Water Treatment Using Ultrasound Technology in Aquaculture

Figure 5 a

Figure 5 b

Figure 5 c

Figure 5 d

"Enhancing fish yield quality, lowering maintenance costs, less antifouling chemicals usage, reduction of algae growth, bacterial counts, biofilm and fouling formation by means of ultrasound produced by the LG Sonic® technology."

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Introduction

Among the numerous applications of ultrasound, the approach is used in the field of water treatment. In this scenario, forces other than cavitation forces are being used to achieve a certain goal. An example of such ultrasound technology which can be found on the market are the LG Sonic systems, which are manufactured to suppress algal growth and biofilm formation.

The ultrasounds produced by using the LG Sonic® technology does not induce any stable (non-inertial) nor unstable cavitations. They do not even come close to reaching cavitation levels. Other mechanical forces induced by the produced mechanical pressure waves are use to suppress algal growth and reduce biofilm growth, such as resonance forces, longitudinal and transversal sound wave forces.

To reach this goal, the LG Sonic® systems for example use a 'blend' of very specific ultrasound frequencies of certain power which is emitted into the water by specific transducers. This will enhance the specificity and selectivity of the ultrasonic treatment. The algae are treated with ultrasonic sound waves set in precise frequencies that directly target the cellular structure of the algae. The amount of algae in the water is reduced and controlled in an efficient, cost-effective manner, and further growth is inhibited. Green layers disappear, biofilm formation is prevented, and the appearance and clarity of the water is visibly improved. The continuous use of such a device prevents the water from becoming polluted again.

This kind of ultrasound technology can be used in all situations where water is stored, from large industrial water applications to small private pools or ornamental ponds. These systems range from large capacity units to small ones, enabling a 'tailor-made' solution to all purposes. The amount of time needed to see improvements depends on parameters, such as the type of the algae present in the algal population, water temperature, the amount of light, the amount of nutrients present (especially phosphate and nitrate), size and depth of the water body, TSS levels, total dissolved solids (TDS) levels, turbidity, retention time, etc. To obtain the successful treatment of the water, one should first know that no water body is the same - every water body is unique and should be treated uniquely. Ultrasound systems like the LG Sonic do not use chemicals, only needs a low supply of electrical energy, and does not harm plants, fishes, zooplankton, and other types of life present in the water, thus having a low environmental impact.

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Aquaculture Application

Aquaculture is the farming of freshwater and saltwater organisms including molluscs, crustaceans and aquatic plants. Unlike fishing, aquaculture, also known as aquafarming, implies cultivation of aquatic populations under controlled conditions. Mariculture refers to aquaculture practiced in marine environments. Particular kinds of aquaculture include fish farming, shrimp farming, oyster farming, and growing of cultured pearls. Particular methods include aquaponics, which integrates fish farming and plant farming. The most important fish species raised by fish farms are, in order, salmon, carp, tilapia, catfish and cod. Aquaculture production in the world has an important role in balancing the over-catch and protecting wild species and the environment, and represent almost half from total fish production (Figure 1).

Land Based Aquaculture

Land-based fish farms, closed water container fish farms require a large input of energy in order to sustain cultivated biomass in terms of water demand, oxygen supply, food, antibiotics and energy. The potential environmental impacts of aquaculture, eg, increase of algal population, the dissolved oxygen depletion at the water-sediment interface, organic enrichment of the sediments, the effect on bacterial density, biomass, community structure and their possible resistance have been reported in the literature. Development of algae is one of the serious problems, which positively affect the fish during the day by O_2 production, while during the night algae consume oxygen and may even reduce the O_2 level below tolerable limits of 4mg/L. Another factor is fluctuating pH value due to diurnal cycles of CO_2 release, causing additional stress to fish.

For eg, the food conversion ratio in recirculation trout farms is high, eg about 64% of P and 53% of N supplied by food are lost. A possible solution to reduce the water pollution by nutrients is diversion of recirculating water into closed loop treatment system. Treatment of water in which fish are bred is also important due to limited water sources or water saving. A recirculation of water in a closed loop treatment system represents sustainable methods to reduce the environmental impact of aquaculture, especially for small-scale farmers.

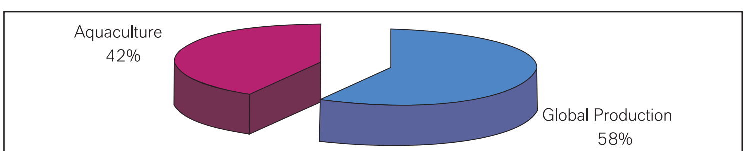

Figure 1: World Aquaculture Production from Global Fish Production 2006

Chem-fre pond		Reference pond	
Chl.-a bound	Chl.-a free	Chl.-a bound	Chl.-a free
(mg/m³)	(mg/m³)	(mg/m³)	(mg/m³)
37.3	1.5	1565.6	10.6

Figure 2: Average Values of Bound and Free Chlorophylla in the Chem-Free Pond and in the Reference Pond

A European research project (of about $2.6mn) was executed by LG Sound (the producers of the LG Sonic® systems) to study the effect of ultrasound in the treatment of fish farming, carps farming. This was the Chem-Free project, which is a Co-operative Research Project (CRAFT) funded within the EU 6th Framework Programme, Horizontal Research Activities involving SMEs. The Chem-Free project is in accordance with the Water Framework Directive (2000/60/EC) that aims to achieve sustainable water use, sustainable management and protection of freshwater resources. The experiment run in two fish ponds (5m x 9m x 0.8m) of which one served as an experimental (Chem-free), and one as a reference pond. In each pond 34 carps were added. From the Chem-free pond the water was pumped by a bypass and was treated first by the roughing filter (RF) (1.5m x 1.5m, h=1.1m, 0.5m gravel 4/8mm, 0.3m 8/16mm, 6/22mm 1:1) followed by two batteries of fibre-filters (FF) without pressure, and two UV-C devices (UV) running in parallel. Treated water flowed back to the Chem-free pond. An LG Sonic® system unit was installed in the Chem-free pond. Both ponds had constant aeration. The Reference pond did not have any treatment. In the case that water conditions treated fish population, groundwater was added. Groundwater was also added in the Chem-free pond occasionally to compensate evaporation losses.

The results were promising. The average values of free and bound Chlorophyll-a in both ponds are presented in Figure 2. Measured values of free Chlorophyll-a were low in both ponds, especially low values were measured in Chem-free pond. Measured values of bound Chlorophyll-a were much higher in the Reference regarding to the Chem-free pond, especially high values of bound Chlorophyll-a were measured in the Reference pond during the 1st experiment. Clear visual effect was observed in the ultrasound treated pond with regard to colour and parameters such as nitrite, TOC, TSS. Reduction in other physico-chemical parameters could be observed, refer to Figure 3. Another research was executed by Ph.D. Paul V. Zimba from the USDA-ARS Catfish Genetics Research Unit, USA and Casey C. Grimm from the Southern Regional Research Centre New Orleans, USA, utilising the LG Sonic® ultrasound technology in channel catfish production.

Limit Value According to Legislation						
Parameter	Reference pond	Chem-Free pond	Slovene	Italian	Austrian	Dutch
Temperature (°C)	13.6	15.6	xxxx	max 28	16–26	24–26
Dissolved oxygen (mg O_2/L)	9.0	8.7	≥ 5	≥ 5	5–9	> 3
pH	8.3	8.1	6–9	6–9	6.5–8.5	6.5–8.0
Suspended solids (mg/L)	142.8	10.0	≤ 25	25.0	xxxx	< 25
BOD5 (mg O_2/L)	36.7	3.1	≤ 6	6.0	xxxx	xxxx
Total P (mg PO_4/L)	1.2	0.3	≤ 0.4	0.14	xxxx	xxxx
Nitrate (mg NO_3/L)	1.4	3.1	xxxx	xxxx	xxxx	100.0
Nitrite (mg NO_2/L)	0.8	0.17	≤ 0.03	0.03	0.06-0.1	< 0.5
Ammonium (mg NH_4/L)	0.5	0.1	≤ 0.2	0.2	xxxx	< 8
xxxx: no legislation limits known						

Figure 3: Average Values of Physico-Chemical Parameters in the Chem-Free Pond and in the Reference Pond

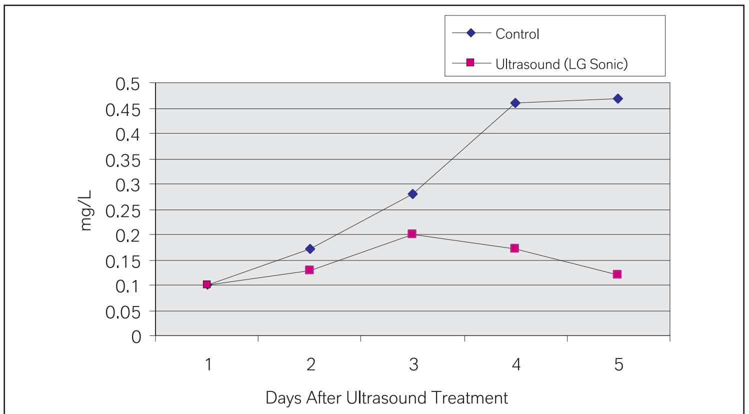

Figure 4: LG Sonic Ultrasound Treatment (Turbidity)

Channel catfish production relies on timely sales of fish, but sales schedules can be hampered by the occurrence of off-flavours and fish mortality from disease. Efforts to control off-flavour have used chemical treatments such as diuron, sodium chloride, hydrogen peroxide, titanium dioxide and copper. These are effective but can lead to increases in chemically resistant pathogens in ponds requiring repeated applications that can be labour-intensive and increase production cost. Diseases can result from the presence of bacteria, viruses and fungi in ponds. An alternative to chemical treatments is the use of ultrasound. An initial laboratory study evaluated the effect of ultrasound produced by the LG Sonic® technology on catfish feeding and weight gain. Catfish fingerlings stocked at 13 fish/tank were acclimated to four control tanks and four tanks that received ultrasound treatments.

Turbidity in tanks was decreased by 60% (Figure 1). Bacterial cell counts using acridine orange direct counts and bacterial plating were significantly lower in the tanks with the ultrasound treatment compared to the counts in control tanks. These results suggested that use of ultrasound could reduce pathogenic bacteria in ponds to levels below those causing fish mortalities. A further laboratory experiment assessed if ultrasound caused greater off-flavour diffusion from water to air. Eight tanks were dosed with 1-ppm 2-methylisoborneol, and four were treated with continuous ultrasound. Samples were collected daily for off-flavour and analysed using gas chromatography-mass spectrometry. Tanks with ultrasound treatment had significantly ($P = 0.09$) lowered off-flavour levels.

A field study was initiated in 0.47-ha production ponds to assess the impacts of ultrasound produced LG Sonic® by technology on off-flavour and algal biomass. Ponds were stocked with channel catfish fingerlings and operated as grow-out ponds according to industry standards. Pond conditions were matched in terms of algal density and composition in two control ponds and two ponds treated with ultrasound. Two ultrasound devices were placed in ponds pointing along the long pond axes. The ultrasound equipment was run from 11-6am continuously, with feeding during the off period. A dense bloom of the cyanobacterium Microcystis c.f. ichthyoblabe Kützing was present in two of the ponds. While dominant in two other ponds, the bacterium was 70% lower in overall biomass. Total algal biomass decreased by about 48% during the four-week study. Off-flavour concentration was decreased to a lesser degree.

Open Sea Based Aquaculture

Growth of fouling organisms on suspended fish cages is an impediment to aquaculture projects in coastal waters around the world. Ecological succession of fouling communities on the netting of fish cages at an open ocean aquaculture can be defined as the process by which a community moves from a simple level of organisation to a more complex community. Routine cleaning of the cages causes loss of organisms and initiation of ecological succession.

Salmon farming is a multi-billion dollar global industry facing considerable difficulties posed by growing pressure from environmental regulatory bodies. Because marine organisms grow on and "foul" synthetic nets, oxygen available to fish is reduced and infectious diseases and parasites can spread among the fish. Antifouling painting for the netting of fish cages, helps reducing fouling formation, but at the other hand they can be very toxic. Furthermore, maintenance of these nets is expansive, time consuming and most if the time the maintenance of the nets involves the usage of toxic products. A test to study the reduction of fouling formation on netting of fish cages by using the LG Sonic® technology was executed in Chile (the leading salmon producing country) at a salmon farming facility in the South of Chile.

An LG Sonic system was installed in a salmon cage of 20m by 20m. The nets used in this experiment were already covered with marine fouling organisms especially filamentous algae. After 28 days, a clear difference could be seen between the nets of the reference cage and the nets of the cage treated with ultrasound of specific frequencies (Figure 5a, b, c and d). The reference net (Figure 5a and b) were heavily covered with marine fouling (filamentous algae and slimy biological substances) in comparisons with the nets treated with ultrasound (Figure 5c and d). Furthermore, there were no changes detectable in the salmons behaviour during the whole experiment. These results indicates that marine fouling formation on salmon cages can be suppressed by the ultrasound, which would subsequently results in less frequent maintenance, less usage of toxic antifouling chemical, and lower maintenance cost. A second test trail is being executed, but this time using clean nets at the start of ultrasound treatment. Plus, no antifouling paint will be used on these nets (reference and ultrasound treated nets). The biomass will be analysed and measured. This will be compared with the biomass of the reference nets. The amount of fouling formation shall be monitored, weighed and analysed. At the end, the results could give an indication if ultrasound could replace or strongly reduce the usage of antifouling chemicals for the netting of fish cages.

Conclusion

Results achieved in the aquaculture using the LG Sonic technology are:

- Strong reduction in algae concentration (about 90% reduction)
- Reduction of biofilm formation
- Reduction of fouling and other growth on fish cages (inland and open sea)
- Reduction β-cyclocitrol, 2-methylisoborneol concentration
- Reduction in microcystines (cyanobacteria toxins)
- Reduction of TSS, Turbidity, BOD, COD levels etc.
- Reduction of free bacterial counts (E. coli, Enteroccoci, total coliforms etc.)
- Reduction of ammonium and nitrite
- Slightly heavier fish yield

Based on the results and in collaboration with universities, LG Sound introduced a new LG Sonic® model, the LG Sonic® Aquaculture.

About the Author

Duddy Heviandi Oyib, MSc, BAsc is Manager big/special projects and chief biologist of LG Sound. LG Sound produces and worldwide markets the newest generation of ultrasonic algae control units, LG Sonic®.

We look forward to your feedback on this case study. To know more about the author, you can write to us at content@eawater.com