AQUACULTURAL ENGINEERING SOCIETY

Newsletter, May 2021

Presidents Letter

Dear AES members,

It has been almost a year and half since the covid pandemic started. To you who have lost friends and family, my deep condolences. There is no certainty when we are back to normal, but we need to hang in there, collaborate as a community and trust everything will be fine.

On our side, things have not been too shining lately, as the industry has faced criticism through a biased documentary film "Seaspiracy", Atlantic Sapphire has lost a 500 ton of Salmon in a marine land-based RAS, and 4.200 tons of salmon farmed in sea cages have been lost in Chile, supposedly because of an algal bloom. Reports say that "aquaculture is the fastest producing food production sector and it is a key solution to sustainable feed the world", is it really true? Do we really believe this statement? I do, but it depends.

In my lectures, I define sustainability as "the way we meet our own needs without compromising the ability of future generations to meet their own needs". Are we achieving this with aquaculture? Will future generations be able to use the resources in the same way as we are doing right now, especially talking about water and its relevance for our life on the planet? It is important to have in mind that aquaculture is not just the cultivation of fish. For every ton of salmonid produced (FCR of 1.1) approximately 53 kg N, 13 kg P, and 320 kg COD mg O_2/L are discharged to the production system water. These nutrients can enhance the growth of opportunistic microbes (algae and bacteria) that will ultimately unbalance the system. However, these nutrients are discharged in different fractions: majority of all N (80%) is found in dissolved form as ammonia and nitrate, while majority of all P (80%) is embedded in the solids fraction. The correct understanding of these fractions is fundamental for a correct manipulation and control of water quality and unwanted microbial blooms.

If we do not take care of the nutrients and still want to feed the world, can we really argue not to cause any impact on the environment? Do we still believe that dilution will do our job? If yes, I think we are making a big mistake. We need to take care of the nutrient waste produced, and I am a true believer in RAS being the way on how to proceed. But not RAS as a sole technology, but RAS coupled with an end-of-pipe treatment, since otherwise we are just concentrating the waste. The technology allows us to know exactly what are our inputs and outputs (water, energy, nutrients and CO_2). It also allows us to transform waste into resources: energy, fertilizers, carbon sources for denitrification, phosphorous recovery, and production of vegetables among other alternatives. Knowing the exact amount of inputs and different resources produced is important to show the consumers that we are doing the work and we are aiming at feeding the world in a sustainable manner. How can we move to the point where the industry is mature, strong, and consolidated? Where documentaries as Seaspiracy will not have such an impact on the general audience, or a sudden loss of biomass does not cause the industry to evaluate if RAS as a completely controlled system is less attractive than sea cage farming. We need to move from the concept of a one system design fitting all and the applying of rules of thumb when designing systems. We need to be more efficient and optimize resource usage (water and energy) through a correct dimensioning and system design. We also need to understand that working with seawater is a different universe as compared to freshwater. Seawater has 1500 times more ions, which allows a higher amount of biological, chemical, and physical processes than in freshwater. In a freshwater RAS, the accumulation of solids will affect biofilter efficiency and increase oxygen demand. But in seawater, the accumulation of solids brings up an additional problem, production of toxic hydrogen sulphide (H_2S). Is there H_2S production also in the bottom of sea cages, where solids accumulate?

Is the real reason behind the recent mass mortality in Chile, microalgae, oxygen deficiency or climate change?

Predictive or optimization models are a strong engineering tool, which in my opinion require much more attention in aquaculture field. We need to develop predictive models that will allow us to react in time before it's too late and define the maximal carrying capacities of systems (tanks, biofilters, fiords, lakes, rivers, and aquifers). It is true that models are as good as the level of information on which they are based on, and that they can fail from time to time, but we have to use them in a same way we use weather forecast: sometimes it is wrong, but we still check how the day will be next day, just in case. A starting point and not only for developing models, but also for comparing systems, discussing results, and comparing technologies is a defined language or nomenclature we agree upon.

We need to understand that a system cannot be described according to the % of recirculation, but should be replaced by a mass unit (kg feed/ kg water or vice versa), also define and agree on the nomenclature we use to evaluate systems; turnover, microbial water quality, fish welfare, or system sustainability. In order to achieve this, we need to intensify the collaboration between academia and industry. This synergy is fundamental for the correct development of the industry, so what we need to do is to leave our egos aside and work together. For scientists to solve problems for the industry, data from real life, from industrial systems are needed. More real data means more precise models, which allows solving of the industry problems faster. In this sense, initiatives, like the Cobália multiuser system from OxyGuard, which will allow model developers to access a database, will become a strong tool for developing production models, improving inventories, and environmental practices. This would allow us to communicate fast with the public audience on how many resources we use to produce a kg of fish or sea food, and on which means we take care of the environment, which would be beneficial especially when we face erroneous negative publicity, like Seaspiracy. Indeed, I would like to congratulate Biomar for their quick response on the wrong information presented in Seaspiracy. I hope next time more universities, companies, and institutions react as strong and quick as Biomar did to defend our sector against this type of accusations.

Again, it all will be fine if we do things in the correct way.

In the following newsletter in the membership spotlight you will find an interview with Thomas Losordo, who is our AES excellence award winner, as well as the information of the other winners of the AES awards. In the scientific spotlight, you will find an article about H_2S production, in the industrial spotlight an article by PR Aqua that will let us know about Oxygenation Strategy for RAS using Pressurized Packed Columns, and of course information on the upcoming events. I hope you will enjoy the newsletter.

A big hug and I hope good water quality is always running in your life.

Best wishes

Carlos

AES Awards 2020

1. Award of excellence: Prof. Dr. Thomas Losordo

2. Meritorious service award: Prof. Dr. Jaap van Rijn

3. Best paper awards:

Superior paper:

Davidson et al. (2020). Depuration system flushing rate affects geosmin removal from market-size Atlantic salmon *Salmo salar*
https://www.sciencedirect.com/science/article/pii/S0144860920300868

Honourable mention papers:

Hüpeden et al. (2020). Taxonomic and functional profiling of nitrifying biofilms in freshwater, brackish and marine RAS biofilters.
https://www.sciencedirect.com/science/article/pii/S0144860920300340

Nilsen et al. (2020). A closer look at closed cages: Growth and mortality rates during production of post-smolt Atlantic salmon in marine closed confinement systems.
https://www.sciencedirect.com/science/article/pii/S0144860920301709?dgcid=rss_sd_all

Member Spotlight

Interview with Dr. Thomas M. Losordo

AES: Can you tell us about how you came to a career in Aquaculture?

Thomas: Firstly, I would like to than the Aquacultural Engineering Society for this honor. I am grateful for this recognition. Now to answer your question. I grew up on the South Shore of Boston, Massachusetts and Cape Cod in a family that lived and breathed sports fishing. From an early age I spent endless hours with my father Frank on his boat fishing the Cape waters for Blue Fish, Striped Bass, Flounder and Sword Fish! While studying at Bates College in central Maine (1970-1974), I discovered the Research Abstracts of the Woods Hole Oceanographic Institution in the college library. In reading these abstracts I came across the project reports of Dr. John H. Ryther a Senior Scientist, who in the late 1960's, began investigations into the field of Aquaculture. More specifically Dr. Ryther and his team were investigating the use of treated domestic wastewater for the production of marine phytoplankton to be fed to bivalves (oysters and clams). Upon graduation from college, I visited Dr. Ryther's' lab, The Environmental System Lab (ESL), in Woods Hole near the family summer home on Cape Cod. After a bit of persuasion, Dr. Ryther offered me summer employment as a technician at the ESL. For the first six weeks I and student sorted 144,000 oysters in 10 raceways into three groups. Big, little and dead. Perhaps this was a test, but in the end, I was offered a fulltime lab technician position for the Fall of 1974. Having grown up in a family of home builders and on a boat that had several engines replaced, I had mechanical skills not learned at a liberal arts college. As such, when the lab engineer departed in early 1975 my technical responsibilities were expanded to include the maintenance of the sizable life support systems of the Environmental Systems Lab and I acquired the title of Lab Engineer. Having a BS in Biology I set out to find the best route to gaining real engineering credentials. In early 1977 the Agricultural Engineering Department of the University of Hawaii advertised a graduate assistantship for MS degree students in Aquacultural Engineering. The program was headed by Dr. Jaw Kai Wang, Professor at UH Manoa. What better way to go to graduate school than to be two miles from Waikiki beach! I moved to Hawaii in the Fall of 1977 and completed the MS degree in December 1980 with my thesis focused on water quality in freshwater prawn ponds. After two years in the private sector and two years working at UH, I was accepted into the PhD program for Aquacultural Engineering at the University of California, Davis. Under the supervision of Professor Raul H. Piedrahita, I completed this degree program in September 1988. My dissertation topic was the computer simulation and modeling of temperature and oxygen stratification in shallow aquaculture ponds. Upon completion of my degree, I was fortunate enough to be offered a tenure track faculty position at North Carolina State University. The position was broadly focused on research and extension (service to industry) in aquaculture.

AES: Ok, so how did you become involved in RAS Technology for which most of us would associate you with?

Thomas: Keep in mind that before I came to NC State my experience and expertise were marine flow-through and pond-based aquaculture. I fully expected to create and be focused on research topics related to pond-based aquaculture. To my surprise in the late 1980's many of the questions I was being asked (in my Extension position) were related to the feasibility of in-door aquaculture based in tanks and requiring water reuse technology. I looked around at the universities in the United States and did not see a lot of faculty involved in RAS and even fewer engineers involved in RAS. Fortunately, the course work I had taken at UH and UC Davis leaned heavily towards Environmental Engineering technology and unit processes. I found this particular skill set lacking in RAS design and development. So, I created a "near commercial scale" laboratory we called the Fish Barn and began looking for non-biased science-based answers. In keeping with my Extension responsibilities, we began a series of workshops open to the public at NC State using the Fish Barn as a teaching tool. Pretty soon, I was being asked to bring the short course to other states and then other countries. Since 1990 we have provided these services globally to thousands of individuals interested in RAS technology. Our goal was to educate the industry so that they could ask the right questions when evaluating opportunities in RAS based aquaculture.

AES: Can you tell us how you started with the Aquaculture Engineering Society?

Thomas: Up until around 1992 the professional society for most aquaculture engineers was the American Society of Agricultural Engineers. As such we would go to these annual meetings and present research results to an audience not much larger than the number of presenters. In contrast, when we would attend the annual meetings of the World Aquaculture Society and presenting in an engineering session there would be standing room only! So finally, the core group of engineers from the United States, met for a lunch and outlined the beginnings of the Aquaculture Engineering Society. If my memory serves me right the founding members at that meeting were John Colt, Michael Timmons, Ron Malone, Raul Piedrahita, Jaw Kai Wang, Fred Wheaton, and me. Out of the meeting came the beginnings of the AES and those attending became Founding Officers and Directors. I served as a Director and President Elect, then President in 1999-2000. As I was President of the World Aquaculture Society in 2000-2001, my publications were shared between the Aquaculture Engineering Journal and the Journal of the World Aquaculture Society.

AES: What role do you think AES should have for the industry and academia, considering the big number of webinars, information and courses offered by other societies.

Thomas: I personally believe that this society, like the WAS, succeeds when it provides a forum both in person, online and in print, for the exchange of research-based science and technology. I am sure there are those that would like the society to take stands related to some industry issues. However, like the WAS, the AES provides a rather unique forum for the exchange of science and engineering-based ideas and discovery. Other groups have and will come along to fill the void of being advocates for the industry. AES can provide support to these groups without becoming one of them.

AES: How do you perceive the evolution of RAS?

Thomas: I started my efforts in the evaluation and development of RAS technology in the early 90's due to a lack of research-based information available to the public. Much of the technology being touted as state-of-the-art had no engineering basis for this claim. As such failures of the technology and the businesses relying on these technologies were common in the industry at that time. After many years of effort by many people in the industry, unit process based, engineered solutions are more common to the industry than before. Hence, we now see more successes the RAS sector and more use of RAS technology where it is appropriate. Continued improvements to the technological base of RAS system is necessary and happening every day. There also remains a need for the education of individuals and the industry in what constitutes state-of-the-art technology. I am happy to see this evolution and expect it to continue at a healthy pace.

AES: Where do you see aquaculture in future?

Thomas: My answer to this question has not changed much during the 47 years I have been professionally involved in aquaculture. If we want to provide protein from the waters of the earth (freshwater and marine), aquaculture is a must. The oceans have been and are at a maximum sustainable yield. Unless only the wealthy of the world are to enjoy “seafood”, then to provide healthy food to an expanding global population aquaculture is a must and is the answer. In the near term I see land-based pond technology providing the majority of freshwater fishes. That said, I believe RAS technology will provide more and more products closer to large markets as we move ahead. I do believe there will be some combination of RAS nursery culture combined with pond growout and aquaponics technology to grow plants and recycle nutrients. I am just not sure of the timeline. We are seeing this playout in real time in the salmon industry. Net Pen culture providing large scale growout with smolts being grown on land in RAS based technology. Not many years ago that was all flow through!

AES: What do you think the aquaculture sector is missing these days?

Thomas: My answer to this question has not changed in a decade! I believe that the treatment of waste created in aquaculture has not received enough attention. In my career in RAS based aquaculture, the last decade at the University and in the Private Sector, was focused on increased water reuse and at the same time the treatment or remove of potentially harmful waste products from the small but concentrated flow stream leaving the RAS technology. So much work remains in this area of engineering and science!

AES: What are you currently working on or doing?

Thomas: As some of you may remember I retired from my Faculty position at North Carolina State University in 2012 after a 25-year career. I went to work for a large globally diverse company named Pentair for what was planned to be my last 5 years of fulltime activity in aquaculture. With 5 years and two days completed I retired a second time in May of 2017. In my first year of retirement, I spent time traveling the globe providing consulting services to 3 or 4 clients. I enjoyed that very much and mostly enjoyed picking projects and clients that “I” wanted to work on and with! But in the spirit of retirement in 2019 I moved with my wife Amy to the Pacific Northwest and settled in the vibrant city of Portland Oregon. While the Pandemic has given me permission to slow down, I am getting into the rhythm of retirement (just bought a boat) and am providing advice to Oregon State University and the Aquaculture Association of Oregon and have one consulting client. I am also looking forward to providing a continuation of the RAS Short Course with my colleagues Dennis DeLong and Raul Piedrahita. The best part of retirement is that YOU get to choose what you are involved in and when!

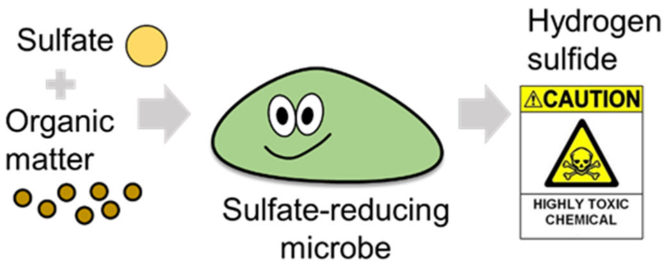
AES: Do you have final remarks?

Thomas: I have been lucky and blessed to have found a career that I love! Not everyone walking this earth has been as fortunate. My work has brought me to many countries around the globe where I met and made good friends in the process. I had the good fortune of spending a sabbatical in Trondheim Norway with my family in 1995 and again in Port Stephen Australia in 2001. Through our travels we have made life-long friends along the way. I hope in some way I have contributed to the betterment of this planet and the people who live here.

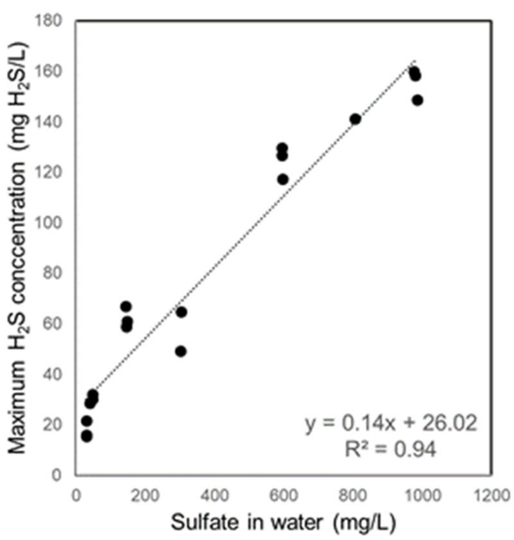
Scientific Spotlight

Hydrogen sulfide in recirculating aquaculture systems - challenges and solutions

Land-based recirculating aquaculture systems have offered a way for aquaculture industry to increase fish production without compromising environmental regulations, first in freshwater to cultivate early stage salmonids, and lately, also in seawater to enable a wider species range and larger fish. Along the way, aquaculture entrepreneurs have faced a series of challenges and uncertainties. Once moving from freshwater to marine RAS, one of the challenges to appear has been the production of rotten egg smell coming from the fish waste accumulation tanks. For example, Danish Salmon A/S, a large salmon producer located to northern Denmark, experienced problems with the commune due to the uncontrollably spreading smell from the facility to the surrounding populated area. The reason for the smell was hydrogen sulfide produced in the sludge holding tanks with a high retention time. Afterwards, hydrogen sulfide has caused additional challenges for aquaculture production. In addition to the unpleasant smell, it is extremely toxic for all living organisms, and already very low concentrations (<1 mg/L) are enough to disrupt physiological processes in fish. Aquaculture companies in both Norway and Denmark have faced sudden massive fish deaths due to the accumulation of hydrogen sulfide in the system water, and it has been acknowledged as a challenge when growing fish in marine RAS.

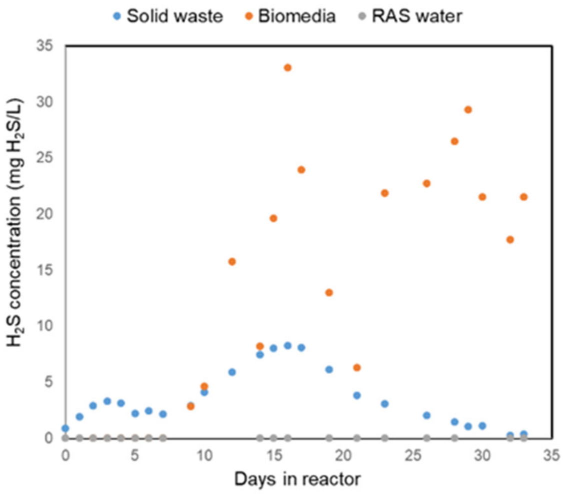


Hydrogen sulfide is produced by sulfate-reducing microbes, which use sulfate to degrade organic matter in the absence of oxygen. There is no one specific group, but rather several different microbial groups, which can carry out the process. Recently, Dr. Letelier-Gordo and Dr. Aalto found out that the role of traditional sulfate reducing microbes is minor in hydrogen sulfide production from marine RAS organic matter, since there are currently unknown microbes which produce a major share of hydrogen sulfide. ***Sulfate reducing microbes can be found in all RAS compartments which offer them the favorable conditions: sulfate, organic matter, and no oxygen; e.g. in tank bottoms, pipes, biofilters.***



Since seawater has a high sulfate concentrations (2 g/L), the possibility for hydrogen sulfide production is more likely in marine than in freshwater RAS. In recent research project, Dr. Letelier-Gordo and Dr. Aalto incubated fish waste collected from marine RAS in the laboratory reactors and found out that the hydrogen concentration produced increased with the amount of sulfate in water i.e. salinity of the system. However, the story is not this simple, since sulfate alone cannot lead to hydrogen sulfide production, but organic matter of right quality is needed. The particulate organic matter accumulating in RAS originates from feed and feces and is too complex to degrade for sulfate reducing microbes. So sulfate reducing microbes are dependent on the activity of other microbes, which degrade organic matter into simple form. A bit of a same principle which is needed to convert sugar canes into table sugar so we humans get some table sugar to our coffee to make through a hard day at work.

In summer 2020, Dr. Letelier-Gordo and Dr. Aalto conducted another set of laboratory trials to test which carbon: sulfate ratio leads to the highest hydrogen sulfide production in reactors run with marine fish waste. The idea behind was to estimate if keeping organic matter accumulation under certain level through system cleaning and operational settings would be a way to control the activity of sulfate reducing microbes. The reactors were started with sulfate concentrations of 1 g/L and organic matter in ratio of 0.5, 1, and 5. After 19 days of operation, hydrogen sulfide concentration was 500 mg/L in the reactors with carbon-to-sulfate of 5, while there was no production in the reactors with ratio of 0.5 and very small concentration (20 mg/L) in the reactors with ratio of 1. This is due to the nature of fish waste organic matter, as it is not fully usable for sulfate reducing microbes.



In a collaboration project "Aquasulfat" with the researchers Dr. Paula Rojas-Tirado and Åse Åtland from the Norwegian Institute from Water Research (NIVA), Dr. Letelier-Gordo and Dr. Aalto looked into the hydrogen sulfide production potential of different RAS environments, including water, solid organic waste, and biofilter biomedia using the anaerobic laboratory reactors. After 32 days, the highest hydrogen sulfide concentrations were produced in biomedia, while solid waste produced lower but more stable concentrations already in the beginning of the experiment. No hydrogen sulfide was produced in sulfate-rich RAS water, due to the absence of both sulfate reducing microbes and organic matter.

Based on our experiments, they have recognized the following key risk factors:

- organic matter accumulation
- Inefficient oxygenation and mixing
- Inefficient cleaning of biofilters, tanks, and pipes

Control measures:

Nitrate addition has been suggested as a measure to control hydrogen sulfide production. Dr. Letelier-Gordo and Dr. Aalto evaluated this in a currently running collaboration project "H_2Salar" project with Nofima and NIVA. The laboratory reactors containing 600 mg/L of hydrogen sulfide were spiked with nitrate (final concentration in the reactor of 150 mg/L NO_3-N), but no hydrogen sulfide reduction was observed. So adding nitrate does not improve hydrogen sulfide consumption, and is not economically and environmentally viable control measure in a commercial RAS. However, microbes rather use nitrate than sulfate due to higher energy gain, so maintaining high nitrate levels in RAS should prevent microbes using sulfate and producing hydrogen sulfide. But Dr. Letelier-Gordo wants to remind that please do not start adding nitrate to RAS, as the levels discharged to the environment needs to be controlled. During the H_2Salar project, Dr. Letelier-Gordo and his student MSc. Julie Hansen have documented that by agitating water, hydrogen sulfide is stripped faster from water that when being oxidized with oxygen. This means that degassers could work as firewalls for removing hydrogen sulfide from water coming from biofilters before it enters the rearing tanks.

Dr. Letelier-Gordo suggests that the main control measure to avoid hydrogen sulfide production is to maintain a frequent backwash of biofilters, clean pipes, and improve fluid dynamics in the rearing tanks to avoid organic matter accumulation. He tells that there are some visual indicators on hydrogen sulfide being possibly formed, including black sludge (due to the oxidation of iron compounds with hydrogen sulfide) and white material/coating on top of the biofilters (indicating that hydrogen sulfide is being oxidized with oxygen into elemental sulfur).

Dr. Letelier-Gordo reminds that it is important to remember that RAS is a living system, where microbial processes and physicochemical water quality variables are tightly linked. The hydrogen sulfide production RAS is a symptom of malfunction, as oxygen is not reaching all parts of the system, which allows anaerobic bacteria (hydrogen sulfide producers) to grow, like gangrene forms in human body when blood is not supplied. Dr. Letelier-Gordo emphasizes thus the importance of the correct system design and frequent cleaning. He suggests that future research should focus on the ways of quickly detecting hydrogen production and finding countermeasures to oxidize hydrogen sulfide before it reaches the rearing tanks.

Author information:
Researcher Dr. Carlos Letelier-Gordo
Researcher Dr. Sanni-Leea Aalto
Technical University of Denmark, DTU Aqua, Section for Aquaculture, The North Sea Research Centre, P.O. Box 101, DK-9850 Hirtshals, Denmark

Original articles:

Letelier-Gordo, C.O., Aalto, S.L., Suurnäkki, S. and Pedersen, P.B., 2020. Increased sulfate availability in saline water promotes hydrogen sulfide production in fish organic waste. *Aquacultural Engineering*, *89*, p.102062.
Rojas-Tirado, P., Aalto, S.L., Åtland, Å. and Letelier-Gordo, C., 2021. Biofilters are potential hotspots for H_2S production in brackish and marine water RAS. *Aquaculture*, *536*, p.736490.

Related projects:
Aquasulfat: https://orbit.dtu.dk/en/projects/sulphate-removal-by-membrane-filtration-technology-to-reduce-the-
H2Salar: https://nofima.no/en/project/h2salar/

Webinar Announcement:

Down the rabbit hole- unravelling H_2S in RAS

DATE: 8th June: TIME: 17:30 CEST

Dr. Sanni Aalto and Dr. Carlos Letelier-Gordo, DTU Aqua

In the webinar, Dr. Aalto and Dr. Letelier-Gordo will present results on H_2S production dynamics and microbiology gained in the laboratory experiments under different salinities, carbon sources, carbon to sulfate ratios and in different marine RAS compartments (fish organic waste, water, and bioelements)

Note: as member, you do not have to register, but you will receive an email with zoom link 3 hours before the seminar

Industrial Spotlight

Oxygenation Strategy for RAS using Pressurized Packed Columns

By KC Hosler, P.Eng. and Ben Briese, EIT – PR Aqua ULC

The Pressurized Packed Column (PPC) is a highly effective oxygenation technology for use in aquaculture applications. A PPC consists of a pressure vessel filled with packing media, a pump, control mechanisms for oxygen addition and pressure relief, and interconnective plumbing. The PPC provides an environment of rapid gas exchange by increasing both the partial pressure of oxygen, and by increasing the gas-liquid surface area.

Figure 1: Fiberglass pressurized packed column from PR Aqua

By Henry's Law, the solubility of a gas in a liquid is directly proportional to the pressure of that gas at the surface of the liquid. Due to the elevated pressure inside the vessel, and the injection of pure oxygen gas, the partial pressure of oxygen within a PPC can be as much as 50x that of oxygen in atmospheric air. The elevated partial pressure is the motive force driving both the speed of gas transfer and the total amount of gas that may potentially be absorbed.

For example, at an operating pressure of 100 psig of an oxygen rich atmosphere, the saturation concentration of oxygen in freshwater at 10°C is 416 mg/L compared to 11 mg/L at normal atmospheric conditions. The saturation concentration within the vessel represents the maximum potential gas that may be transferred into the water.

This potential is realized only when you also provide the opportunity for the gas transfer to occur. The use of random packing media inside the PPC vessel break water into droplets and thin films, increasing the contact between gas and liquid. The height of the packing bed, which is defined by total vessel height and the water level within the vessel, also affects the total contact time. Packing bed depth in a PPC is typically greater than 1.5 m (60 in).

As a result of high pressure and high packing depth, PPCs can achieve very high oxygen supersaturation levels (commonly >2000% of saturation at atmospheric conditions) at a very high transfer efficiency (>98%). Addition advantages of PPCs including a low footprint (due to a high hydraulic loading rate), and rapid response to changing oxygen flow rates (which allows for automated operation in response to dissolved oxygen levels).

The disadvantages of PPCs include relatively high capital cost, energy requirement, and complexity. However, when applied appropriately, these disadvantages may be diminished and the PPC can be one of the most cost-effective oxygenation solutions for aquaculture facilities.

Application

A typical application is to use a PPC to achieve a very high oxygen level in a small side stream flow, and then either blend the oxygenated water with the main process flow or deliver it directly to the culture tanks. Care must be taken in design to ensure that off-gassing does not occur in the conveyance piping after oxygenation. Often it is advantageous to have the injection point as close as possible to the fish tank (or direct into the fish tank) to limit potential for off-gassing.

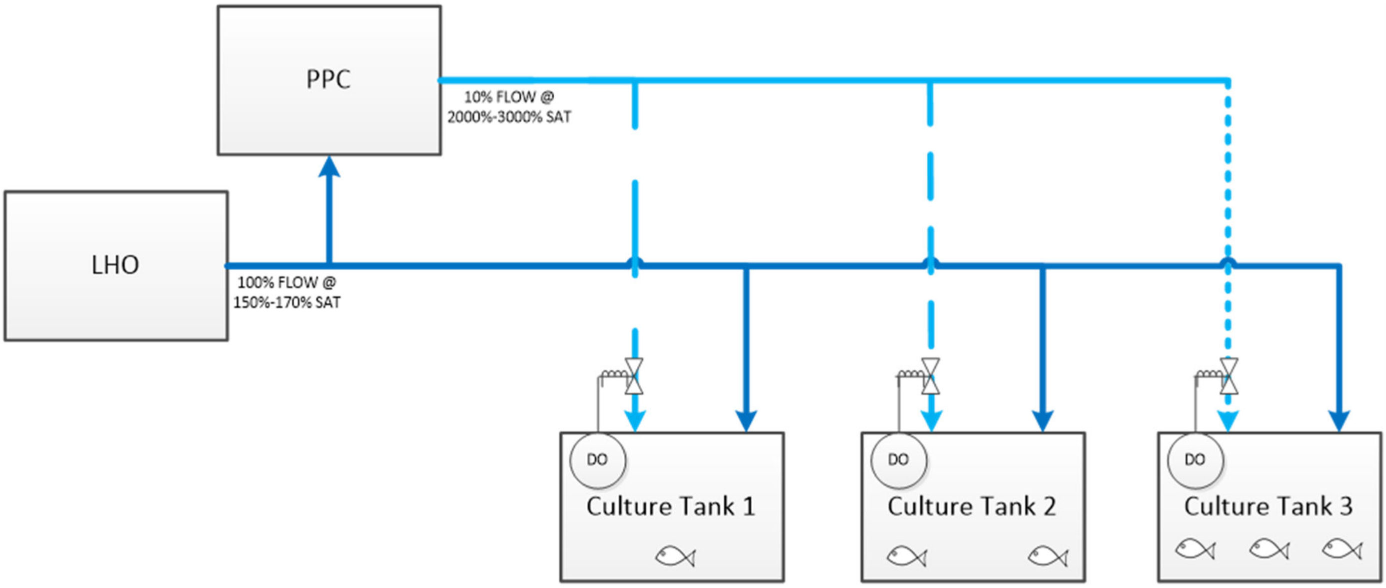


Figure 2: Highly effective oxygenation strategy using both LHO and PPC

At PR Aqua, one of our preferred oxygenation strategies for RAS involves the use of PPC in combination Low Head Oxygenator (LHO). The LHO, which operates at less than 1.0 m of hydraulic head, is a cost-effective method of achieving moderate oxygen levels in large flows. Because of its low operating pressure, the LHO also has the ability to displace dissolved nitrogen as oxygen is added, providing protection against nitrogen supersaturation and allowing the use of low-cost generated oxygen (which has an elevated nitrogen content). However, LHO are slow to respond when operating conditions change and they perform best when both water and oxygen flow rates are consistent. The LHO is most effective when installed centrally and used for setting a consistent baseline oxygen level for all culture tanks. Another technology is required for responding to the rapid fluctuations in oxygen demand that can occur at each tank during feeding, by diurnal variations in fish activity, or during fish transfer and other stress events.

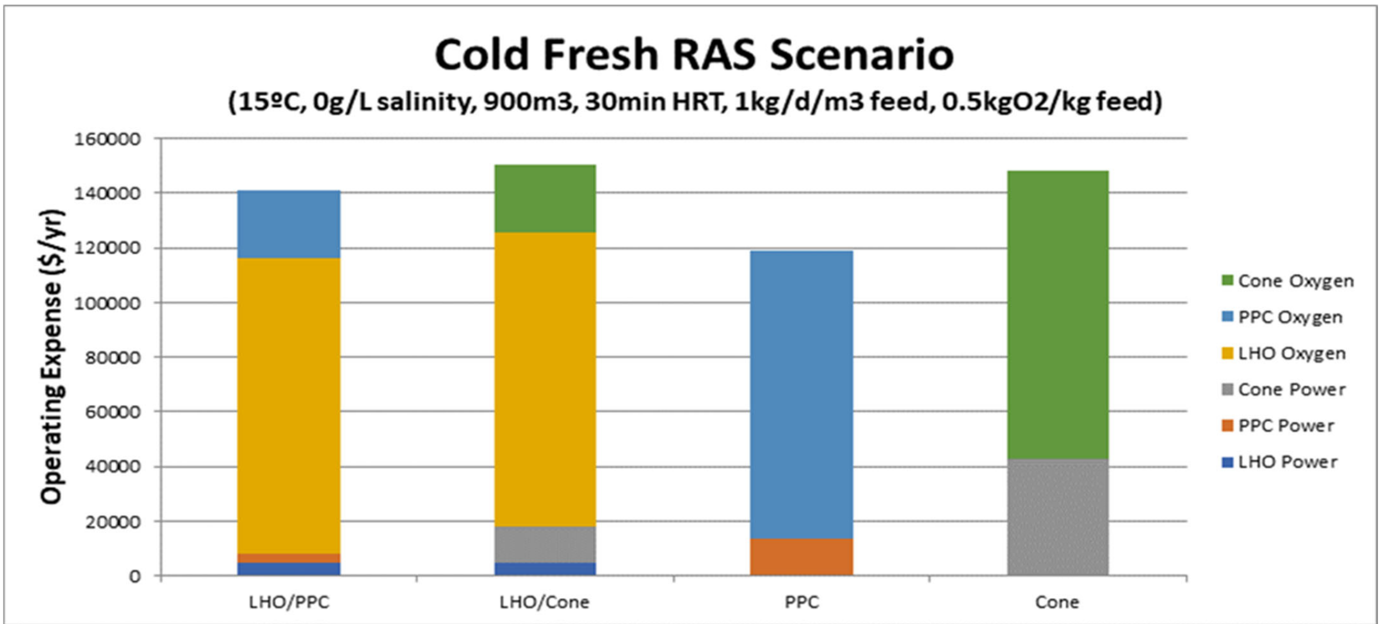
The PPC is an optimal choice for this application as it responds very rapidly and may be self-modulated to maintain consistent oxygen levels. The PPC is generally installed to provide highly oxygenated water through dedicated distribution piping for injection at each culture tank. Solenoid valves at each tank automatically open as required based on dissolved oxygen monitoring at that tank. As valves open and close, pressure changes in the distribution piping cause the PPC pump speed to automatically adjust, maintaining the target pressure within the PPC vessel to ensure optimum conditions for oxygen transfer. Oxygen flow into the vessel is also automatically regulated based on the rate of oxygen absorption which is indicated by the water level within the vessel.

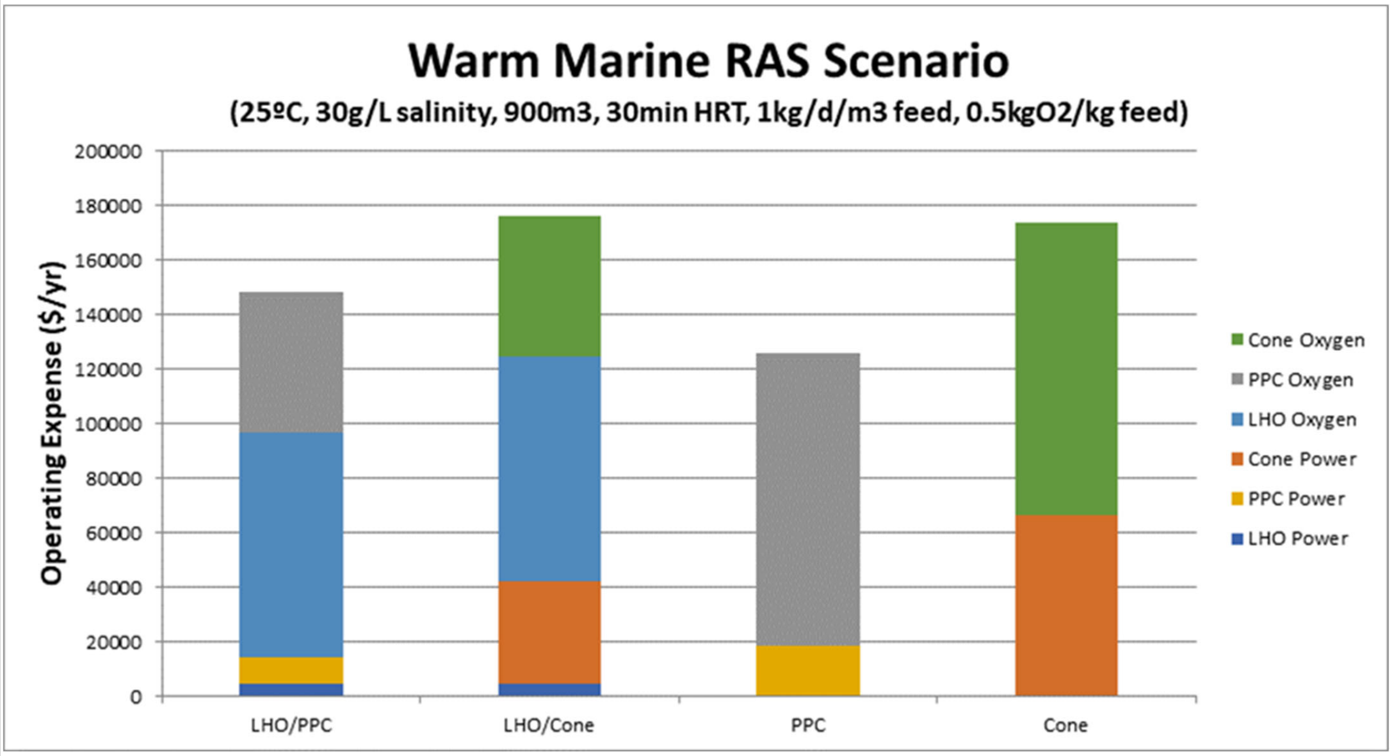
This combination of high pressure and lower pressure oxygenation technologies has been found to be highly effective in optimizing capital and operating costs while realizing all the benefits of each individual technology.

- The LHO provides much of the oxygen load at very low operating pressure, allowing the size and cost of the PPC to be minimized.
- Because the PPC manages the variable load at the tanks, the LHO may be operated under stable operating conditions and at its peak oxygen transfer efficiency.
- The energy intensive high-pressure pumps associated with the PPC only operate as much as required, turning down or off to conserve energy when oxygen demand is low.
- High pressure operation of the PPC allows for downsizing of expensive control valves for injection of oxygenated water at the tanks.
- The LHO may also be used for ozone contact, for control of dissolved nitrogen levels, and may be used with generated oxygen for further operating cost reduction.

Case Study

The following case study compares the operating expense of various oxygenation device configurations for both cold freshwater and warm marine scenarios. The operating expense assumptions were based on oxygen and electrical usage at rates local to Vancouver Island, BC, Canada (\$0.65/kg O_2 and \$0.10/kWh). Mechanical generation of oxygen was not considered in this study. The facility considered would be typical of a smolt production (15ºC, 0ppt salinity) or marine grow-out (25ºC, 30ppt salinity) module, consisting of a culture volume of 900m3, turning over at a rate of two (2) culture volumes per hour (30min HRT). A feed rate of 1.0kg/d/m^3 culture volume is assumed, with an oxygen consumption rate of 0.5kg O_2/kg feed (by fish). It is assumed that aeration treatments upstream of oxygenation will achieve 95% DO saturation, while the mixed tank oxygen concentration will be maintained at 90% saturation. The case study considers the use of a Low Head Oxygenator (LHO), Oxygen Cone, and Pressurized Packed Column (PPC) in various combinations.





The specific configurations compared include LHO/PPC pairing, LHO/Cone pairing, PPC only, and Cone only. Where LHOs were utilized, they were assumed to provide a 170% saturation baseline oxygen concentration. These were assumed to operate with a water level differential of 0.85m (2.3ft) – inclusive of orifice stand over and fall height. RAS recirculation pumps were considered to operate at 75% efficiency while PPC and Oxygen Cone pumps have an assumed operating efficiency of 70%. The graphical results indicate that for both cold fresh and warm marine scenarios, the PPC has the lowest operating cost of the four oxygenation configurations analyzed. The LHO/PPC pairing operates with the lowest power consumption, followed by the PPC, LHO/Cone pairing and the Cone. Oxygen usage is similar for both the PPC and Cone, while the LHO consumes more oxygen (lower transfer efficiency).

While the results shown are specific to resource costs for Vancouver Island, BC. In all cases the PPC or PPC/LHO pairing will have the lowest operating cost independent of regional resource cost variations. However, the other benefits of the LHO/PPC pairing (as discuss above) generally makes this solution more advantageous overall for RAS applications.

PR Aqua ULC

PR Aqua is a leading aquaculture design and technology provider based in British Columbia, Canada. For more than 20 years, PR Aqua has been providing integrated water treatment and fish handling solutions for both the public and commercial aquaculture industries.

The PR Aqua team is a group of project management, engineering, and operations professionals, with specific expertise in aquaculture systems design, construction, and operation, specializing in Recirculating Aquaculture Systems (RAS). We support our clients with a broad range of services including project planning, engineering design, delivery of specialty process equipment, construction support, and startup and training services.

Upcoming Events 2021

AQUACULTURE AMERICA 2021

San Antonio, Texas, USA August 11-14 2021 New dates

———————————————————————————————-

ASIAN PACIFIC AQUACULTURE 2021

Surabaya, Indonesia Sept 7-10

———————————————————————————————-

WAS North America & Aquaculture Canada 2021

St John's Newfoundland, Canada, Sept 26 – 29 New Dates

———————————————————————————————-

AQUACULTURE EUROPE 2021

Madeira, Portugal Oct 5-8

———————————————————————————————-

WORLD AQUACULTURE 2021

Merida, Mexico November 15-19

———————————————————————————————-

AQUACULTURE AFRICA 2021

Alexandria, Egypt December 11-14 new dates

AES Sponsors

YSI Inc.

1700/1725 Brannum Lane

Yellow Springs, OH 45387

Tel: 937-767-7241

environmental@ysi.com

www.ysi.com

Aqua Logic, Inc.

9558 Camino Ruiz

San Diego, CA 92126

Tel: 858-292-4773

info@AquaLogicinc.com

www.aqualogicinc.com

PR Aqua, ULC

711 Poplar St

Nanaimo, BC V9S 5L8

ph: 250-714-0141

info@praqua.com

www.praqua.com

Megasupply

3559 NW 82nd Avenue

Miami, FL 33122

ph: 305-381-0210

orders@megasupply.net

www.megasupply.net

Our sponsors are an integral component to the society and we encourage you to reach out to them when you are seeking products or services.

Interested in becoming a sponsor?

Sponsorship of the AES includes:

- Listing your company as a sponsor in the AES News
- Posting your company as a sponsor on the AES webpage
- Annual membership and journal subscription

If you are interested in becoming a sponsor please visit www.aesweb.org/sponsors or contact **info@aesweb.org**

AQUACULTURAL ENGINEERING SOCIETY

AES Officers & Board of Directors

Carlos Letelier, PhD
Denmark
President

Maddi Badiola, PhD
Spain
1st Vice President

Matt Campbell
USA
2nd Vice President

Astrid Bulan Holan
Norway
Past President

Tim Pfeiffer, PhD
USA
Secretary/Treasurer

K.C. Hosler, P.Eng
Canada
Director

Mark Schumann
Germany
Director

Paulo Fernandes, PhD
Norway
Director

Farshad Shishehchian, PhD
Singapore
Director

Sanni Aalto, PhD
Denmark
Director

John Colt, PhD
USA
Administrative Assistant

THE AQUACULTURE ENGINEERING SOCIETY

EMAIL: info@aesweb.org **WEBSITE: www.aesweb.org**

To ensure receipt of our email, please add info@aesweb.org to your address book.