

## **Water Treatment Process Efficiencies in Replicated Recirculating Systems Operated With and Without Ozonation at High and Low Flushing Rates**

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In the Americas, a number of Atlantic salmon (*Salmo salar*) smolt and rainbow trout (*Oncorhynchus mykiss*) growout systems use a type of water recirculating system (WRAS) that includes the following common components: dual-drain circular culture tanks, radial flow settlers (to treat the tank bottom-drain flow), microscreen drum filters, fluidized-sand biofilters, forced ventilated cascade aeration columns, and low head oxygenation (LHO) units. These salmonid production systems are often operated with a makeup water supply that flushes the WRAS volume approximately completely on a daily basis. These WRAS could be operated at much lower water exchange rates if heat accumulation did not create temperature problems or performance of the water treatment processes was not compromised by accumulation of fine solids. Ozonation is a process that can improve water quality (Summerfelt et al., 1997; Summerfelt, 2003; Summerfelt et al., 2009) and reduce bacterial gill disease mortalities in rainbow trout cultured in WRAS at relatively low, non-disinfecting dosages (Bullock et al., 1997). The objective of the present study was to compare the water treatment process performance measured in six replicated WRAS, three systems per treatment, operated with and without ozonation at high and low flushing rates.

### **Materials and Methods**

The study consisted of three trials. In the first trial, all RAS were operated at low flushing (makeup flow was 0.26% of the total recycled flow, exchanging the system volume once every 6.7 day); half of the systems were operated with ozonation and half of the systems without ozonation during rainbow trout growout to food-size. In the second trial, three systems were operated without ozonation at high flushing rates (makeup flow was 2.6% of the total recycled flow, exchanging the system volume once every 0.7 day) and three systems were operated with ozonation at low flushing (same as noted before). In the third trial, all six systems were operated at near-zero exchange (> 10 day system retention time), i.e., only backwash water was flushed from the system, but half of the systems operated with ozonation and half operated without ozonation. Each identical 9.5 m<sup>3</sup> system recycled 380 L/min of water, which provided a 15min exchange rate of the 5.3 m<sup>3</sup> culture tank. A process controller was used to automatically adjust O<sub>3</sub> generator output to produce tan oxidation reduction potential (ORP) in the culture tank of 250-280 mV. A 24-hr photoperiod was provided and fish were fed every 2-hrs, twelve times daily. Rainbow trout were randomly stocked, 1000 fish/system. During a one week period when fish were at maximum feed levels (6.6kg/day/tank) and densities (80kg/m<sup>3</sup>), water samples were collected across all unit processes to compare water quality and process removal efficiencies. Mean feed loading per unit of makeup water flow for all systems were approximately 0.40 kg feed per m<sup>3</sup> makeup water during high flushing conditions (trial 2), 4.0 kg/m<sup>3</sup> during low flushing conditions (trial 1 & 2), and 45 kg/m<sup>3</sup> during near

zero flushing conditions (trial 3). All tanks were fed equal portions during a two week period of intense water sampling when fish were near maximum density and feed rate.

### **Results and Discussion**

TAN removal efficiencies across the fluidized sand biofilters were significantly greater in the ozone treatments versus the no ozone treatments during trials 1 and 3, when WRAS operated at low or no flushing, respectively,  $66\pm 3\%$  and  $51\pm 2\%$  during trial 1 and  $50\pm 5\%$  and  $26\pm 5\%$  during trial 3. During trial 2, TAN removal efficiency across the biofilters was  $81\pm 8\%$  at high flushing rates (but no  $O_3$ ) and  $61\pm 7\%$  when the systems were operated with ozonation at low flushing. The biofilters, however, maintained relatively low mean TAN and nitrite nitrogen concentrations, ranging from 0.5-1.2mg/L and 0.05-0.21 mg/L, respectively, overall all conditions. TSS removal efficiencies across the radial flow clarifier and drum filter were also better in the  $O_3$  treatment than in the no  $O_3$  treatment during trials 1 and 3, when WRAS operated at low or no flushing. When ozone was applied with low flushing (trial 1 and 2) or no flushing (trial 3), TSS removal efficiency across the settler ranged from 72-81%. However, under the same conditions without ozone, TSS removal efficiency across the settlers ranged from 45-50%. TSS removal efficiency was always higher across the settler than across the microscreen filter. In addition, mean TSS removal efficiency across the drum filters were always better when  $O_3$  was applied (versus no  $O_3$ ) under conditions of low flushing (trials 1 and 2) or no flushing (trial 3). Dissolved  $CO_2$  removal efficiency across the stripping column was about the same for all conditions. Mean  $CO_2$  stripping efficiencies ranged from 40-49%, which was quite good considering that the  $CO_2$  entering the stripping column averaged only 11-12mg/L. Oxygen transfer efficiency across the LHO was near 90% for all trials.

Trial	Conditions	Constituent Removal Efficiency (Process), %			
		TAN (biofilter)	TSS (settler)	TSS (drum)	$CO_2$ (stripper)
1	6.7 day HRT, no $O_3$	$51 \pm 2$	$50 \pm 10$	$7 \pm 3$	$40 \pm 1$
1	6.7 day HRT, plus $O_3$	$66 \pm 3$	$72 \pm 2$	$25 \pm 1$	$49 \pm 5$
2	0.7 day HRT, no $O_3$	$81 \pm 8$	$85 \pm 1$	$33 \pm 3$	$43 \pm 3$
2	6.7 day HRT, plus $O_3$	$61 \pm 7$	$76 \pm 2$	$15 \pm 9$	$44 \pm 4$
3	>10 day HRT, no $O_3$	$26 \pm 5$	$45 \pm 15$	$-7 \pm 13$	$42 \pm 5$
3	>10 day HRT, plus $O_3$	$50 \pm 5$	$81 \pm 1$	$46 \pm 9$	$42 \pm 1$

### **References**

- Bullock, G. L., S. T. Summerfelt, A. Noble, A. W. Weber, M. D. Durant, and J. A. Hankins. 1997. Ozonation of a recirculating rainbow trout culture system: I. Effects on bacterial gill disease and heterotrophic bacteria. *Aquaculture* 158: 43-55.
- Summerfelt, S.T. 2003. Ozonation and UV irradiation - An introduction and examples of current applications. *Aquacultural Engineering* 28: 21-36.
- Summerfelt, S. T., J. A. Hankins, A. W. Weber, and M. D. Durant. 1997. Ozonation of a recirculating rainbow trout culture system: II. Effects on microscreen filtration and water quality. *Aquaculture* 158: 57-67.
- Summerfelt, S.T., M.J. Sharrer, S.M. Tsukuda, and M. Gearheart. 2009. Process requirements for achieving full-flow disinfection of recirculating water using ozonation and UV irradiation. *Aquacultural Engineering* 40: 17-27.