Recirc Today — A SPECIAL SECTION ON WATER RE-USE AND RECIRCULATION

Ozone Safety
in Aquaculture Systems

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Ozone is a dangerously reactive, oxidizing gas. By itself it is not combustible, yet it poses a serious fire and explosion risk by reacting with other combustible materials. It is very toxic, and the US Occupational Safety and Health Administration (OSHA) has set a time-weighted average (TWA) for an 8-hr human exposure to ozone gas at a maximum limit of 0.1 ppm. The 10-minute short-term exposure limit (STEL) is 0.3 ppm. Exposure to ozone gas at 5 ppm can be immediately dangerous to life and health. Potential effects include dryness of the mouth, coughing, and irritation of nose, throat, and chest, difficulty in breathing, headache, dizziness, and fatigue. Ozone can also irritate the eyes by causing pain, lacrimation, and inflammation. It is important to note that the detectable odour threshold for ozone gas varies widely. Ozone has a sweet smell that is noticed by some at a concentration as low as 0.005 ppm; others may not detect it until the concentration is as high as 2.0 ppm.

Material Safety Data Sheets must be posted prominently.


Hand-held ozone sensor

Ozone and Water Quality

Ozone is now commonly used for disinfecting water in intensive aquaculture and seafood processing applications, and more recently in recirculating aquaculture systems. Ozone's strong oxidizing potential breaks down, or helps to remove fine- and colloidal solids, organic compounds, nitrite, and pathogens. Its effectiveness depends on concentration, contact time, pathogen loads, and the concentration of organics and other constituents in the water. Depending upon the system design and the species being farmed, the optimum ozone dosage rate can be highly variable. However, recent research at the Conservation Fund Freshwater Institute shows that only modest ozone dosages in combination with a UV irradiation dose of 50 mW-sec/cm² in a well designed RAS, (e.g., one with an effective solids removal system) can give nearly complete bacterial inactivation in the recirculating flow.

Production System Risks

Just as critical as human exposure is the risk of exposing fish to high ozone concentrations, which can produce gross tissue damage and even kill the fish. The dissolved ozone concentration that damages gills or kills rainbow trout is reported to be between 0.008 and 0.06 ppm. Dissolved ozone can destroy the epithelium covering the gill lamella, resulting in a rapid drop in serum osmolality, and if mortality does not occur immediately, can leave the fish highly susceptible to microbial infection. The first signs of exposure to toxic concentrations are noticeable changes in fish behavior. Fish stop feeding and congregate near the surface and sometimes gasp for air. Their swimming behavior becomes progressively erratic, attempts to jump out of the tank increase and some fish show darting behavior followed by listless swimming. Fish then lose vertical equilibrium and became pale, with vertical patches of dark pigment on the sides of the body. Fish that reach this latter condition rarely survive. Gills of fish exposed to high levels of ozone show excess mucus, hyperplasia, and aneurysms.

Additional concerns arise when ozonating brackish or seawater systems. The bromine- and bromate by-products that can result from ozonating water that contains any bromide are also toxic to fish, and have a much longer half-life than dissolved ozone itself. When ozonating brackish or seawater systems, restrictions on the ozone dose or the oxidative reduction potential (ORP) are sometimes used to minimize bromine production. For example, modest levels of ozone can be applied safely to seawater RAS to improve water quality, and it is also possible to control bromine accumulation using high dosages of UV irradiation


Cyclobio fluidized sand bio-filter at the Conservation Fund Freshwater Institute. The CO2 stripper is stacked directly above a low head oxygenator and UV irradiation filter. The LHO unit is used to transfer an ozonated oxygen feed gas into the 4,800 l/min recirculating flow.

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Ozone generator and high-concentration ozone gas monitor used at the Conservation Fund Freshwater Institute.

Ozone generator emergency shut-off should be located OUTSIDE the generator room!

or activated carbon filtration (or both). Bromate production, on the other hand, can be minimized during ozonation by maintaining a modest concentration of total ammonia nitrogen.

Long-term ozone use can also introduce some risk to bio-filter performance. When nitrite is removed primarily by ozonation over an extended period, there is the potential for losing nitrifying bacteria. If ozonation were to suddenly cease, then a potentially dangerous nitrite spike might follow. If fewer nitrate-forming bacteria were present, the bio-filter would be less capable of converting nitrite to nitrate. This complication does not always occur: for example in an RAS that incorporates a highly efficient bio-filter that does not export nitrite.

Design Considerations

Ozone is generated on-site with a commercial ozone generator and must be used immediately. Generating ozone involves using a dried air- or oxygen gas feed, and an excitation of oxygen molecules to create atoms of oxygen (O) that bond to molecules of oxygen (O_2) in the feed gas to create ozone (O_3). Generating and transferring ozone to the culture system requires proper design and construction of reactor and transfer mechanisms for safe and effective ozone use. A fully enclosed system using type 316 stainless steel for all materials, piping, and valves (with Teflon gaskets and membranes) is recommended for use with high concentrations of dry ozone gas. There are several locations where ozone may be injected into an aquaculture system. Choosing this location will depend on the results desired, and must take into account the effect of residual O_3 concentrations on the system, fish stocks, effluent, and personnel.

Engineering Controls

Due to the risk of fire and explosion electrical sparks, heat, and intense light flashes must be avoided. A mechanical ventilation system should be operating at all times to eliminate any build up of ozone gas in and around fish production and ozone generation rooms. Ambient ozone gas monitors should be installed close to the ozone generator, and in a central location of the production area. To be conservative and effective, these monitors should be connected to alarms (audible and visible) that will engage at levels below the TWA, of 0.07 ppm. Hand-held ozone detection devices should also be available to make spot-check measurements around piping and poorly ventilated areas, e.g., sumps and low-lying vessels. Concentrations of ozone in air that are measured at the dedicated monitoring locations, and at specific locations tested with the hand-held unit should be recorded. In addition, there should be controls that will shut off ozone generation in the event that the water supply at the injection site becomes too low, reducing the likelihood of ozone gas escaping into the room. Emergency shut-off switches controlling the ozone generator should be located outside the ozone generation- and ozone transfer rooms (i.e. outside the building) eliminating the need to enter the building if an emergency shut-down is required.

Production System Safety Measures

Ozone monitoring instruments and analytical capabilities are vital components to the safe management of the production system. A dissolved ozone analyzer, indigo method reagents and supplies, and/or an oxidation reduction potential (ORP) sensor should be utilized routinely to screen the culture tank for any build-up of dissolved ozone. If fish show signs of ozone stress, if the ozone concentration in the culture tank meets or exceeds 0.01 ppm, or if the ORP measured in the culture tank exceeds approximately 350 mV in freshwater, then the ozone generator should be turned off immediately. Continuous on-line monitoring instrumentation (e.g ozone analyzer or ORP sensor) can be placed at the inflow to or inside the culture tank, and connected to the ozone generator with a shut-off mechanism that would be activated toxic ozone levels are encountered.

To help prevent toxic dissolved ozone concentrations in the culture tank, encourage dissolved organic carbon and nitrite in the system by ensuring that fish are fed whenever ozone is being applied. The mass of ozone being applied should be no greater than approximately 15-25 g ozone per kg of feed added to the system. This is a strong enough dose to achieve satisfactory water quality.

Personnel Protective Measures

The first and foremost concern is for the health and safety of the personnel. Everyone who could potentially be exposed to ozone gas must be familiar with the Material Safety Data Sheet (MSDS) for ozone. This document, and a placard indicating when ozone is in use, should be posted at the entries to the production- and ozone generation rooms. Staff should be familiar with the LED screen on the ozone generator, and the dedicated ozone gas detection equipment, so that they can identify when ozone is being generated. They should know the location and operation of the ventilation fans, the hand-held and dedicated monitoring instruments, and all safety procedures.

If the ozone detector alarm is activated in the production or generation room, the recommended actions are as follows:

1. Exit the room immediately.
2. Go to the control switch located outside of the room or building, and turn off the ozone generator.
3. Ensure that the room ventilation fan is operating.
4. Contact the designated 'ozone safety officer,' who will inform all staff that a leak has occurred, and address any questions or concerns that arise.
5. Do not return to the room for at least 30 min after the ozone generator has been shut down, and the room has been well ventilated.
6. Return to the production and generation rooms with a hand-held ozone monitor to ensure that room air concentrations are below the TWA (<0.1 ppm ozone) before allowing others to return. To be entirely safe, the operator returning to monitor the room should wear a supplied air respirator (SAR) that meets the company's Respiratory Protection Program (RPP).

These procedures are used at the Conservation Fund Freshwater Institute. Others can develop their own written safety procedures by referencing this article and reviewing local site-specific conditions with their own Safety Committee. Implementing these types of measures to protect personnel and components of the aquaculture system can reduce the risks and hazards associated with using ozone as a disinfectant, and its safe and effective use can lead to strong improvements to the productivity of your aquaculture system.

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