Oxygen Management at a Commercial Recirculating Aquaculture Farm producing Atlantic Salmon (*Salmo salar*) Smolts

Edward Parker, B.Sc.
M.Sc. Biology candidate
University of New Brunswick
Fredericton, NB, Canada
E3B 5A3

Michel Couturier, Ph.D.
Professor
Department of Chemical Engineering
University of New Brunswick
Fredericton, NB, Canada
E3B 5A3

Tillmann Benfey, Ph.D.
Professor
Department of Biology
University of New Brunswick
Fredericton, NB, Canada
E3B 5A3

Introduction

The effective management of dissolved oxygen (DO) levels is the most critical factor in the operation of commercial recirculating aquaculture systems. The fish, nitrifying bacteria in the biofilter, and heterotrophic bacteria that feed on the uneaten food and organic wastes all need oxygen. Close control of the DO level is critical because failure of the aeration or oxygenation system can lead to a total loss of the crop within minutes.

Atlantic salmon (*Salmo salar*) smolt production facilities are intensive aquaculture systems in which direct oxygenation must be used together with aeration to meet the oxygen demand of the fish and bacteria. However, it is crucial that oxygen gas be used efficiently because it is expensive. The commercial profitability of these systems can be improved directly through decreased oxygen expenses or indirectly through better system performance.

This paper will discuss oxygen management at a commercial freshwater recirculating aquaculture farm annually producing 400,000 Atlantic salmon smolts in New Brunswick, Canada. About 68,000 kg of pure oxygen is consumed per production cycle at this facility. The oxygen is stored in bulk on site and injected into the water by bubble diffusers and low head oxygenator (LHO) units. The level of DO in each tank is controlled by manual adjustment of the flow of injected oxygen. The objectives of this study were to determine the oxygen utilization efficiency of the system and to test the effectiveness of an automatic on/off DO control system.

System Description

A schematic of the recirculating system on which this study was done is provided in Figure 1. Before entering the settledeck, which serves as a water reservoir and sedimentation tank, the make-up water from an artesian well is ozonated and heated. Water from the settledeck is pumped to three fluidised sand-bed nitrification biofilters. After each nitrification biofilter, the water is degased by bubbling atmospheric air into the water and oxygenated by an LHO unit. The water then flows to the tank field where twenty 33 m^3 double drain tanks hold the fish. Within each tank is a bubble diffuser for adding pure oxygen into the water and an airlift pump for creating current. Most of the water exits the tanks from the middle of the water column and flows directly back to the settledeck. The remainder exits from the bottom and is treated by a swirl separator and microscreen drumfilter to remove solids before flowing back to the settledeck. Effluent water exits the recirculating system through an overflow pipe located in the settledeck and a discharge pipe located at the bottom of the swirl separator. The recirculating system operates at a 95 to 96% recirculation rate, meaning that 5% to 4%, respectively, of the system flow is exchanged during each turnover.

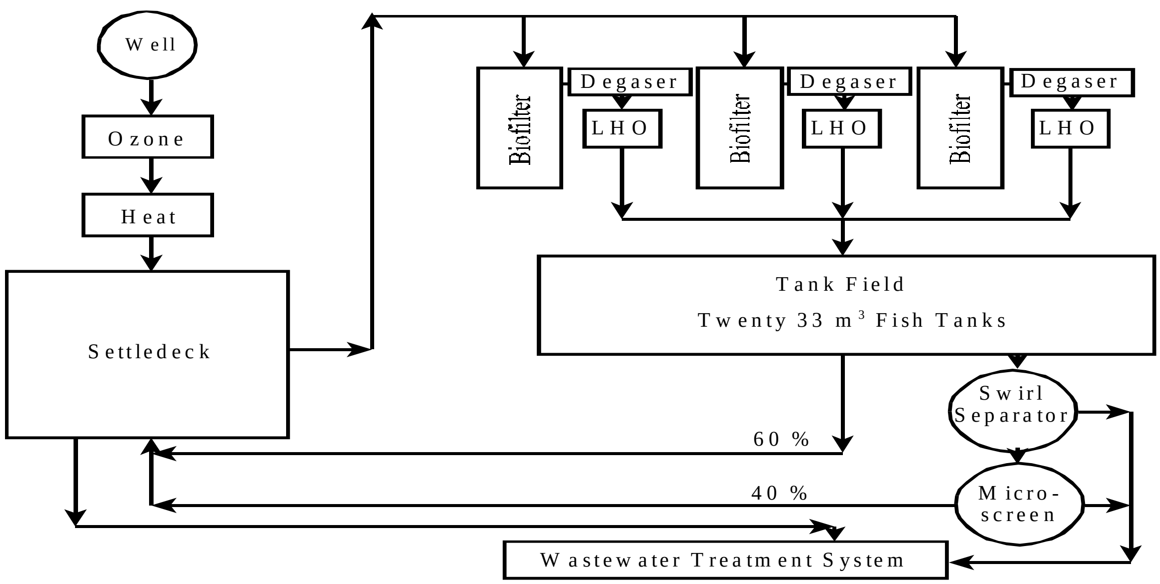

Figure 1: Layout sketch of the recirculating aquaculture system, with arrows showing direction of water flow.

Methods

The amount of DO added by the make-up water, LHO units, degasers, bubble diffusers, and settledeck, and the amount consumed by the effluent, nitrification biofilters, settledeck and fish, was obtained by performing oxygen and water mass balances at five system biomasses of 4076, 7889, 8180, 10093, and 12743 kg. The mass of DO added or consumed by each unit was obtained by multiplying the measured water flow rate by the difference between the outlet and inlet DO concentrations. The DO consumed by the fish (oxygen consumption rate) was calculated by measuring the rate of DO decrease in the fish tank while water and oxygen flow through the bubble diffusers were turned off.

The effectiveness of an automatic on/off DO control system to control fish tank DO at 100% was tested on 4 different tanks. DO levels before and during DO control were logged once a minute for 24 hours and compared.

Results and Discussion

Figure 2 shows kg DO/day added to the recirculating system by the make-up water, LHO units, degasers and bubble diffusers at the five system biomasses. Most DO was added by the bubble diffusers and LHO units, which had average absorption efficiencies of 72% and

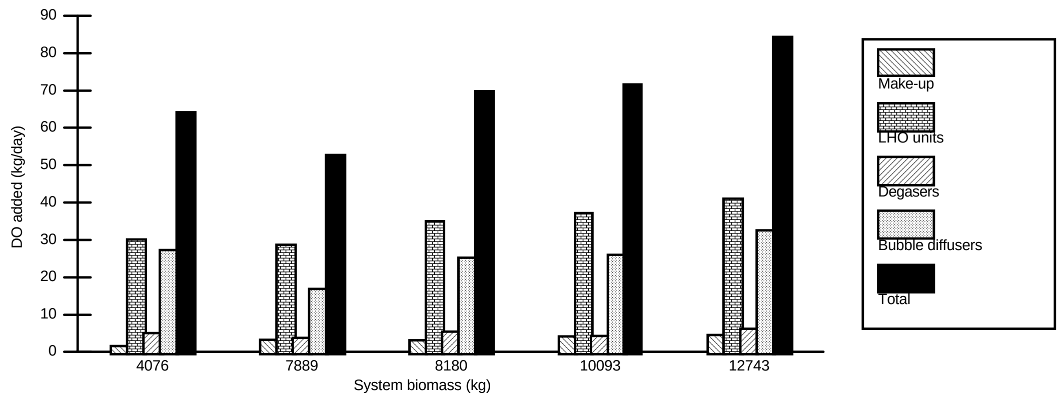

Figure 2: DO added to the recirculating system.

75%, respectively. LHO unit absorption efficiency decreased linearly with increasing gas-to-liquid ratio.

Figure 3 shows kg DO/day consumed within the recirculating system by the effluent water,

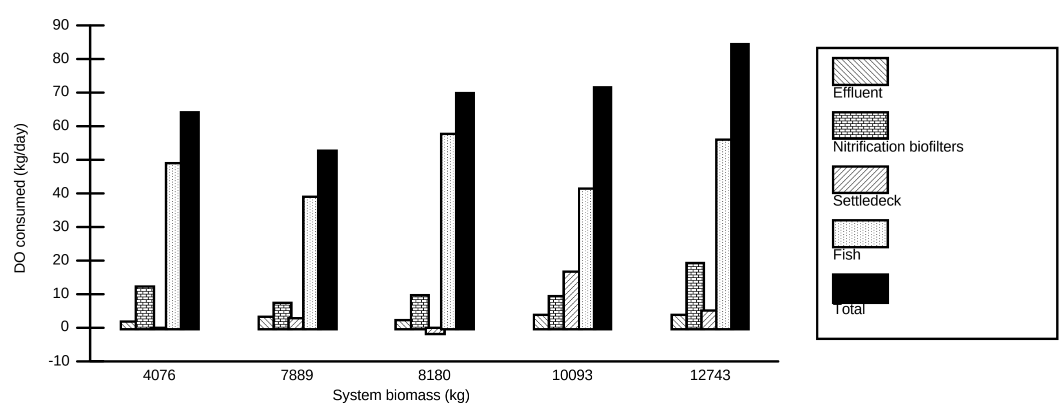

Figure 3: DO consumed by the recirculating aquaculture system.

nitrification biofilters, settledeck and fish at the five system biomasses. Most DO was consumed by the fish and nitrification biofilters. Fish DO consumption did not vary with system biomass and averaged 0.5 kg DO/kg feed (72% of the total) during daylight hours. Nitrification biofilter DO consumption averaged 0.12 kg DO/kg feed (17% of the total). However, not all of the DO consumed by the nitrification biofilters was for nitrification because an average of 6.86 kg DO were consumed/kg total ammonia-nitrogen removed in the nitrification biofilters. This is more than expected for nitrification alone.

Figure 4 shows the wide fluctuations in DO observed in fish tanks over 24 hours when oxygen flow rate through the bubble diffuser is constant. Without control or adjustment of oxygen flow through the bubble diffuser, it is continually supplying enough oxygen to meet peak DO demand throughout the day but DO concentrations rise greatly at night when fish

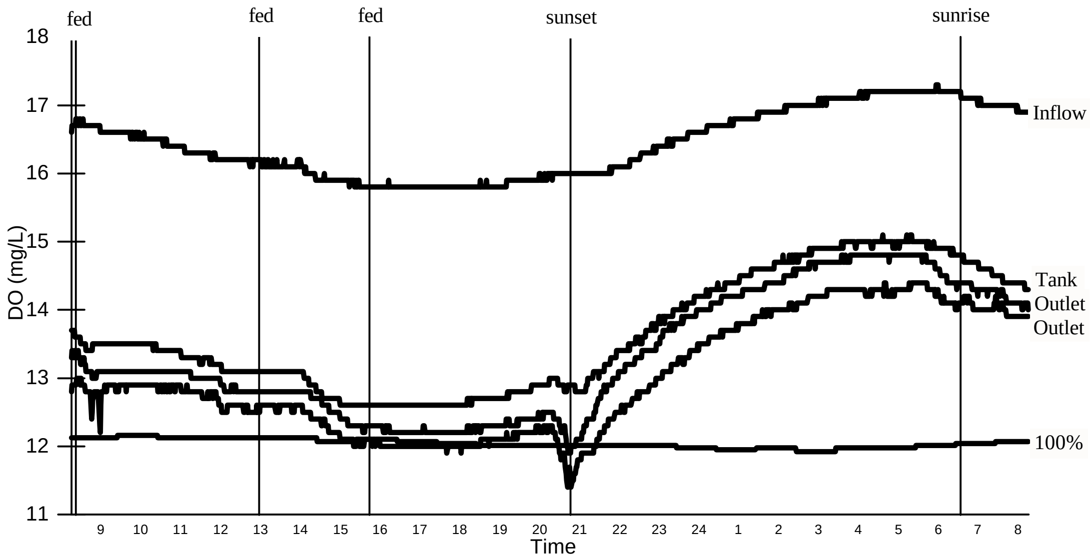

Figure 4: DO levels over 24 hours in a fish tank when oxygen addition rate is kept constant.

DO demand is least. The automatic DO control system eliminated the wide fluctuations in fish tank DO and proved to be effective at controlling it at 100%.

Conclusions

In total, an average of 26% of the pure oxygen that flowed through the LHO units and bubble diffusers at each system biomass was lost due to absorption inefficiencies. On average, 11% of the total DO consumed at each system biomass was due to processes or components other than the fish and nitrification biofilters. Fish DO consumption during daylight hours averaged 0.5 kg DO/kg feed (72% of the total). The total DO consumption for the recirculating system at each system biomass averaged 0.73 kg DO/kg feed. The automatic on/off DO control system was effective at controlling the fish tank DO at 100% saturation. Control of DO concentration at levels not exceeding 100% saturation is key in the proper management of oxygen in recirculating systems. Loss of oxygen to the atmosphere can be significant at higher concentrations.

Acknowledgments

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