APPLICATION REPORT
PROCESS ANALYSIS
LDO OPTICAL OXYGEN PROBE
TROUT FARMING

Reliable oxygen levels in trout farms with LDO

An adequate level of oxygen must be maintained in the water of fish farms. If the level is too low, fish production suffers. Stocking density, feed intake and resistance to disease are just three of the key variables that significantly affect profitability and are directly dependent on the oxygen concentration.
Kirsten and Alexander Tautenhahn have run a trout farm in Germany, since 1991. Oxygen levels at the farm have been monitored by HACH LANGE LDO sensors since July 2005. The ➔*accuracy of the measurements, also at high concentrations,* ensures optimal oxygen transfer even during the night, when there is no flow around the sensors. The ➔*rugged sensor* and extensive ➔*warranty* assure reliable long-term operation.

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The significance of oxygen for fish farming

Fig. 1: Trout eggs

Farm data

Water supply	Spring water
Water temperature	8-10 °C
Yield	50-150 l/s
Degassing	100 mg/l down to 8-10 mg/l
Annual production	3000 kg/l·s
Disease-free licensed farm	
Strictly separated stage production	
In-out principle	

Pure oxygen for fish farming

"Fish need oxygen… Oxygen is essential to life under water… Enriching the water with pure oxygen enables the farm's stocking density (weight of fish) to be increased, thus increasing production… By balancing out the weather related fluctuations in the oxygen level, feed intake and resistance to diseases are improved and growth is accelerated. An optimal supply of oxygen is a key factor in achieving a long-term increase in fish production". (Excerpt from: Linde AG, Lebenselixier für erfolgreiche Fischzucht, Reiner Sauerstoff steigert die Produktion ganz natürlich).

As the water temperature goes up, the amount of oxygen that can be transferred to the water by means of mechanical surface aeration goes down. At the same time, the amount of energy required for aeration rises sharply. At temperatures above 15 °C, it is therefore much more cost-efficient to use pure oxygen. Increasing numbers of fish farms are using pure oxygen to achieve the optimal level of oxygen saturation for the fish (100 %).

The scientific approach to fish farming

To the uninitiated, it might come as a surprise to learn about the significance of the oxygen supply to a trout farm. When it is said, for example, that temperature fluctuations cause stress, the main source of this stress is the lower oxygen concentration in the water at higher temperatures. The situation is especially critical when the fish are fed, as this results in higher levels of metabolic activity and, therefore, higher levels of oxygen consumption. Fish farmers prefer to use pure oxygen because it is more readily soluble in water. However, the continuous addition of too much oxygen would not only incur unnecessary costs but the fish would respond to such abundance by producing fewer red blood cells and becoming more suseptible to diseases. The only solution to this problem is precision measuring technology.

The water chemistry of fish farming is a complex subject. We have to make way for the sober reality of chemical equilibrium reactions.

An increase in carbon dioxide can push the pH of the water below 6.5 and increase its toxicity by allowing nitrate to form nitrous acid (HNO_2). However, if the plants assimilate higher amounts of carbon dioxide during the day and drive the pH above 8.5, the fish are confronted with an increase in the precipitation of lime and, depending on the concentration of ammonium (NH_4^+), are exposed to higher levels of ammonia (NH_3). There are so many substances that have to be kept in equilibrium! Without continuous monitoring of the pH and the ammonium concentration, there would be an almost incalculable risk.

Trout farming

Let us start at the beginning, Kirsten and Alexander Tautenhahn have run a large trout farm since 1991. The eggs come from the world's biggest producer – Troutlodge, Inc., in the USA.

Batches of about 800,000 eggs are regularly incubated (Fig. 1). After they have hatched, the initially tiny fish pass through several growth stages before

they reach the outdoor pools. The processes that take place in each new and spacious tank to which the fish are transferred as they grow older and bigger (Fig. 2) are always the same, namely:

- Regular automatic feeding every 10 minutes for 30-40 seconds, to prevent stress and avoid any turbidity which could obscure the food from the fish's sight
- Water circuits with up to 90 % recirculation water
- As required, 150-400 % oxygen enrichment and carbon dioxide degassing of the circulated water before it is returned to the tanks
- Laminar flow for stress free oxygen transfer and removal of waste products

Life in the outdoor pond

In the rearing tanks, the fish live in a mixture of fresh water, recirculation water and oxygen supersaturated water. When they are transferred to the outdoor ponds, their living conditions change enormously. The oxygen level in the water is maintained with the help of a drum aerator (Fig. 3). LDO oxygen sensors continuously monitor the oxygen concentration and automatically ensure additional aeration when the level falls below 10 mg/l (Fig. 4). Paddle wheel aerators keep the carbon dioxide and ammonia content of the water at acceptable levels.

The "automatic cleaning" is also rather different. The laminar flow is no longer able to remove all the solid waste particles, some of which settle firmly between the stones on the bottom and have to be removed during the next high-pressure cleaning session. The size and structure of the stones on the bottom are based on experience, as not every stone holds back the waste products and remains "settled" during high-pressure cleaning.

Fig. 2: One of the many stages for the fish on their way to the outdoor pond

Fig. 3: Outdoor pond with drum aerator

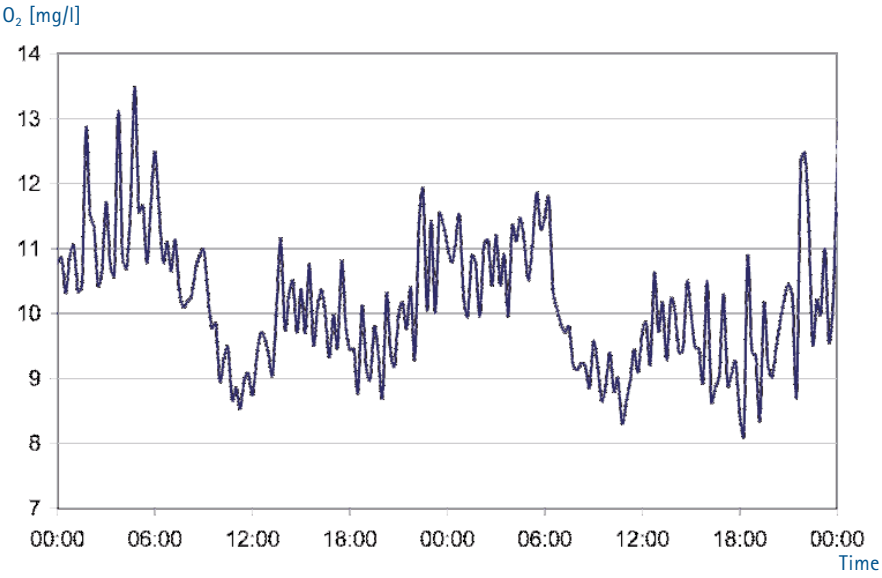

Fig. 4: LDO oxygen time-course curve from one of the outdoor ponds (values in mg/l O_2)

Successfully applied measuring technology

Fig. 5: LDO oxygen sensor in use

Process measuring instruments used

LDO oxygen sensor
Calibration-free sensor for measuring dissolved oxygen by the luminescence method. No interference by H_2S, reducing or oxidising substances; no polarisation time, no flow around the sensor necessary.

SC 100 controller
Universal controller for wall mounting, pipe mounting or control panel mounting. Two digital sensors can be connected via splash-proof connectors. Two analogue power outputs, three potential free changeover switches (5 A 115/230 VAC, 5 A 30 VDC), digital interface for bus connection (ModBus, Profi-Bus, LonBus).

The path to LDO

The trout stocks of the trout farm have been supplied with pure oxygen since 1998. Before July 2005, a system based on modified Clark electrodes was used to monitor oxygen content and regulate oxygen transfer. Design-related factors made the system's operation rather unpredictable. In particular, longer and more frequent maintenance was required when oxygen levels were high. Also, more than 90 % of all malfunction warnings (oxygen) were attributable to faulty measurements. Moreover, the low rate of flow around the probes during the night regularly caused faulty measurements to be obtained.

In July 2005, the farm switched over completely to the HACH LANGE LDO system (Fig. 5). Since then, false alarms caused by malfunctioning probes have been a thing of the past. So far, the probes have needed no maintenance (apart from regular cleaning, which is necessary for every type of probe).

Correct and reproducible values are obtained even when there is no flow around the LDO probes.

The monitoring was connected to a SC 100 controller via a digital BUS. The production process and the oxygen data can therefore be monitored from almost anywhere via the existing network. In our view this is a revolutionary new technology that will soon be in widespread use, especially in the intensive fish production sector.

LDO saves more than 7.000 euros per year

The Clark oxygen sensors that were replaced in 2005 sometimes showed concentrations of up to 2 mg/l below the actual oxygen level. Such low-bias readings resulted in more oxygen being transferred to the water than was necessary, so that oxygen consumption was at least 20 % too high equivalent to about 7.000 euros per year. And this figure takes no account of the additional costs attributable to false alarms and the greater maintenance requirement of the conventional measuring technology.

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