Gas Super-Saturation – Causes and Solutions

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Water supersaturated with dissolved gases has long been a source of health problems for fish, both in natural waters and aquaculture operations.

Gas super saturation occurs when the partial pressure of one or more gases becomes greater then that of the atmosphere. The blood and tissue of fish will quickly reach equilibrium with its surrounding environment. Thus, if the surrounding environment is supersaturated, the fish's blood and tissue will also become supersaturated. Unfortunately, once in the blood and tissue, the supersaturated gases may come out of solution to form bubbles (embolism) which can physically block circulation and lead to death.

Gas super saturation can occur in a variety of ways. The list below describes some of the more common causes of gas saturation in land-based aquaculture:

- Hole on the suction side of a pump or leaks in pump seals. If air is allowed to enter on the suction side of a pump, the subsequent venturi effect and compression of air bubbles as the water passes through the pump can cause super saturation.

- Heating of water more then 6C. If water already saturated with air is suddenly heated, super saturation could occur.

- Injecting air at depth. Increasing water depth increases the gaseous carrying capacity of water. The greater the depth at which air is injected, the greater the super saturation will be.

- Pumping water from depth- water pumped from deep wells can often be saturated with one or more gases. Once the water is pumped to the surface, the reduction in pressure can cause these gases to become supersaturated.

Super saturation resistance is species, gas and environment specific. For instance, inert gases such as argon, radon and nitrogen are particularly harmful, as most finfish do not have the physiological capability to cope with these gases. However, gases such as oxygen and carbon dioxide can be tolerated at much higher concentrations due to the fishes metabolic pathways, designed to use oxygen and remove carbon dioxide.

In general terms, total gas saturation should not exceed 103% to protect salmonid eggs, fry and fingerlings and 110% to protect salmonids up to smolt size.

The following provides a list and general description of the more common gases observed in ground or surface waters:

Carbon Dioxide

It is common knowledge that carbon dioxide is a major product of fish respiration in intensive aquaculture operations. As fish respire, they consume oxygen and release carbon dioxide. For every 1 kg of oxygen consumed, salmonids will release approximately 1.4 kg of carbon dioxide to the surrounding water.

However, carbon dioxide can also be supersaturated in make-up water as well. Carbon dioxide concentrations are much higher in soil versus air (due to bacterial respiration and organic decay). As groundwater percolates through soils, carbon dioxide concentrations can increase and accumulate at depth.

In surface waters of high productivity, phytoplankton or aquatic plants can cause carbon dioxide super saturation through respiration at night.

In general, carbon dioxide levels above 20 ppm can lead to stress. Although mortality may not occur, even at levels of 30-40 ppm, the stress created from these elevated levels can lead to substantial mortality upon transfer to ocean cages.

Carbon dioxide can be easily air stripped using standard degassing technology.

Nitrogen & Argon

Both are biologically inert gases and are the typical cause of gas bubble disease in fish. Nitrogen and argon typically become supersaturated as a result of rapid temperature increases (greater then 6C) or entrapment of air under pressure (eg. aeration at depths greater then 6 ft of water, saturated well water pumped from depth, hole in suction side of pump).

Nitrogen and argon can be easily air stripped.

Methane

Can occur in the sediment of deep lakes or ocean bottoms or deep wells where high nutrient levels and anoxic conditions are prevalent.

Can be easily removed via air stripping.

Hydrogen Sulfide

Can occur in the sediment of deep lakes or ocean bottoms or deep wells where high nutrient and sulfate levels occur along with anoxic conditions. In the absence of oxygen, certain bacteria can reduce sulfate ions, producing hydrogen sulfide as a by-product.

Hydrogen sulfide is highly toxic to aquatic animals. For salmonids, levels greater then 0.003 mg/L can lead to mortality.

Hydrogen sulfide is highly soluble in water making it impractical to use air stripping as a means of removal. Alternatively, ozone can be used to destroy hydrogen sulfide.

Ammonia Gas
Unionized ammonia is highly toxic to fish. The suggested limits are:

< 0.0125 mg / L for salmonid fry and fingerlings
< 0.02 mg / L for salmonid adults

Ammonia is a common by-product of fish metabolism. As a general rule, approximately 3% - 4.5% ammonia is produced per Kg of feed consumed. The literature generally states 3% ammonia production per Kg feed. However, this 3% figure is based upon trout feed having a protein content of approximately 35%. Atlantic salmon feed has a protein content of approximately 50% and hence has a higher production of ammonia per Kg of feed consumed.

Ammonia can also occur in groundwater supplies either as naturally occurring concentrations or as a result of pollution from septic systems, agriculture or, municipal discharges.

Ammonia is highly soluble and cannot be air stripped. Ozone will oxidize nitrite but will not affect unionized ammonia. As a result, biofiltration is commonly used in intensive aquaculture systems to remove ammonia.

With a recirculation application, if high ammonia levels are experienced in make-up water, the water can be simply put directly through the biological filter.