Aquaculture

Gaining a higher yield by using sensors in recirculation systems.

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The history of aquaculture dates back to antiquity. 8,000 years ago, mankind started cultivating fish with the aim of producing more food for society. Signs of those early plants are found everywhere on the planet. Even though aquaculture was an economic factor in those early ages, according to The State of World Fisheries and Aquaculture published by the Food and Agriculture Organization of the United Nations, the use of aquaculture in the production of fish has increased significantly during the last decades. From 1950 onwards, when one million tonnes of fish were produced in aquaculture, numbers rose to 68 million tonnes in 2013 and 82 million tonnes in 2018. Adding the amounts of aquatic algae (32.4 million tonnes) and ornamental seashells and pearls (26,000 tonnes), aquacultures generated a recordsetting volume of 114.5 million tonnes in live weight.

In 2018, aquaculture production reached a record high of 114.5 million tonnes in live weight.

In the same year, global aquaculture production had a farmgate sale value of 263 billion US dollars. The use of aquaculture in fishing provides a solution for many unsolved questions in the fishing industry. As more and more problems with overfishing in the global seas arose, aquacultures faced great challenges in providing the required capacity for producing fish. The problems were obvious: To run an aquaculture plant, a lot of water is needed. During breeding and nursery of the fish, water quality is reduced. Therefore, older plants had to get rid of that used water without transferring it to another use, like agriculture or fertilization. Of course, losing vast amounts of water creates a lot of economic problems. Aquaculture companies have to constantly provide fresh water to breed the fish, which leads to a big financial impact. The solution is the revaluation of the used water.

The economic problem of the huge amount of water needed has to be solved.

Fish breeding offshore and onshore

The term aquaculture refers to the cultivation of the natural produce of water. This includes fish, shellfish, algae or other aquatic plants. Aquaculture technology follows a certain scheme: Fish are bred and raised in freshwater ponds or offshore plants. After they reach a predefined level of maturity, the fish are extracted from the pond and used for further production. Aquaculture plants are often used as a method to culture pearls, farm salmon or to raise catfish and tilapia. Such plants can be constructed onshore and offshore: While offshore aquacultures tend to be very consumptive of resources due to the big mass of feed that is used to breed the fish, onshore plants use ponds and water circulation systems without affecting natural ecosystems. These farms are also known as land-based closed-containment systems (LCS).
Onshore aquaculture farms are highly technological agricultural production sites. The water flow must be managed efficiently, and numerous ponds have to be installed to raise the fish in an economic and ecological way. In addition, aquacultures consist of water storage and disposal tanks as well as pumps, pipes and filtration systems. To control this complex agricultural process, plants are controlled remotely with the help of digital control systems, sensors and water analyses in laboratories.

Challenges of aquacultural farming

Offshore plants have to reduce the impact on the environment.

Managing these different systems can be a challenging task for farmers. The ecological balance has to be maintained. This is especially a problem due to water pollution through fish food in offshore plants. Organic waste from the fish cages and ponds can have a significant effect on water quality and therefore on the development of the fish. With growing pollution, toxic algae might bloom. Countries such as Scotland, Chile and China have faced serious toxic algae blooms in recent years, which caused the death of thousands of wild fish and other sea dwellers. This environmental impact has drawn the attention of non-governmental associations that criticize the use of offshore aquaculture plants. As a result, farmers all over the world have stopped using conventional fish meal, which often consists of the trimmings and discards of commercial species and moved to a more vegetable-based food. To reduce the impact on the sea, aquacultures are more and more built on private land, where there is no direct impact on the marine ecosystem. However, even on land, some problems arise: Aquaculture farming can only be carried out by using a lot of fresh water. Often, this water is taken from deep wells. Even in onshore tanks, fish meal causes pollution, which leads to a constant water exchange in the ponds and a constant relocation of the fish. The high consumption of water can create economic concerns for local aquaculture farmers. To solve these different problems, farms have increased their use of technological systems such as the Recirculation Aquaculture System (RAS).

RAS: The answer to the challenges of onshore plants.

Gaining higher efficiency by using recirculation systems

The Recirculation Aquaculture System (RAS) is a technological solution which allows fish farmers to produce fish in a more efficient, economical and sustainable way. With RAS, responsible farmers can control all parameters in the production such as oxygen levels, temperature, light, salinity, pH measurement, stocking density, feeding rate and carbon dioxide ratio.

The main argument for the use of RAS is the reuse of the water during the production via mechanical and biological filters. With recirculation, the amount of water used in the process can be hugely reduced: While traditional fish farms use around 30,000 liters of water per kilogram of produced fish, recirculation systems are able to breed fish by using 3,000 liters of water per kilogram of fish in large outside aquaculture farms or even 300 liters of water per kilogram of fish in superintensive indoor farming systems.

The required amount of fresh water can be reduced by up to 99 percent.

This reduction is achieved by using different filters. An example of a recirculation based aquaculture farm can be pictured as follows: The water from the fish culture tank is transferred to a radial flow settler, where solids are extracted from the water. Afterwards, as the water flows through microscreen filters and biofilters, smaller particles are filtered. At the end of the process, the water quality is enhanced by pumping oxygen into the fluid. By doing so, polluted water can be reused, the aquaculture process becomes much more cost- and eco-efficient. Of course, these filters must not be overloaded.

Second solution: Improve the Feed Conversation Rate.

Managing the Feed Conversion Rate (FCR) can help preventing outages. The FCR describes how many kilos of feed are used for every kilogram of fish produced. For example, if 1.2 kilograms are fed to produce one kilogram of fish, the FCR is 1.2. Uneaten feed is very expensive and, in addition, leads to an unnecessary load on the filter system. The higher the FCR, the higher the amount of unused feed. To improve the Feed Conversion Rate in recirculation systems, feed suitable for RAS applications is available. This special composition is maximizing the uptake of protein in the fish while minimizing the excretion of ammonia in the water.

By using RAS and an optimized FCR, aquacultures can be designed far more efficiently and are able to provide a higher production yield to the fish farmer. Naturally, controlling RAS plants can be a difficult task for the farmer, therefore special sensors are a key to achieve the aim of an optimized aquaculture plant.

Sensors and RAS

Users of aquaculture plants face a lot of questions when it comes to a more efficient handling of the system. They want to save water and energy, reduce losses and environmental impacts and want to rely on a stable and predictable production. To achieve this, users need full and reliable control of the production parameters during the process. In particular, this includes monitoring of the equipment. Furthermore, critical points in the system must be identified to ensure a safe RAS process and to guarantee the availability of pumps, fans and additional equipment. By doing so, the operating costs can be reduced and the Feed Conversion Rate can be optimized. An indicator for the optimized use of RAS is the amount of makeup water required for each kilogram of feed delivered per day.

Reliable monitoring of aquaculture plants helps to improve and keep up the efficiency.

Sensors and PLC enable recirculation systems

A way to address these needs are sensors and structures which measure different parameters. The sensors have to offer security: They need to be available, high-performance and of high quality. Also, there has to be a device to connect the sensors and a possibility of gathering data. Usually, the controlling is realized by using a programmable logic controller (PLC) which connects sensors and controlling devices digitally. To prevent outages, sensors need to be connected in a secure and fault-proof way. Therefore, in addition to the selection of high-quality, robust sensors, it is crucial to use equally robust cables suitable for harsh environments like aquacultures.

IO-Link: Easy to use, robust and future-ready solution for plant-monitoring.

In order to keep the automation system open for future expansions, it is advisable to opt for a solution with a purely digital data transfer path. IO-Link offers such a possibility – and has the advantage of being an open, manufacturer-independent and easy-to-use communication standard. For an easy setup, the IO-Link devices are connected to IO-Link masters by a point-to-point connection. The IO-Link master itself is then connected to the PLC and sends the data to the IT infrastructure while also enhancing the possibilities of data-supported plant control. The range of requirements for RAS is broad and leaves a lot of space for different solutions – and so does a strong automation solution. To manage the Feed Conversion Rate, the distribution has to be checked constantly. Users must make sure that the food is falling into the ponds. Usually, the level is managed via capacitive, photoelectric or ultrasonic sensors.

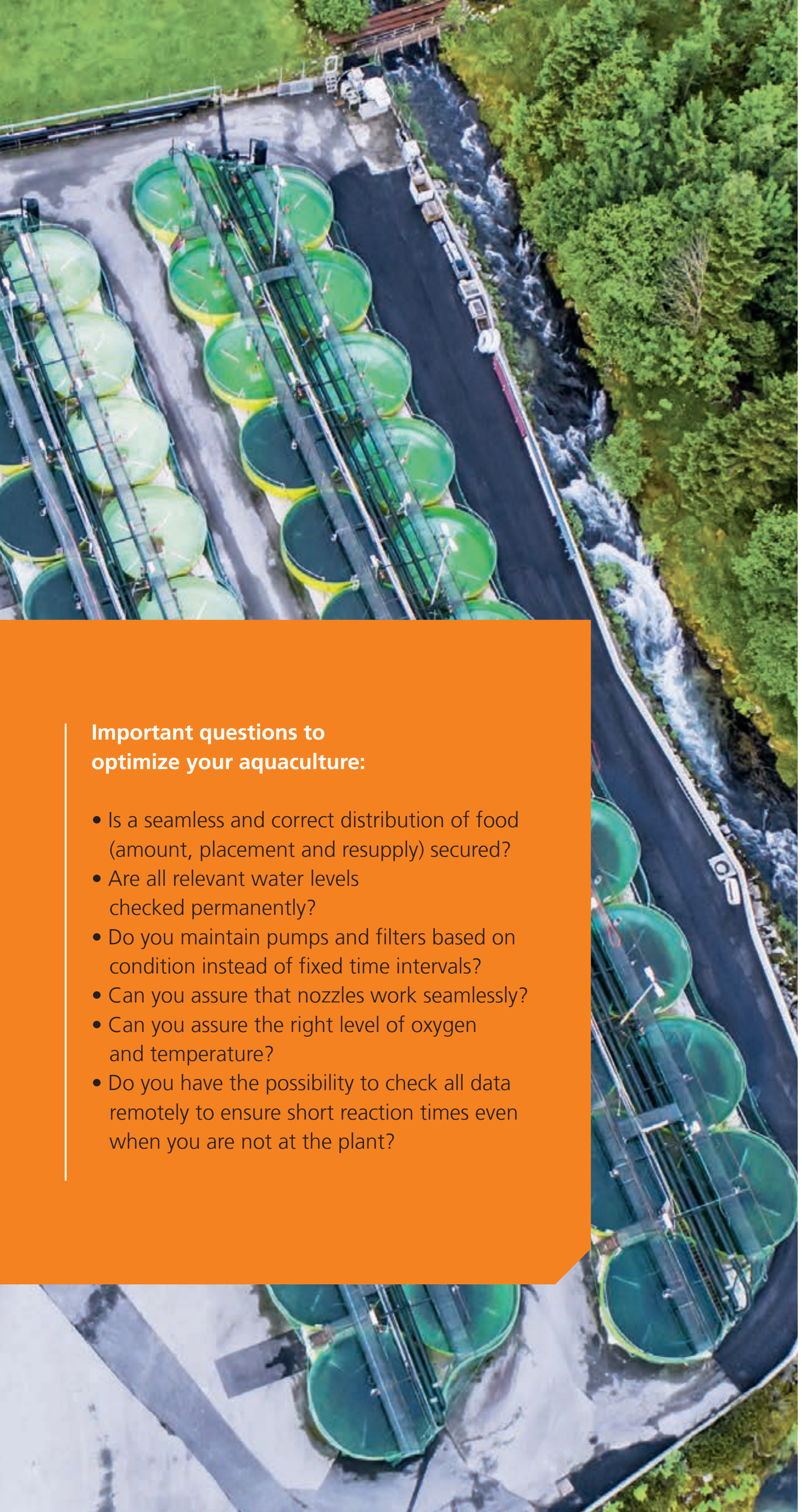
Food management with capacitive, photoelectric or ultrasonic sensors.

The same applies for nozzles spraying on mechanical filters: Flow and pressure sensors detect whether water sprays with the right volume, speed and pressure out of the nozzles. Capacitive sensors are also a reliable solution for level monitoring in pump sumps and in buffering tanks as they can be used for detection of overflow and leakages as well.

Measure oxygen satiation and water temperature for healthy breeding.

As aquacultures tend to be very complex systems, many other parameters need to be measured. To ensure a healthy breeding of the fish, the water temperature in all pipes must be at an appropriate level and the oxygen satiation has to be carried out in the right way. The water temperature is measured using flow sensors, the pressure in the oxygen cones is monitored by various types of pressure sensors.

Monitoring the usage of fresh water with ultrasonic sensors



Important questions to optimize your aquaculture:

- Is a seamless and correct distribution of food (amount, placement and resupply) secured?
- Are all relevant water levels checked permanently?
- Do you maintain pumps and filters based on condition instead of fixed time intervals?
- Can you assure that nozzles work seamlessly?
- Can you assure the right level of oxygen and temperature?
- Do you have the possibility to check all data remotely to ensure short reaction times even when you are not at the plant?

A major interest of farmers is the use of outside resources such as fresh water and electricity. To register the used electricity, the effective nominal current, the output voltage, data of the triggering counter and current unit states such as short circuit or overload, undervoltage or limits are transferred to the IO-Link master by special IO-Link fuses. In return, activation, deactivation and reset orders are transferred from the IO-Link master. Using IO-Link devices, the volume of new water used can be registered with ultrasonic flow sensors that monitor the exact water consumption.

Reduce unforeseen emergencies and keep the production safe.

Condition monitoring: acting instead of reacting

But not only the process values themselves need to be monitored. Also existing – or better, emerging – failures need to be detected as quickly as possible. Light towers that are installed in the plant and connected to the PLC can be a helpful onsite solution. So, it is clearly visible for everyone whether all values are in the correct range, and whether emergency oxygen supplies, pumps and motors work well or need to be checked. With some more monitoring solutions, a softwarebased predictive maintenance system that helps to reduce unforeseen emergencies can be established.

Identify the status of biofiltration with flow sensors.

Condition monitoring keeps an eye on the status of spraybar nozzles, filter plates in mechanical filters and ventilators for trickling filters and signalizes when they have to be cleaned or changed. Another highly technological part of recirculation systems are the biofilters. Usually, biofilters are found at the end of the process before the water is flowing to the stripper and LHO. Biofilters are a key element of RAS and therefore need to be checked and managed constantly. One aspect is checking the distribution of air bubbles across each of the biofilter chambers. Flow sensors detect air flow and monitor the consumption of air. In addition, pressure sensors monitor the correct pressure in the system. To identify flow changes through the biofilter and microparticle filter, the height between the water surface level in the biofilter and the PEC cylinder wall top edge needs to be checked. The level is detected by capacitive sensors.
By using sensors in the RAS process, farmers achieve a higher efficiency, can produce more fish and act more sustainably. Different action points need to be identified and changed, but the yield will show the success shortly after the installation.

Conclusion: usage of sensors in RAS

It can be stated that Recirculation Aquaculture Systems are a sustainable way of improving the fish production in aquacultures. Farmers do not waste as much water as before and by optimizing the Feed Conversion Rate, they save a lot of uneaten feed. When using less feed, the water is polluted less and recirculation systems gain a higher life cycle due to less load on the filters. Of course, this can only be achieved by investing in technology-driven solutions. Sensors in different stages – from the supply of fresh water to water quality in the ponds and a wellgoing recirculation system – provide a lot of possibilities for farmers. To connect all those sensors, programmable logic controllers are used. By relying on strong and highclass solutions, a sustainable and longlasting recirculation system can be established.

Using these methods leads to a more eco-friendly fish production which is independent of offshore sea plants. After 8,000 years of aquaculture farming, Recirculation Aquaculture Systems are the next logical step to a more efficient and economic future.

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