OpreX™ Analyzers | Application Note

YOKOGAWA

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pH in Fish Farming

pH Process Liquid Analyzers

Water quality determines the success or failure of an aquaculture operation. Yokogawa's reliable pH process analyzers and sensors ensure the optimum pH for fish is controlled and maintained.

Introduction

Understanding the physical and chemical qualities of water is critical to successful aquaculture. Fish are totally dependent upon water to breathe, feed, grow, maintain a salt balance, and reproduce. Water quality determines the success or failure of an aquaculture operation.

pH is important in aquaculture as a measure of the acidity of the water. The pH scale ranges from 1 to 14. The quantity of hydrogen ions (H+) in water will determine if it is acidic or basic. A value of 7 is considered neutral, neither acidic or basic; values below 7 are acidic; above 7, basic.

The acceptable range for fish culture is normally between pH 6.5 and 9.0. Fish will grow poorly, and reproduction will be affected at consistently higher or lower pH levels.

Very high and very low pH values, respectively, greater than 9.5 and less than 4.5, are unsuitable for most aquatic organisms. Young fish and immature stages of aquatic insects are extremely sensitive to pH levels. Fish cannot survive in waters below pH 4 and above pH 11 very long (see Figure 1).

Example: Fish Farm Nets

pH	Effect on Fish
4	Acid death point
4 to 5	No reproduction
4 to 6.5	Slow growth
6.5 to 9	Desirable range for reproduction
9 to 10	Slow growth
> 11	Alkaline death point

Figure 1: The Effects of pH on Warm Water Pond Fish

Challenges

Monitoring and control of pH are critical. High pH levels (9-14) can harm fish by denaturing cellular membranes. Changes in pH can also affect aquatic life indirectly by altering other aspects of water chemistry. Low pH levels accelerate the release of metals from rocks or sediments in the stream. These metals can affect a fish's metabolism and the ability to breathe.

At a pH greater than 9, most ammonium in water is converted to toxic ammonia (NH_3), which can be fatal to fish. Moreover, cyanobacterial toxins can also significantly influence fish populations. pH is critical for the bacteria that clean the water and nitrifiers that remove excess nutrients.

Related challenges include maintenance of ammonia and alkalinity levels and buffering systems.

pH	12.2°C	16.7°C	20°C	23.9°C	27.8°C	32.2°C
7.0	0.2	0.3	0.4	0.5	0.7	1.0
7.4	0.5	0.7	1.0	1.3	1.7	2.4
7.8	1.4	1.8	2.5	3.2	4.2	5.7
8.2	3.3	4.5	5.9	7.7	11.0	13.2
8.6	7.9	10.6	13.7	17.3	21.8	27.7
9.0	17.8	22.9	28.5	34.4	41.2	49.0
9.2	35.2	42.7	50.0	56.9	63.8	70.8
9.6	57.7	65.2	71.5	76.8	81.6	85.9
10.0	68.4	74.8	79.9	84.0	87.5	90.6

Table 1: Percentage of Total Ammonia that is Unionized at Various Temperatures and pH

Ammonia

Fish excrete ammonia and lesser amounts of urea into the water as waste. Two forms of ammonia occur in aquaculture systems, ionized and unionized.

The unionized form of ammonia (NH_3) is extremely toxic while the ionized form (NH_4+) is not. Both forms are grouped together as "total ammonia." Through biological processes, toxic ammonia can be degraded to harmless nitrates.

In natural waters such as lakes, ammonia may never reach dangerously high levels because of the low densities of fish. However, a fish farmer must maintain high densities of fish and, therefore, runs the risk of ammonia toxicity. Unionized ammonia levels rise as temperature and pH increase (Table 1).

Example: Underwater View of Fish in Farm Nets

To determine the concentration of unionized ammonia, multiply the total ammonia concentration by the percentage that is closest to the observed temperature and pH of the water sample. For example, a total ammonia concentration of 5 ppm at pH 9 and 20°C would be:

5 ppm total ammonia X 28.5% = 1.43 ppm.

Toxicity levels for unionized ammonia depend on the individual species; however, levels below 0.02 ppm are considered safe.

Dangerously high ammonia concentrations are usually limited to water recirculation system or hauling tanks where water is continually recycled and in pond culture after phytoplankton die-offs. However, the intermediate form of ammonia--nitrite--has been known to occur at toxic levels (brown-blood disease) in fish ponds.

Example: Offshore aquaculture in floating fish farming cages of fish farm

Buffering Systems

A buffering system is employed to avoid wide swings in pH and is essential in aquaculture. Without some means of storing carbon dioxide released from plant and animal respiration; pH levels may fluctuate in ponds from approximately 4-5 to over 10 during the day. In recirculating systems constant fish respiration can raise carbon dioxide levels high enough to interfere with oxygen intake by fish and reduces the pH of the water.

Alkalinity

Alkalinity is the capacity of water to neutralize acids without increasing pH. This parameter is a measure of the bases, bicarbonates (HCO_3-), carbonates (CO_3-) and, in rare instances, hydroxide (OH-). Total alkalinity is the sum of the carbonate and bicarbonate alkalinities. Some waters may contain only bicarbonate alkalinity and no carbonate alkalinity.

The carbonate buffering system is important to the fish farmer regardless of the production method. In pond production, where photosynthesis is the primary natural source of oxygen, carbonates and bicarbonates comprise a storage area for surplus carbon dioxide. By storing carbon dioxide in the buffering system, it is never a limiting factor that could reduce photosynthesis, and in turn, reduce oxygen production.

Also, the buffering system prevents wide daily pH fluctuations.

Without a buffering system, free carbon dioxide will form large amounts of a weak acid (carbonic acid) that could potentially decrease the night-time pH level to 4.5. During peak periods of photosynthesis, most of the free carbon dioxide will be consumed by the phytoplankton and, as a result, drive the pH level above 10. As described earlier, fish grow within a narrow range of pH values and either of the above extremes will be lethal.

Example: Fishing ponds in the open ocean at coldest temperatures during the night

In recirculating systems where photosynthesis is practically non-existent, a good buffering capacity can prevent excessive build-ups of carbon dioxide and lethal decreases in pH. For catfish production, it is recommended that the fish farmer maintain total alkalinity values of **at least** 20 ppm. Alkalinities of at least 80-100 ppm are suggested for hybrid striped bass. For water supplies that have naturally low alkalinities, agriculture lime can be added to increase the buffering capacity of the water.

Solution

Several factors contribute to reducing the pH in ponds. Rain is acidic, usually with a pH of 5.2 to 5.6, but industrial pollution can lower it to 2.5. In areas with coniferous forests, rain percolates through the pine needles, making it even more acidic. Over time, this leaches all the minerals out of the soil. Also, the clay bottom necessary to keep a pond from leaking is acidic, and decaying plants can release additional acids. Agricultural lime or crushed limestone (calcium carbonate) will neutralize these acids and form a buffer to keep the pH from changing rapidly.

Example: A Trout Fish Farm

Rapid changes in pH, even within an otherwise survivable range, can be fatal to fish. While they can adjust their body chemistries as pH changes in the environment, this takes energy, which could instead used for growth and reproduction. Maintaining a constant internal pH in an extreme environment causes stress, making the fish susceptible to disease and parasites.

In a limed pond, phosphorus from fertilizer is in the soluble, orthophosphate form that plankton can use; other forms settle at the bottom. Finally, liming can increase the amount of carbon dioxide in water, which is used in photosynthesis. For these reasons, liming ponds has been shown to double bluegill production in ponds, without adding any fertilizer.

Summary

Measurement points: In the tank

Typical problems: Installation of the pH sensor at an appropriate location

Remedies: Using an immersion fitting with support for 2” pipe mounting accessories

pH can be measured using Yokogawa's 2-wire/4-wire pH Analyzer with a suitable immersion fitting and sensor.

Cleaning: Simply remove the pH sensor, clean the sensor following the provided instructions and re-install it.

Benefit: The pH sensor uses double junction electrodes, which provide long-term stability and durability.

More reliable and accurate pH analysis enables improvements to the end product quality.

Product Selection

Process Liquid Analyzer:

2-wire 24 VDC Loop-powered FLXA202 Analyzer

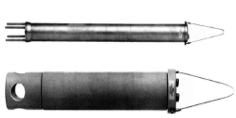
4-wire AC/DC Line powered FLXA402 Analyzer

Features:

- Dual sensor measurement on a 2-wire or 4-wire analyzer
- Indication of sensor health status
- Simple touchscreen operation
- Trending display up to 2 weeks
- Advanced process temperature compensation

Sensor Selection:

Analog and Digital SMART sensors are available. Analog options allow users to interface with a traditional system. SENCOM™ technology allows sensors to transmit and receive data when connected to a transmitter/analyzer or any PC.




The SMART digital sensors maintain sensor-specific measurement and calibration data on an integrated circuit to provide easy plug and play solutions.

The data management software optimizes sensor performance for enhanced reliability and process safety.

pH immersion fitting (such as FD20 series or equivalent) with FU20 pH sensor.

Features:

The FU20 combination sensor applies Yokogawa’s “Simply the Best” technology. The wide body sensors (26 mm diameter) hold four separate measurement elements in one unbreakable and chemically resistant PPS 40GF (RytonTM) body. The integrated industrial 3/4” tapered thread simplifies installation. Temperature fluctuations are compensated to extend the sensor life.

Digital SMART Option:

The re-usable smart adapter, SA11, offers full measurement parameter functionality for analog sensors equipped with a VarioPin (VP) connector and Yokogawa ID chip. The SA11 automatically recognizes the installed sensor and prepares the appropriate configuration.

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