EXCITON CLEAN

A novel advanced oxidation technology that rapidly removes geosmin and MIB from water and significantly reduces Atlantic Salmon depuration time

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Introduction

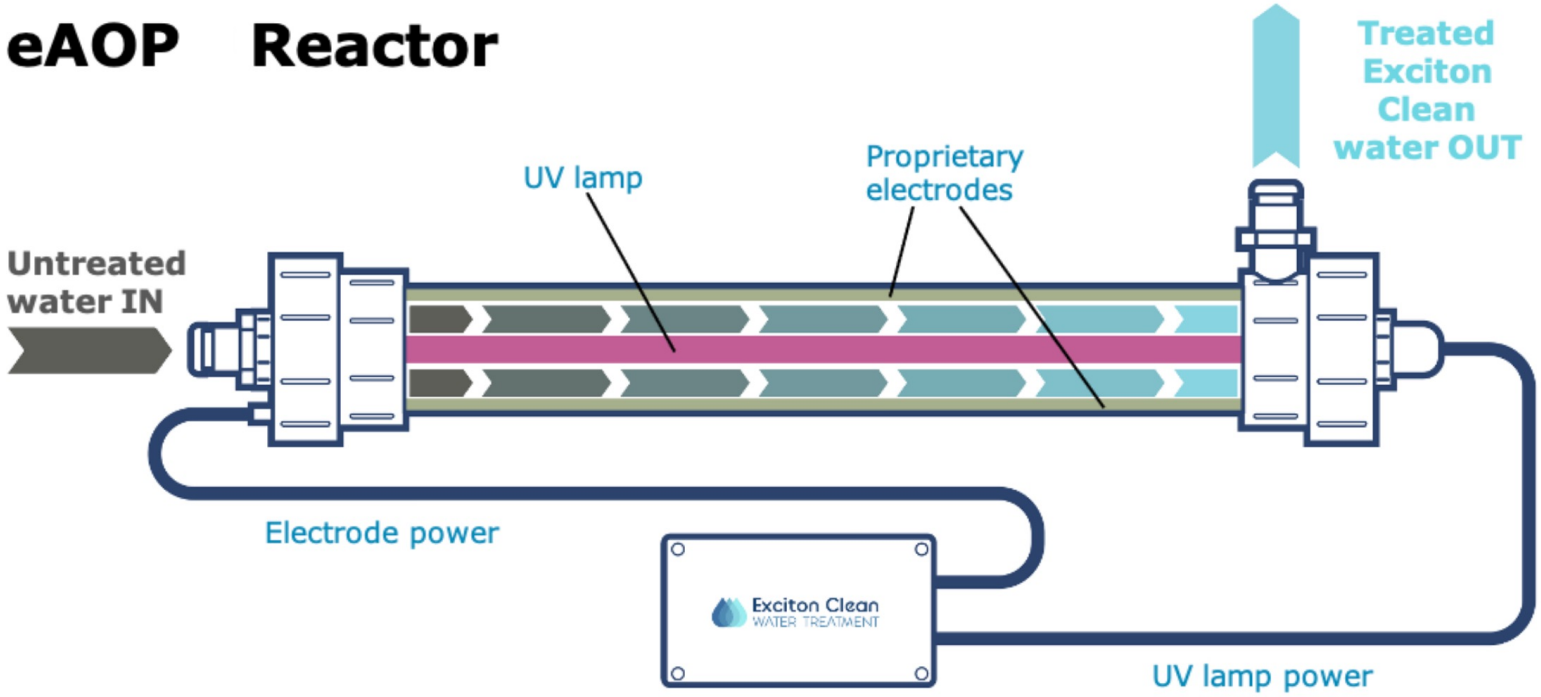
- Atlantic salmon reared in RAS accumulate off-flavors
  - Primarily due to geosmin (GSM) and 2-methylisoborneol (MIB)
- Off-flavors must be purged from fish before they can be sold
- Current solution: Hold fish for up to two weeks in separate depuration tanks flushed continuously with fresh water
- Depuration represents dominant water consumption for RAS salmon farms (70-90% of total farm consumption)

Problems with Current Purging Approach

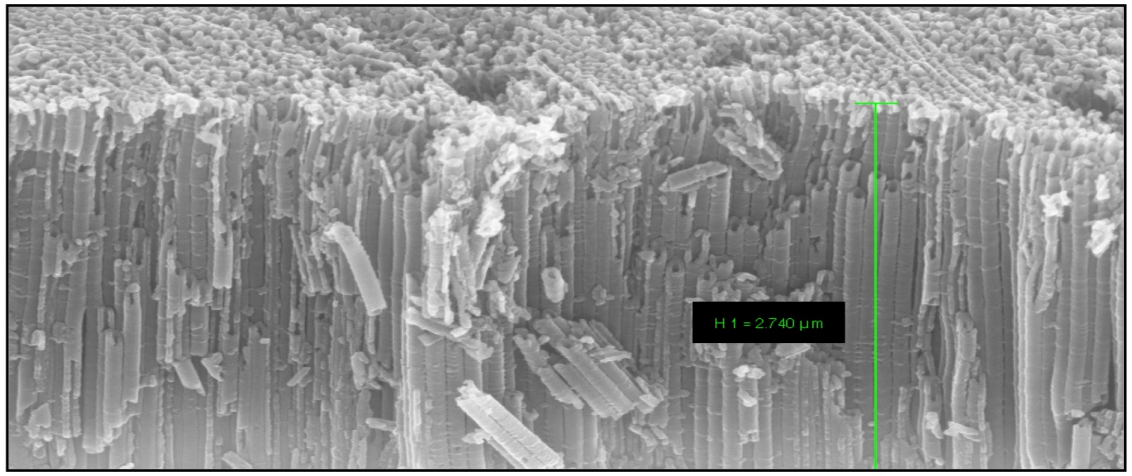
- Fish are not fed – they lose weight and value
  - Up to 4.2% biomass loss, per Freshwater Institute
- Large volumes of water are required
  - FI guidelines of ~1,000 Liters / kg for depuration

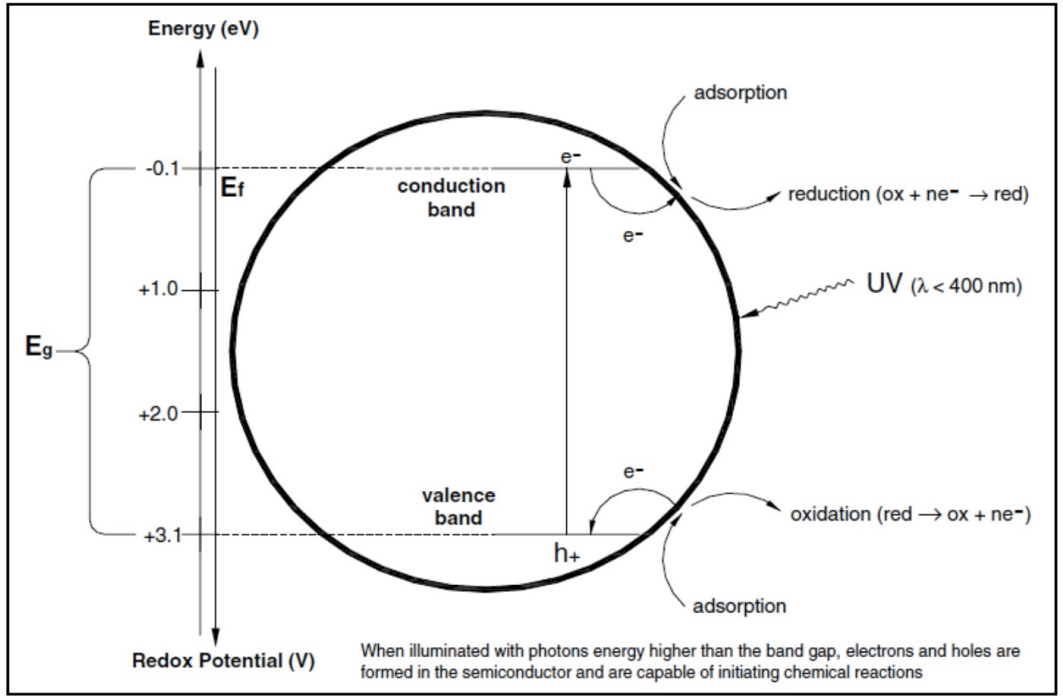
Exciton Advanced Oxidation Process (eAOP®)

A technology that uses germicidal UV light to activate a proprietary photocatalyst that can effectively destroy a wide variety of microbial and chemical contaminants in water, including GSM and MIB



eAOP®: How it Works





Multiple Mechanisms of Action

eAOP® chemical reactions

No.	Type:	Chemical Reaction:
1	Anode	$2Cl^- \rightarrow Cl_2 + 2e^-$
2	Anode	$Cl_{2(aq)} + H_2O \rightarrow Cl^-_{(aq)} + HClO + H^+$
3	Anode	$6HOCl + 3H_2O \rightarrow 2ClO_3^- + 4Cl^- + 12H^+ + 3/2\,O_2 + 6e^-$
4	Anode	$6ClO^- + 3H_2O \rightarrow 2ClO_3^- + 4Cl^- + 6H^+ + 3/2\,O_2 + 6e^-$
5	Anode	$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
6	Anode	$2OH^- \rightarrow O_2 + 2H^+ + 4e^-$
7	Anode	$6ClO^- + 3H_2O \rightarrow 2ClO_3^- + 4Cl^- + 6H^+ + 3/2\,O_2 + 6e^-$
8	Anode	$h^+ + OH^-_{ads} \rightarrow OH^\bullet$
9	Cathode	$O_2 + e^- \rightarrow O_2^{\bullet-}$
10	Cathode	$O_2 + 2e^- + 2H^+ \rightarrow H_2O_2$
11	Cathode	$H_2O_2 + Cl_2 \rightarrow 2Cl^- + 2H^+ + O_2$
12	Cathode	$2H_2O + 2e^- \rightarrow 2OH^- + H_2$
13	Bulk	$HOCl \rightarrow ClO^- + H^+$
14	Photolysis	$Cl^- + h\nu \rightarrow Cl^\bullet + 1/2O_2$
15	Photolysis	$HOCl + h\nu \rightarrow Cl^\bullet + OH^\bullet$

1. UV photolysis
2. Photocatalysis
3. Electrolysis
4. Hydroxyl radical production
5. UV/peroxide AOP

Research Objectives

1

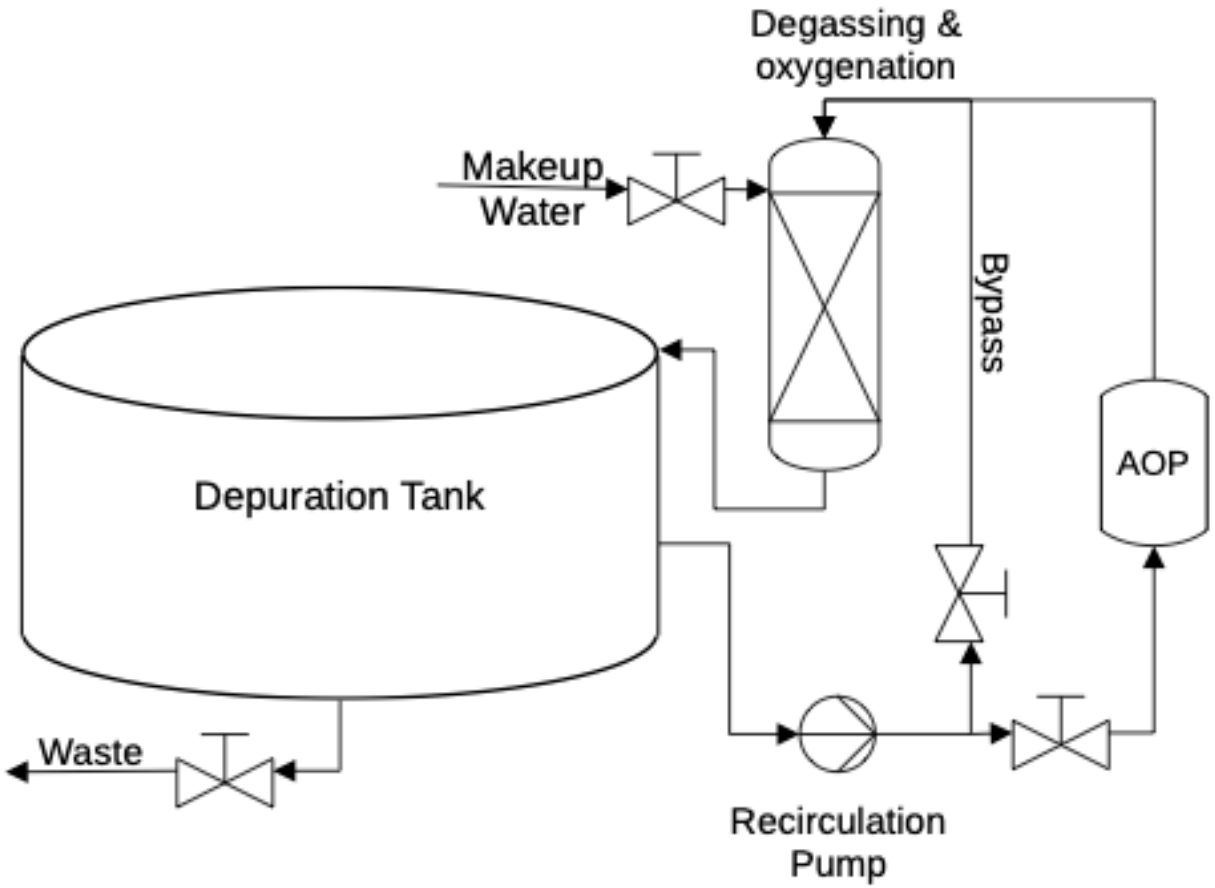
Test the effects of eAOP® on geosmin and MIB removal from depuration tanks at a commercial Atlantic salmon RAS facility

(Superior Fresh, Hixton, WI)

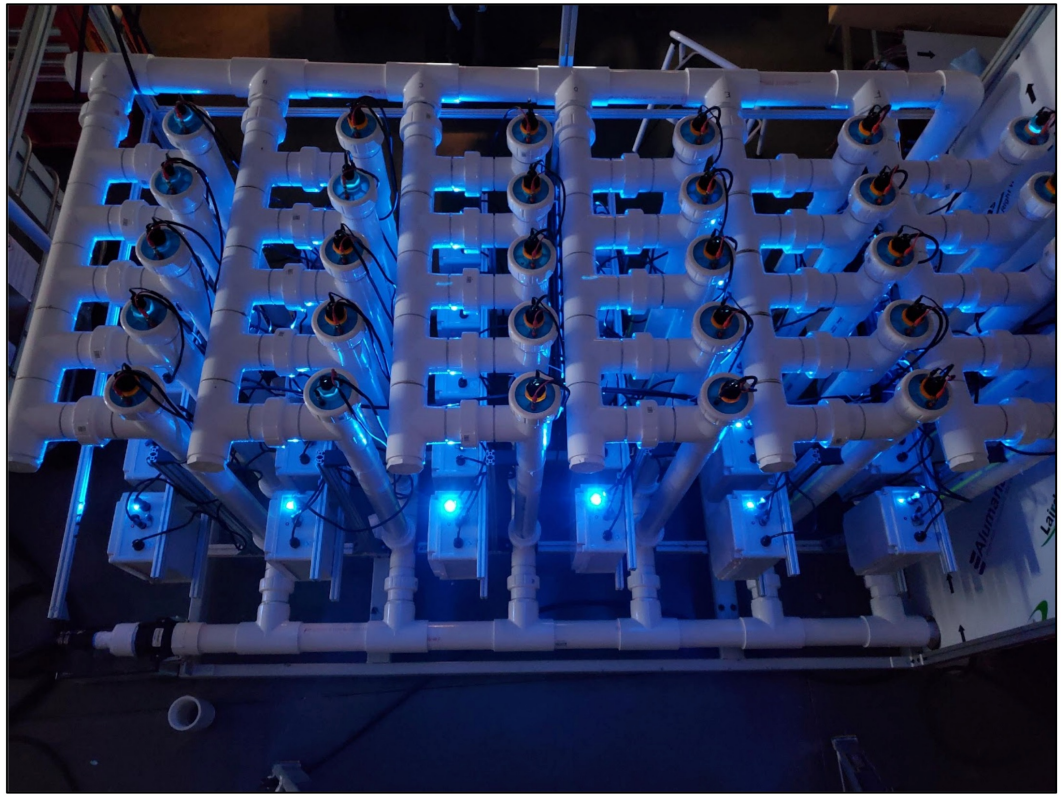
2

Determine if depuration times can be shortened using eAOP®

Experimental Depuration Setup



Exciton Mark III-30 Reactor – Prototype Used for Trial



Methods - Experiments

Chemical Spiking Experiments

- Spike 18m^3 depuration tank with GSM and MIB (no fish present)
- Control: sample water before eAOP reactor turned on
- Experiment: sample water after the reactor is turned on

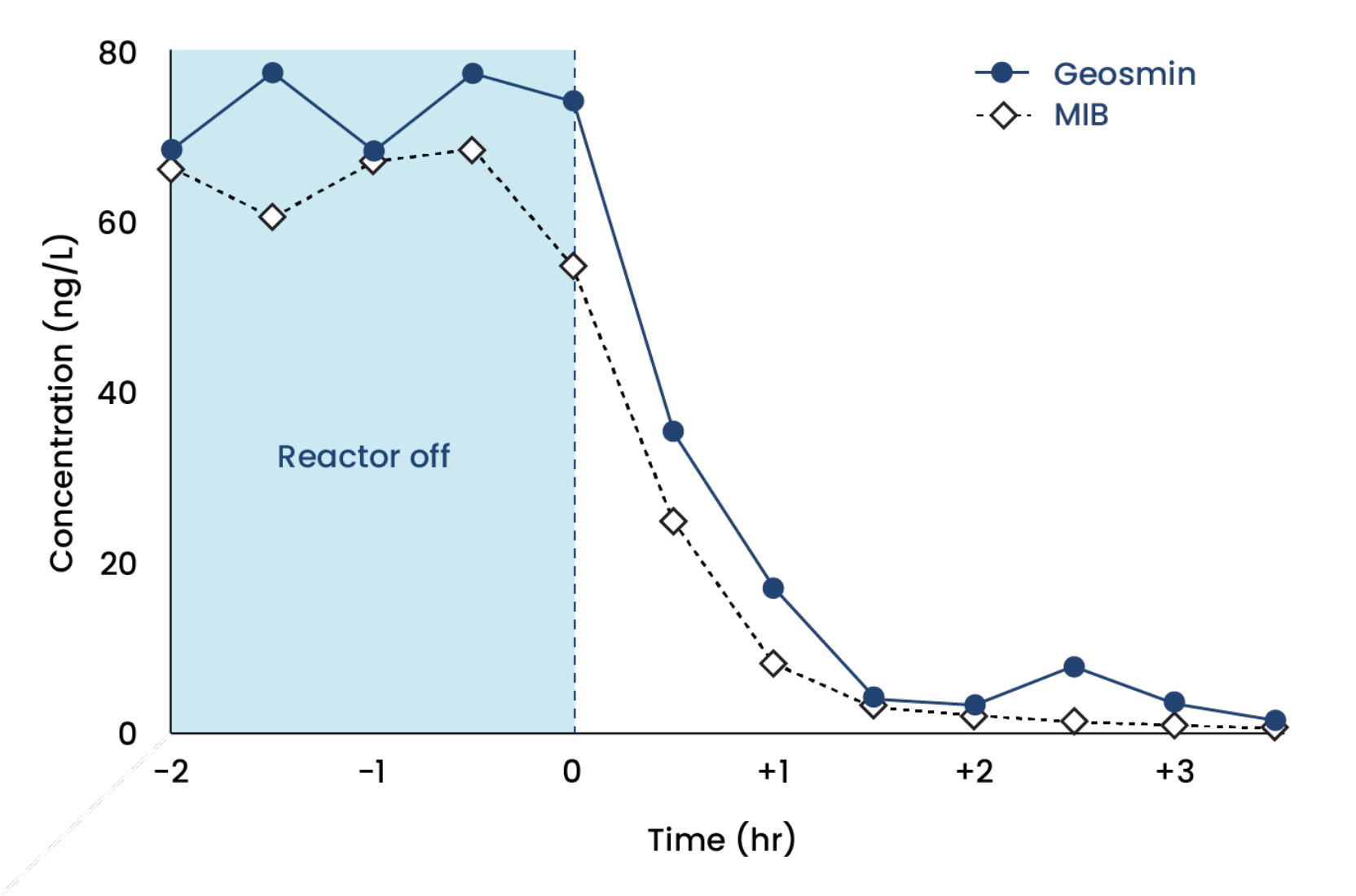
Depuration Experiment

- Transfer fish (~4 kg) from main RAS and split cohort evenly between two tanks
- Control Tank: standard depuration procedure
- Experimental Tank: continuous use of eAOP treatment
- Sample water and fish over 10-day depuration cycle

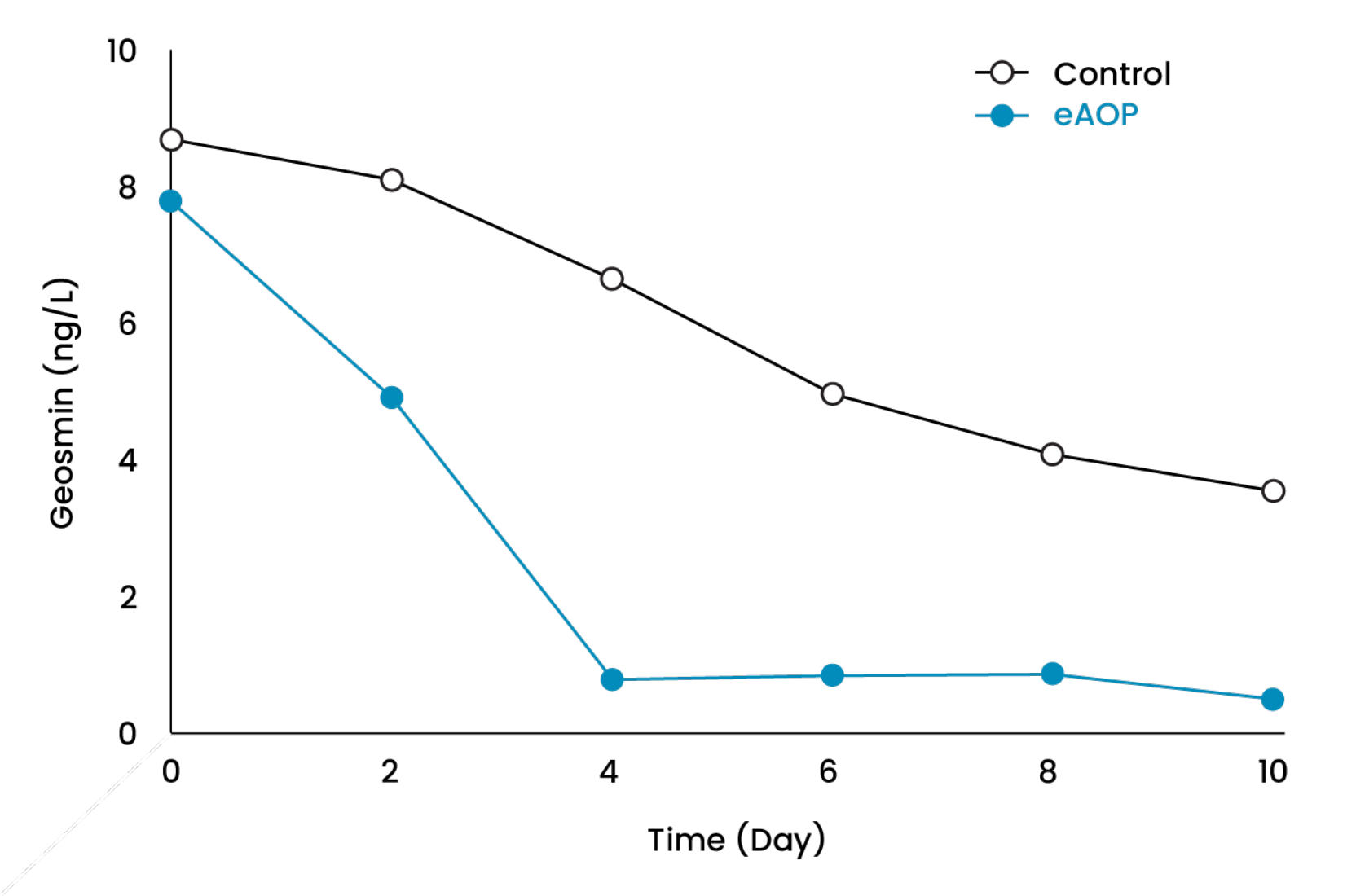
Methods - Analytical

- Sample analysis: Gas Chromatography / Mass Spectroscopy
- Water samples:
  - 40 mL, standard vials, preserved with sodium omadine
- Fish samples:
  - ~100g sample, taken from anterior dorsal portion of fillet

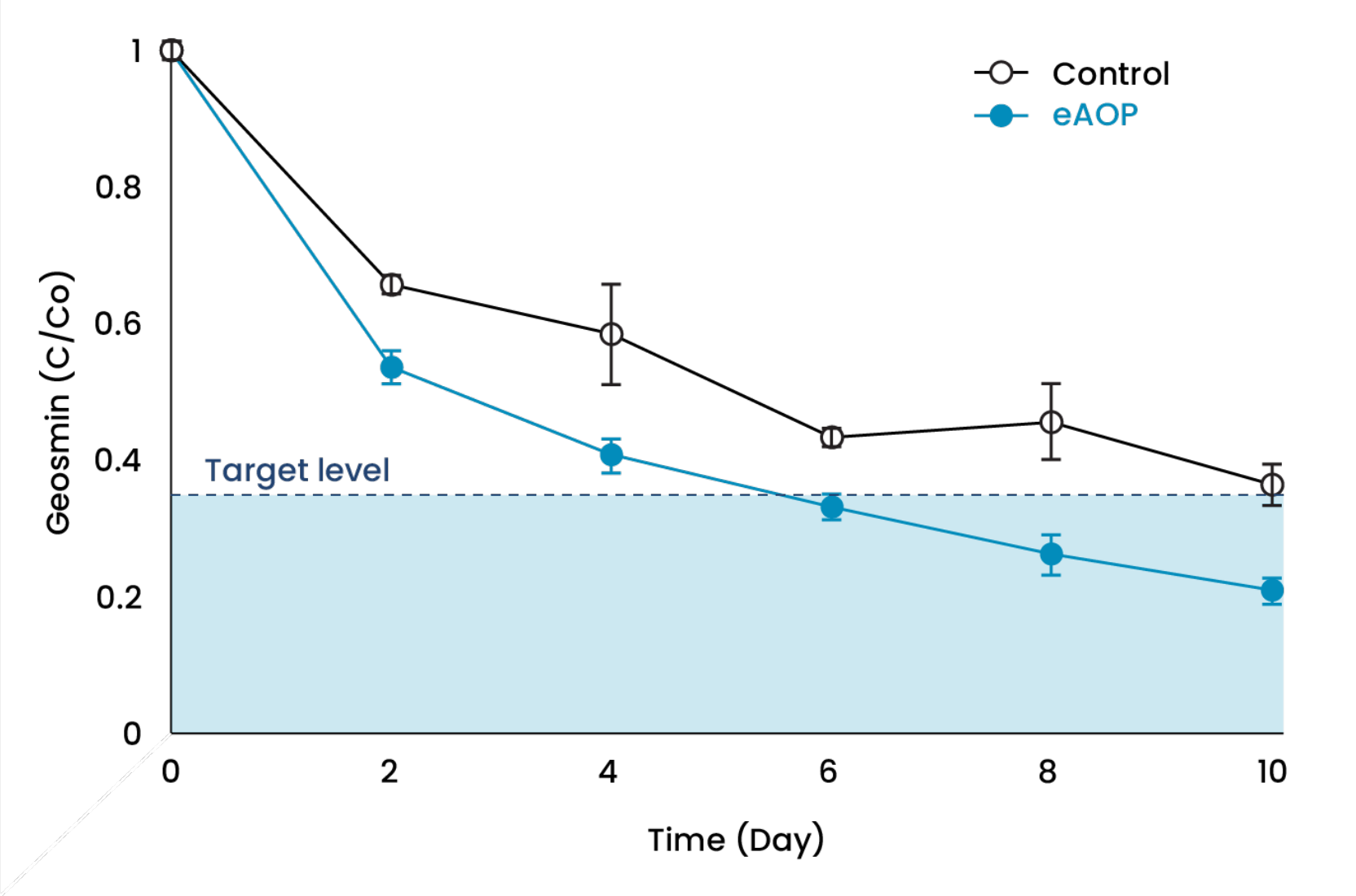
Chemical Spiking Experiment: Geosmin / MIB levels in water



Fish Trial: Geosmin levels in the water



Fish Trial: Geosmin levels in the fish



Conclusions

eAOP rapidly removes geosmin and MIB from water, including when fish are present

eAOP technology can be used to significantly reduce depuration times (40-50% faster) and/or water usage

Economics

By reducing depuration time by 40-60%, we calculate that RAS operators can save between $0.12 and $0.22 per kg of salmon produced (fish weight + water usage)

Farm Size (metric tons)	Annual savings
1,500	$180 - $330 thousand
10,000	$1.2 - 2.2 million

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A novel advanced oxidation process (AOP) that rapidly removes geosmin and 2-methylisoborneol (MIB) from water and significantly reduces depuration times in Atlantic salmon *Salmo salar* RAS aquaculture

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ABSTRACT

Atlantic salmon reared in RAS accumulate off-flavor chemicals in their flesh that must be depurated ("purged") before the fish can be sold. The purpose of the present investigation was to evaluate the effects of a novel advanced oxidation process (AOP) on the removal of geosmin (GSM) and 2-methylisoborneol (MIB) from the depuration tanks of a commercial Atlantic salmon RAS operation, with the goal of speeding up the purging process while using less water. The technology, called the Exciton Advanced Oxidation Process® (eAOP®), works by multiple mechanisms of action including photocatalysis, ultraviolet (UV) photolysis, electrolysis, and UV/oxidant AOP. In chemical spiking experiments without fish, both GSM and MIB were almost completely removed from 18 m^3 purge tanks by eAOP® in less than two hours. A 10-day experiment with market-sized Atlantic salmon was conducted to compare the rates of depuration of fish purged using traditional water flushing (control) or treated with eAOP®. In the eAOP®-treated fish, fillet GSM concentrations declined 60% faster than in the controls, and the fish were "on-flavor" in less than six days compared to ten days in the controls. The results indicate that eAOP® can be used to reduce depuration times in Atlantic salmon RAS aquaculture, saving water and minimizing the loss of fish biomass that typically occurs during longer depurations when the fish are not fed. These savings have significant positive economic impacts for commercial RAS operators, as well as positive implications for environmental impact and fish welfare.

1. Introduction

with water in a single pass or operated with limited water recirculation

Ongoing Research – Depuration in Brackish Water

IMET

AquaCon™

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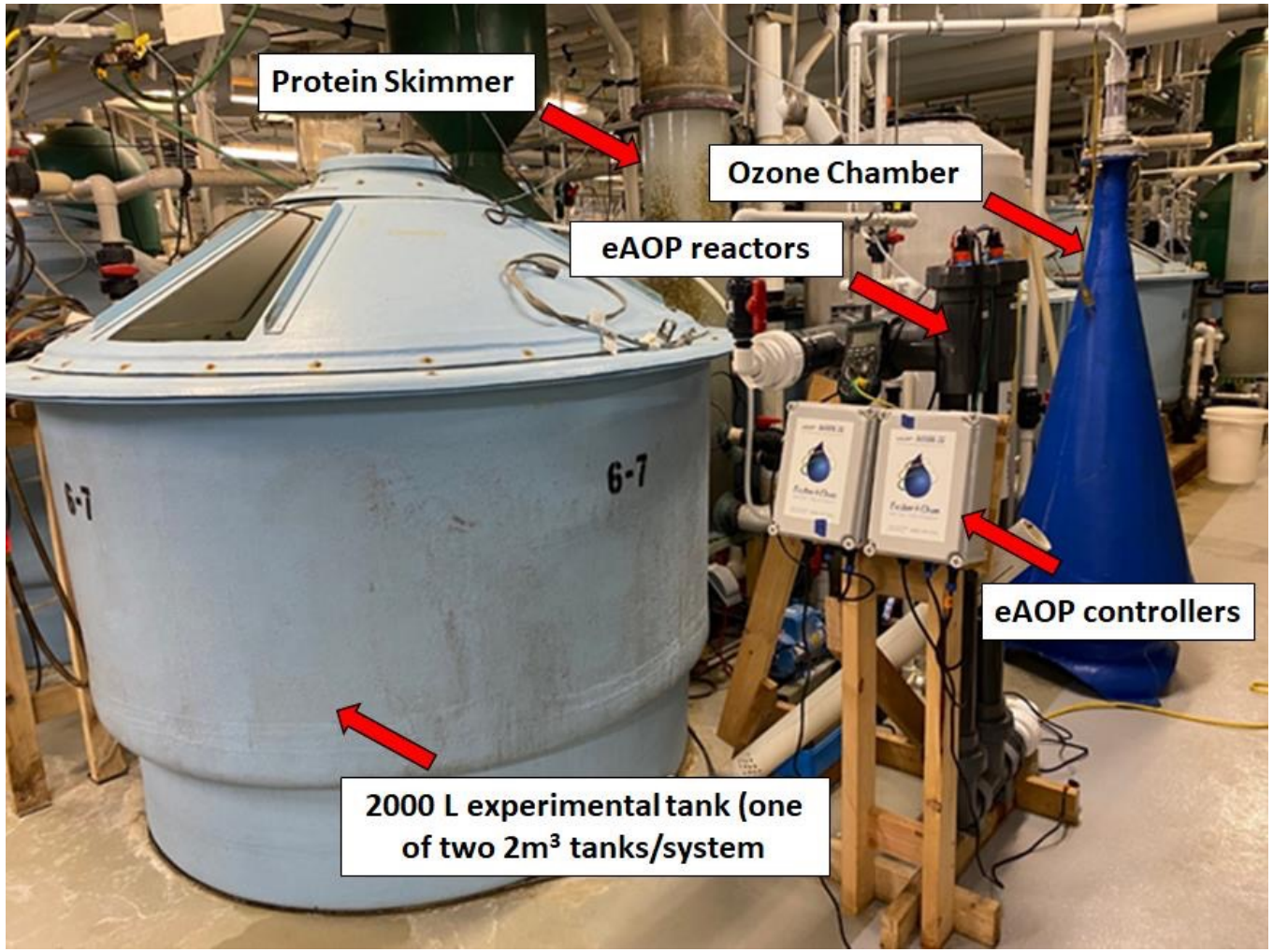
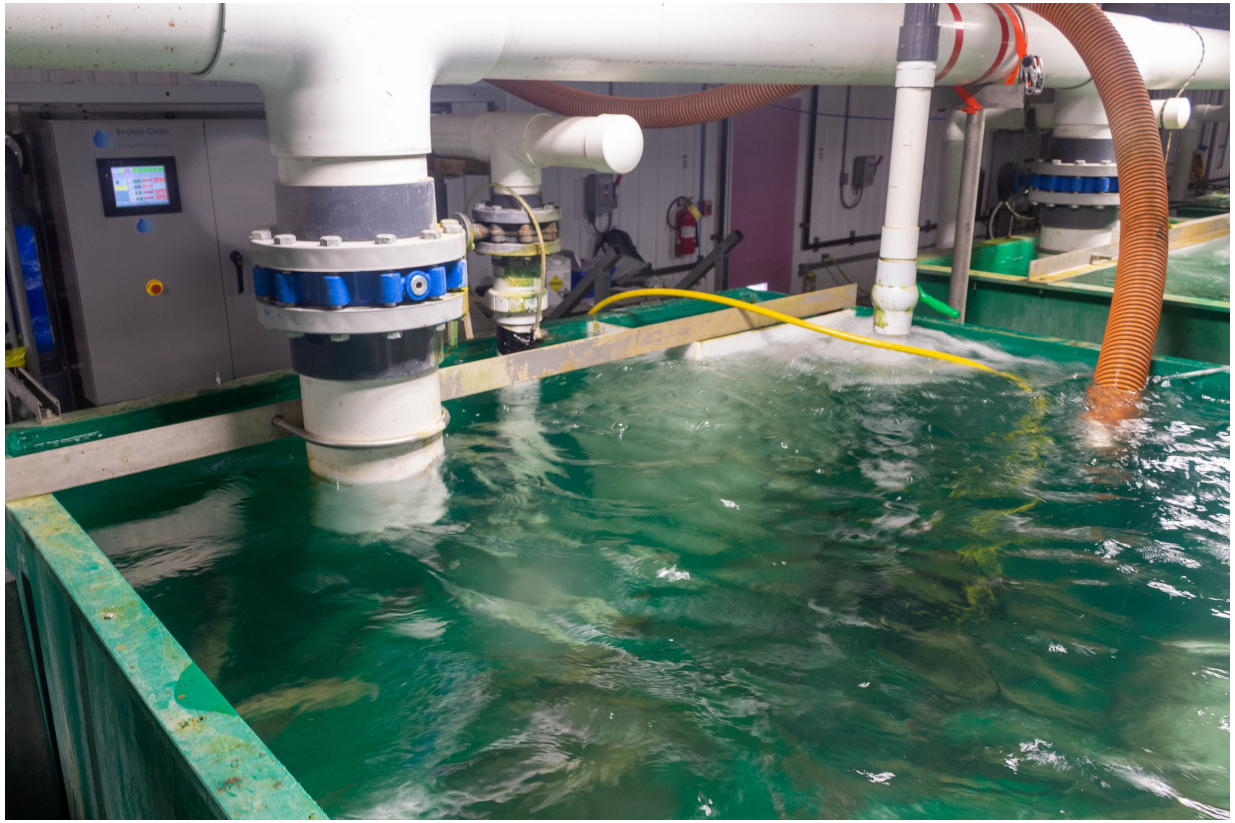


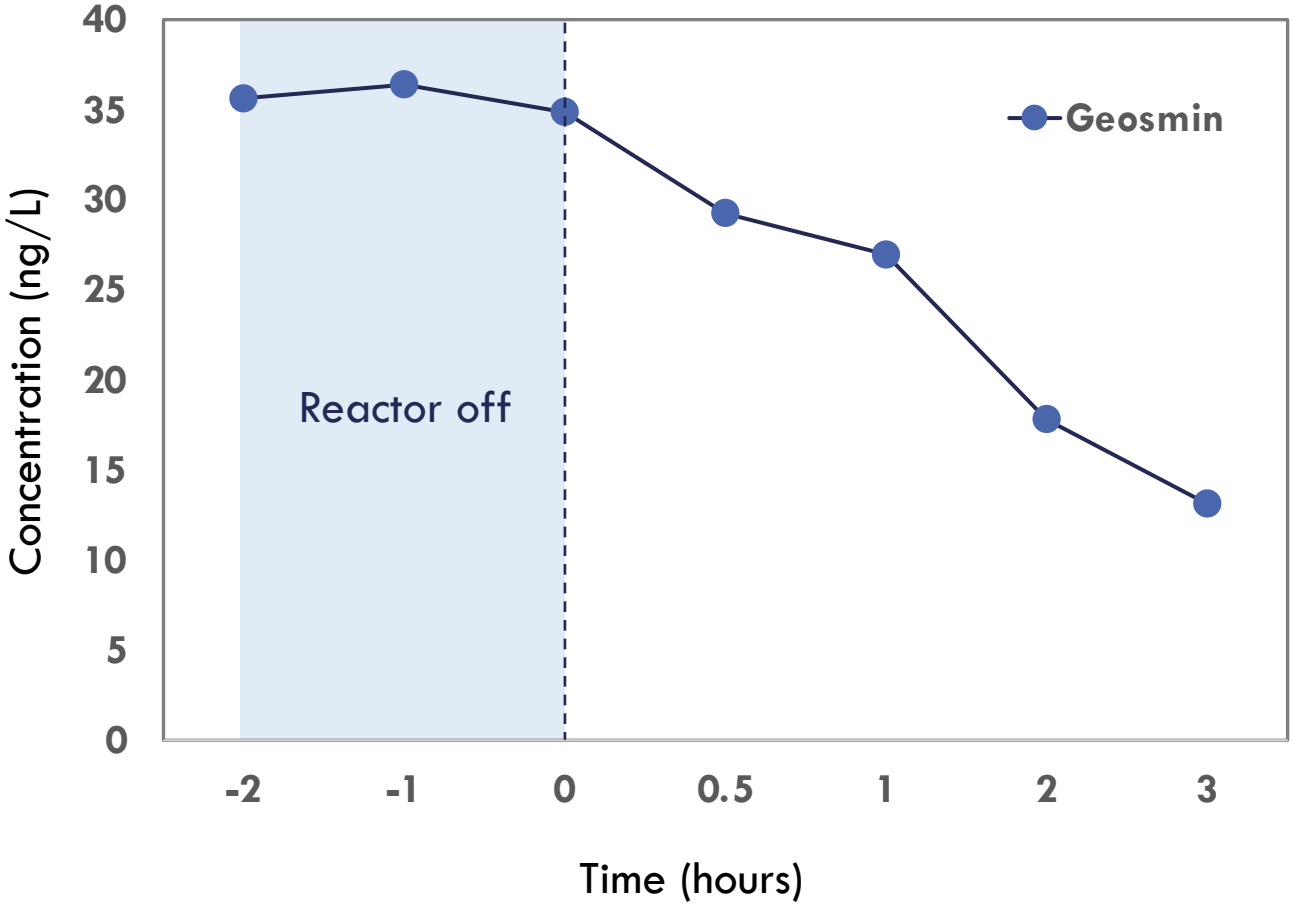
Ongoing Research – Commercial-scale RAS Salmon Farm (I)

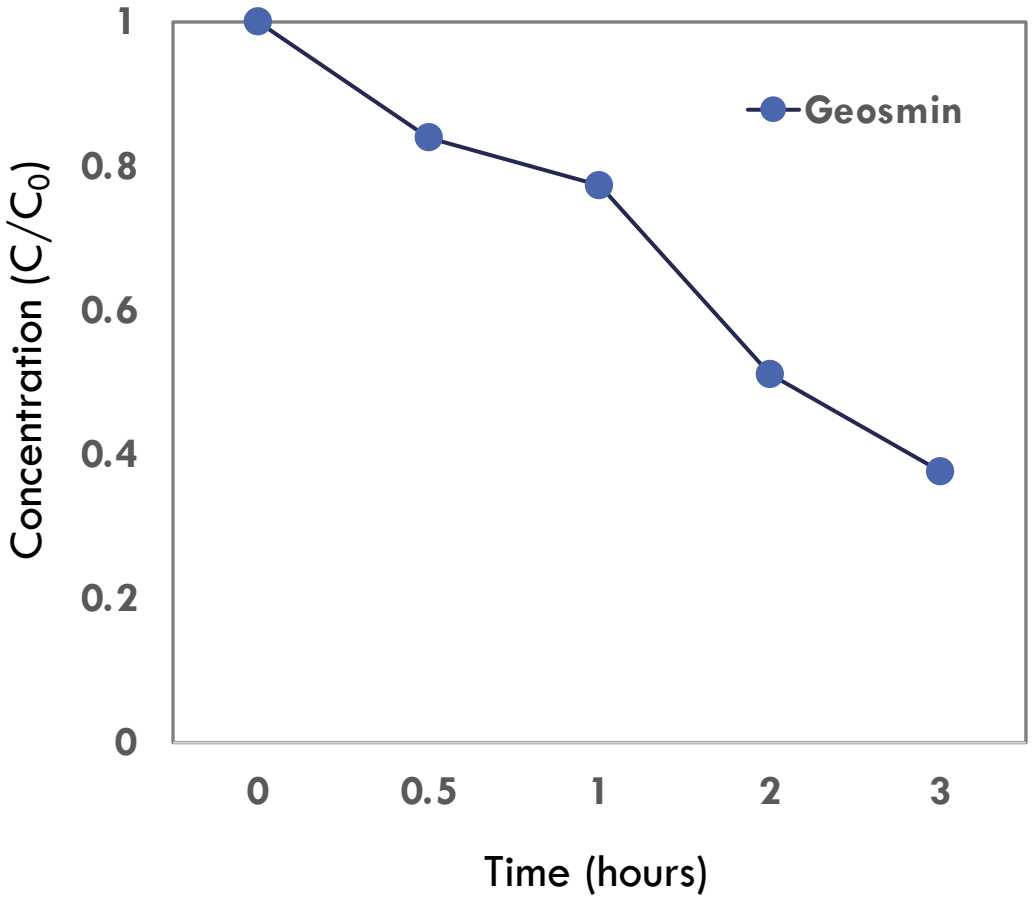
Geosmin spiking and fish depuration experiments conducted at working RAS Salmon farm



Ongoing Research – Commercial-scale RAS Salmon Farm (II)

Geosmin spiking experiment conducted in ~64 m3 depuration tank at working RAS Salmon farm





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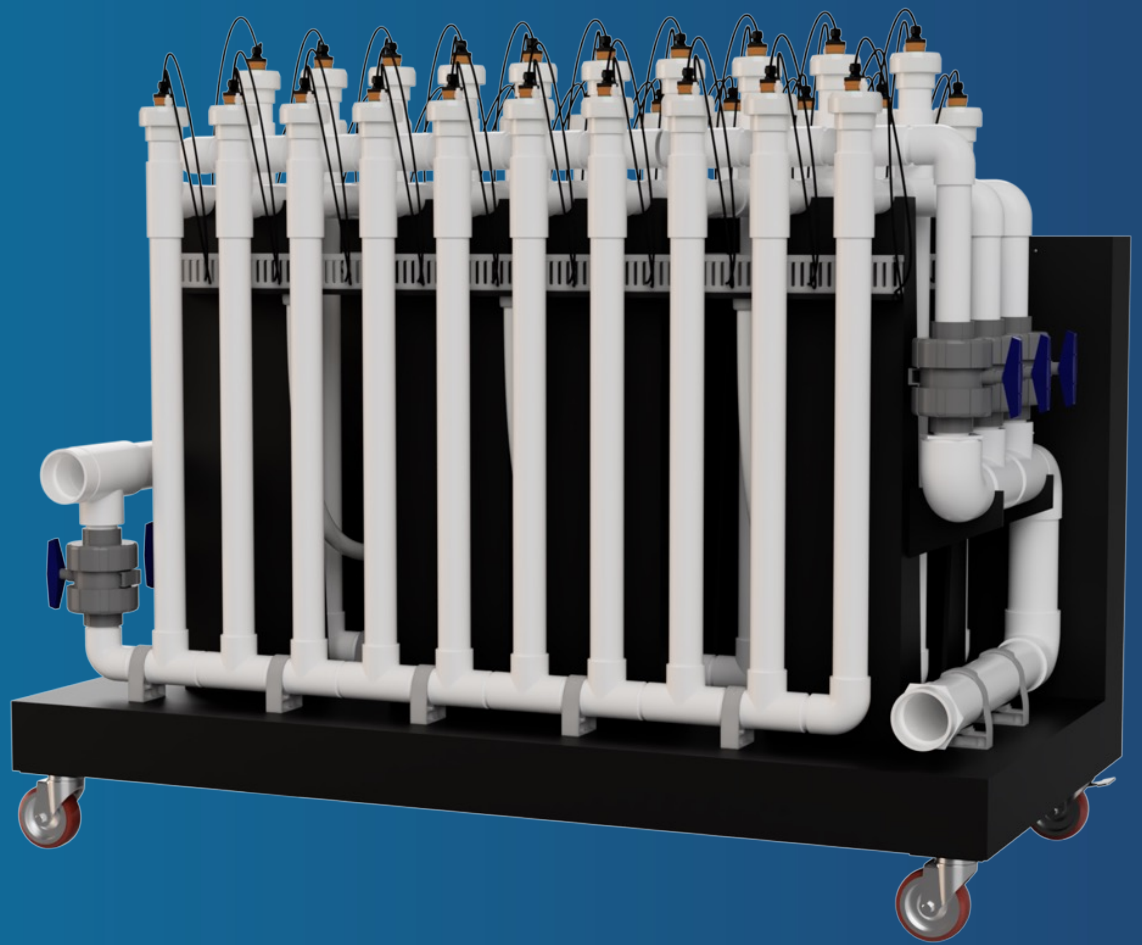
Thank You



Exciton Clean Mark III-30 Reactor (Production Series)