Ozone Dose and Equilibrium TOC in Recirculating Systems

Valdis Krumins, Faculty Research Associate

James Ebeling, Research Assistant

Fred Wheaton, Professor and Chair

Department of Biological Resources Engineering
University of Maryland, College Park

Introduction

Ozone is applied to recirculating aquaculture systems (RAS) for many purposes, including color and organic carbon removal. Although the interaction of ozone with organics in RAS is complex, it is suggested that ozonation decreases organic carbon concentrations by: 1) direct oxidation of organic compounds 2) coagulation of particulates into larger ones more easily removed by mechanical filtration, and 3) breaking down large, "refractory," organic molecules into more biodegradable ones.

Several authors have confirmed that ozone does decrease the amount of organic carbon in recirculating systems. Brazil *et al*, (1996) compared the water quality in systems receiving ozone to controls. While they found no significant differences in dissolved organic carbon (DOC), the ratio of DOC to cumulative feed in the treated units was significantly different from the control. Summerfelt *et al* (1997) found that ozonation reduced DOC levels by approximately 17%, although the reductions for two different ozone dosage rates were 'similar.' This report presents the progress of an experiment to quantify the decrement in organic carbon as a function of the ozone dose.

Methods

Two identical recirculating aquaculture systems were used in this experiment. Ozone was added to only one system at a time. The systems are described elsewhere (system #1, Ebeling *et al*, 1997), and consist of a 2 m^3 culture tank, 60μm rotating micro-screen filter, and 57 L (bed volume) bubble-washed bead biofilter. The water flow rate was 60-65 L/min. For the ozonation runs, an Emperor Aquatics "Atomizer" ozone contactor was installed between the screen filter and the bead filter. The systems were stocked with 54-80 kg of hybrid striped bass, weighing 270 – 560 g each. Each tank was fed 1.5% - 1% of biomass (800 g feed) daily.

Tanks were drained and cleaned at the start of each test, which ran for 28 days. Ozone was added at a rate of 0 g/d (control), 8 g/d, 12 g/d and 24 g/d (0, 10, 15 and 30 g ozone / kg feed). Water samples were collected each morning before feeding and analyzed for total organic carbon (TOC) using a Shimadzu TOC-5050A analyzer.

At this time, the control (both tanks), 8 g/d (tank 1), and 12 g/d (both tanks) experimental trials have been completed. Preliminary experiments were run on both tanks at the 24 g/d dose. However, these trials lasted 7-10 days and did not start with "clean" water. (Trials were started with a feed burden of 1.2 and 2.1 g/L in tanks 1 and 3, respectively.)

Results and Discussion

Cumulative feed burden (CFB) is a concept championed by Dr. Dallas Weaver to compare the water use efficiency among systems with different management schemes for feeding or water replacement. It is simply the weight of all of the feed ever put into the

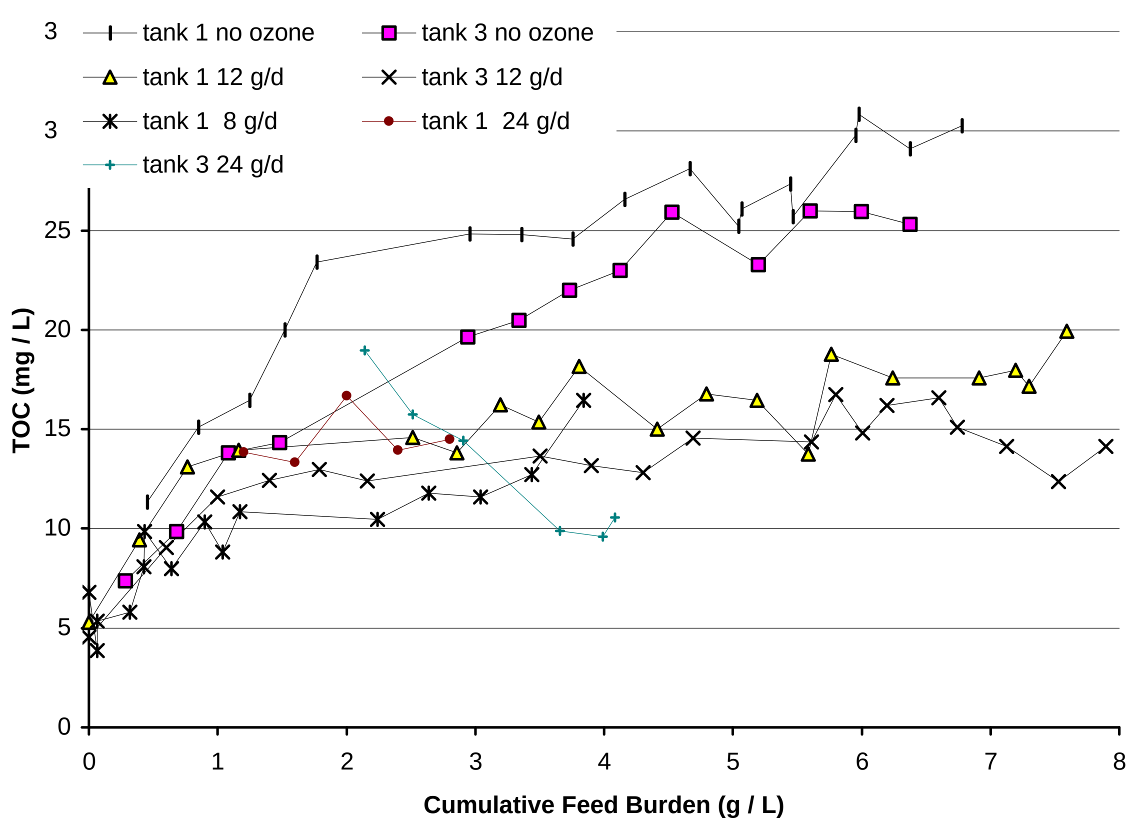

Figure 1. Total organic carbon with accumulating feed burden. Two runs (tanks 1 and 3) each for control, 12 g/d and 24 g/d ozone, only tank 1 data available for the 8 g/d run. 24 g/d runs began with "dirty" (CFB ≠ 0) water.

tank, divided by the system volume. If system water is flushed and replaced with clean water, the CFB is multiplied by $\exp(-V/V_{tot})$, where V is the volume of water replaced, and V_{tot} is the total system volume. Although CFB only truly applies to inert components of the feed (that do not break down), it can be used to model system water organic carbon, a large portion of which is resistant to biological decomposition. CFB starts at zero when the tanks are filled with clean water and freshly stocked with fish. It rises somewhat every day with feeding, and drops when the bead filters are flushed or water is otherwise exchanged. Eventually, the systems reach equilibrium, where the amount of flushed material balances the amount of feed. For systems that have been operating for a long time, CFB is the daily feed rate divided by the daily water exchange.

Figure 1 plots the morning TOC concentrations as a function of CFB. Initially, TOC concentrations rise rapidly, then appear to level off after a CFB of 2 g/L. The fact that TOC remains constant even with increasing CFB indicates that organic carbon is being removed by some mechanism other than flushing. Therefore, rather than analyzing the data as TOC/CFB (similar to Brazil *et al*, 1996), all the data collected after the CFB reaches 2 g/L are considered to be "in equilibrium," and analyzed by a two-factor ANOVA (general linear model, SAS Institute, Cary, NC). Table 1 lists the resulting average equilibrium TOC concentrations.

The ANOVA reveals that TOC is significantly ($p < 0.001$) affected by tank and ozone dose, but interaction between tank and dose is not significant. For the control, 12 and 24 g/d treatments, the average equilibrium TOC concentration in tank 3 (16.95 mg/L) is about 4 mg/L lower than in tank 1 (20.89 mg/L). (The 8 g/d replicate for tank 3 has not yet been completed; therefore, 8 g/d data are not included in the mean comparisons.) This can be seen most clearly for the control and 12 g/d runs in Figure 1, where the tank 3 curves are consistently lower than the corresponding tank 1 curves.

In both tanks, the equilibrium TOC concentration with 12 and 24 g/d ozone is significantly lower than the control, although the two dosage rates do not differ significantly from each other. For the 8 g/d trial in tank 1, the TOC was significantly lower than both the no ozone and the 12 g/d ozone dose, though not the 24 g/d rate.

Table 1. Equilibrium TOC concentration with ozone dose.

Treatment		control	8 g/d ozone	12 g/d ozone	24 g/d ozone
Tank 1 only	TOC (mg/L)	27.17[a]	12.61[b]	16.61[c]	15.04[b,c]
	n	13	5	15	3
Tank 3 only	TOC (mg/L)	23.50[a]	N/A	14.36[b]	13.19[b]
	n	9	N/A	14	6
Both tanks	TOC (mg/L)	25.67[a]	N/A	15.52[b]	13.81[b]

n – number of samples
N/A – Data not available
[a, b, c] – data in the same row not sharing a letter are significantly different at the 0.05 level.

The results show that ozonation decreases organic carbon equilibrium concentrations, but among the ozone doses investigated here, increasing ozone dose does not seem to change the final TOC. In fact, the lowest average TOC concentrations were observed with the smallest (nonzero) ozone dose, 8 g/d in tank 1. This result is surprising, because during the 8 g/d run, the system water had a slight but noticeable yellow color, while the water in the higher ozone treatments was crystal clear. The color (absorbance) was not quantified in this experiment.

Clearly, more research is needed to determine to what extent equilibrium TOC in a recirculating system depends on the rate of ozone addition.

Conclusions

- TOC concentrations in recirculating systems rise and then level off with water use (increasing CFB). Equilibrium is reached (in our systems) at about CFB = 2 g/L.
- In these experimental systems, ozonation lowers the equilibrium TOC from an average of about 26 mg/L to approximately 15 mg/L.
- The difference in equilibrium TOC between two identical recirculating systems is approximately 4 mg/L. This intrinsic variability among systems is not negligible compared to the effect of ozone.
- A difference in equilibrium TOC among the different ozone doses could not be detected.

Acknowledgement

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