

Hydrolab's Total Dissolved Gas (TDG) probe is a submersible total dissolved gas pressure sensor intended to monitor total dissolved gas pressures in a variety of natural waters. The probe utilizes a gas permeable membrane tube, which is permeable to all gases including water vapour. As such, the probe will measure Total Gas Pressure (TGP) directly. This type of analysis is commonly called the membrane diffusion method (MDM) and most closely models the behaviour of fish gills. The sensor provides a calibrated and temperature compensated output in mm Hg. Overall response time is 2 minutes in 11°C water. The TDG sensor requires cleaning occasionally to remove bio-fouling. The bio-fouling only affects response time and not calibration. Depending on the desired



accuracy, calibration may only need to be performed once per year. Membrane cartridges may be replaced in the field and have no effect on the calibration.

Supersaturation

Water can become supersaturated with atmospheric gases by various means. Heating and air entrainment in spilled or pumped water are the most common. The primary sign of gas supersaturation is the formation of bubbles on submerged surfaces or within the vascular systems and tissues of aquatic organisms.

Gas supersaturation can limit aquatic life and interfere with water treatment processes. Levels of supersaturation lethal to aquatic organisms have been found in springs, rivers, wells, estuaries, and seawater. Gas supersaturation can be induced in pumped or processed water intended for drinking, fish hatchery supply, and bioassays. Seasonal and other temporal variations in supersaturation may occur. Because the rate of equilibration may be slow, supersaturation may persist in flowing water for days. Excessive dissolved gases therefore, can persist far from the source of supersaturation.

Bubble Formation

Gas bubbles form only when the total dissolved gas pressure is greater than the sum of compensating pressures. Compensating pressures include water, barometric and, for organisms, tissue or blood pressure. The total dissolved gas pressure is equal to the sum of the partial pressure of all the dissolved gases, including water vapour. Typically, only nitrogen, oxygen, argon, carbon dioxide, and water vapour pressures need to be considered in most natural waters. Gas bubble disease of fish or other aquatic organisms is a result of excessive, uncompensated gas pressure. A single supersaturated gas such as oxygen or nitrogen may not necessarily result in gas bubble disease because bubble formation depends on total dissolved gas pressure.

Gas Bubble Disease

Gas bubble disease is a condition, which affects a wide variety of fish and other aquatic animals in waters (fresh or saline), which are supersaturated with atmospheric gases. This condition has been recognized since the turn of the century. Gorham first described in 1901 the symptoms of gas bubble disease: gas bubbles or blisters in the fins of affected fish, and in other tissues, including behind the eyeballs to produce "pop-eye". Numerous instances of gas bubble disease have been reported in the past eight decades, gas supersaturation variously resulting from air



entrained in water supply systems, naturally supersaturated well or spring water, intensive photosynthesis, warming of hatchery of aquaria water supplies, and air entrainment below spillways of major dams. Since the mid-1960's extremely serious mortalities because of gas bubble disease were recognized in the Columbia River System, and a large number of papers have subsequently been published concerning this problem. For detailed discussions of the most recent research results, the collection of papers published as a special module in the November 1980 issue of the Transactions of the American Fisheries Society is recommended.

Symptoms

For juvenile salmonids, the first external sign of gas bubble disease reportedly is very small bubbles along the lateral line. These bubbles are not easy to recognize, and in any case, their presence or absence is not conclusive proof of G.B.D. The most pertinent symptom to look for is the appearance of bubbles of air in the gill blood vessels. Two additional symptoms for juvenile salmonids are bubbles or blisters under the skin, and particularly in the fin rays, as well as noticeable abnormal behaviours: adult salmonids show similar symptoms and additionally frequently develop gas blisters in the roof of the mouth. Salmon fry develop bubbles in the yolk sac and between the yolk sac and the perivitelline membrane, these bubbles often result in noticeable erratic swimming. Salmon eggs generally appear quite tolerant of gas supersaturation.

Mortality reportedly results when gas bubbles are present in sufficient quantity in the heart to prevent movement of the blood. Various sublethal effects have also been reported, most importantly blindness, decreased tolerance to stress, loss of lateral sense, and secondary infections. Affected fish may recuperate if exposed to equilibrated water, or to hydrostatic pressure.

Species, life-stage, size and generics all seem important in determining a fish's tolerance to supersaturated waters. Steelheads have been

reported to be least tolerant of salmonids. As rule-of-thumb, eggs and newly hatched alevins seem most tolerant to supersaturation. However, advanced yolk sac, newly buttoned up and swim-up stages seem to be least tolerant of waters supersaturated with atmospheric gases. Fingerlings are more tolerant, and yearlings and adults still more tolerant.

Only two atmospheric gases, nitrogen and oxygen are present dissolved in water in quantities important re gas bubble disease. Experiments have shown that it is the summed tension of nitrogen plus oxygen – called Percent Total Saturation – which is most important in determining whether gas bubble disease is likely to occur or not. Less important is the fact that for two waters having identical percent total saturation, that the one having greater percent saturation of oxygen will generally have somewhat less effect on the fish.

Safe Level Limits

Safe limits generally are segregated into wild/natural circumstances, where behaviour and hydrostatic pressure can modify the exposure by horizontal and vertical movements away from dangers, and captive environments such as aquaria, hatcheries, or laboratories, where conditions not only preclude escape but also include other significant stresses. Of these two realms, captive circumstances are more likely to cause illness or mortality from gas bubble disease and will do so sooner and at lower ΔP levels. ΔP is defined as the difference between total dissolved gas pressure and the ambient barometric pressure.

In the wild/natural circumstances, the limit of safe levels of gas supersaturation depends on the depth available to the species and/or species behaviour, but this limit usually occurs at a ΔP between 50 and 150 mmHg. Under captive conditions, the ΔP should be as close to zero as possible. For sensitive species and life stages, sublethal and lethal effects have been observed at ΔP of 10 to 50 mmHg.