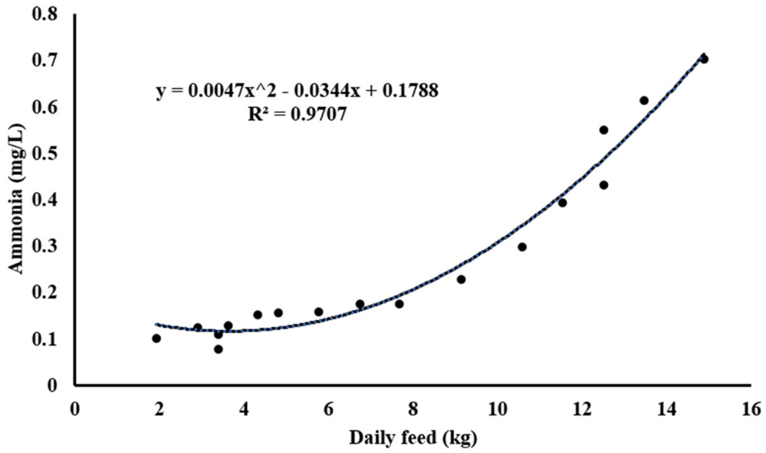


Figure 9. *Ammonia levels in RAS with an IBC fluidized bed biofilter in relation to the amount of food fed per day in the system while rearing 4,80,000 larval walleye (Sander vitreus)*

Conclusion

The denitrifying performance of the IBC fluidized bed biofilter indicates its suitability for use in RAS. In addition to being relatively inexpensive, this innovative biofilter is also relatively easy to construct and maintain. It provides a non-commercial biofilter option for smaller recirculating aquaculture systems, particularly those in use by governmental fisheries management agencies that are using RAS to produce fish for recreational or conservation needs [17,21,22].

Acknowledgement

None.

Conflict of Interest

The author declares there is no conflict of interest in publishing this article.

*Correspondence to

Jill M. Voorhees

Department of Game, Fish, and Parks,

McNenny State Fish Hatchery,

USA,

Email: jill.voorhees@state.sd.us

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