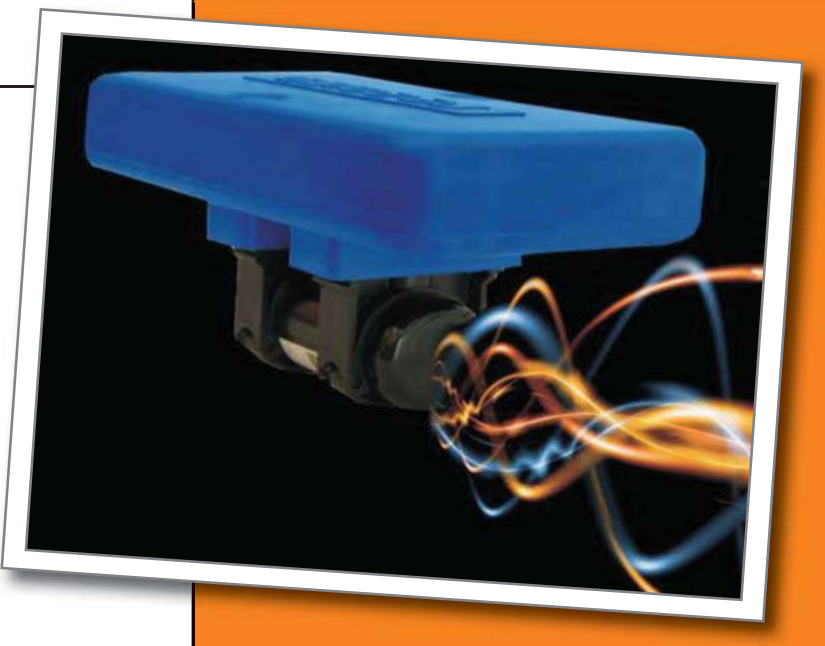


Water Treatment by Means of Ultrasound

By Duddy H. Oyib

To achieve successful treatment of the water, one should first know that no water is the same, every water is unique and should be treated uniquely.

Sound

Sound can be described as mechanical energy transmitted by pressure waves in a material medium. Thus, sound can be described as a form of energy or a sound is said to be mechanical.

This distinguishes sound energy form other forms of energy, such as electromagnetic energy. This general definition encompasses all types of sound, including audible sound, low frequency seismic waves (infrasound), and ultrasound.

Ultrasound

Ultrasound is cyclic sound pressure with a frequency greater than the upper limit of human hearing. Although this limit varies from person to person, it is approximately 20 kilohertz (20,000 hertz) in healthy, young adults and thus, 20 kHz serves as a useful lower limit in describing ultrasound.

Ultrasound applications

Current applications of ultrasound includes, for eg, sonochemistry (emulsification, acceleration of chemical reactions, extraction etc) dispersion, and disruption of biological cells (ultrasonic disintegration), removal of trapped gases, cleaning of microscopic contamination, ultrasonic humidifier, ultrasound identification (USID), and typically to penetrate a medium and measure the reflection signature or supply focused energy. The reflection signature can reveal details about the inner structure of the medium. Most well known application of this technique is its use in sonography to produce pictures of fetuses in the human womb. Other application is using ultrasound in cancer diagnose. The numbers of ultrasound application is numerous. Combining the right frequencies, the right amplitude and using the right transducer numerous types of ultrasound application can be achieved. The sky is the limit.

Ultrasound forces

Exposing liquids to high mechanical pressure waves (or sound waves), forces as acoustical streaming, stable cavitation and transient (unstable or inertial) cavitation can be induced. For eg, ultrasonic disintegration, sonochemistry and sonoluminescence arises from acoustic cavitation: the formation, growth, and implosive collapse of bubbles in a liquid. Cavitational collapse produces intense local heating (~5000 K), high pressures (~1000 atm), and enormous heating and cooling rates (>10 9 K/sec). Acoustic cavitation provides a unique interaction of energy and matter, and ultrasonic irradiation of liquids causes high energy chemical reactions to occur, often accompanied by the emission of light. This can only be achieved in specific situation involving specific frequencies of high ultrasound power (high W/h & dB) exposed to relatively low liquid volumes of relatively low temperatures.

Ultrasound and water treatment

At present, ultrasound is also being 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 systems 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 these kind of systems does not produce 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 are being send into the water by very special transducers. This will enhance the specificity and selectivity of the ultrasonic treatment. The algae are treated with ultrasonic sound waves set in precise frequencies, which directly target the cellular structure of the algae. The amount of algae in the water are 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.

These kinds of ultrasound algae control systems 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 certain physicochemical parameters of the water such as the type of the algae present in the algal population, water temperature, the amount of light, the amount of nutrition (especially phosphate and nitrate), size and dept of the water body, TSS levels, TDS levels, turbidity, retention time, etc. To achieve a successful treatment of the water, one should first know that no water is the same, every water is unique and should be treated uniquely. Such a ultrasound system does not use chemicals, needs a low supply of electrical energy, and does not harm water plants, fishes, zooplankton, and other types of life present in the water. Thus, the environment is spared. At the other hand many of the traditional methods to fight algae or biofilm growth are either insufficient, cumbersome, environmentally unfriendly, or all of these.

Algal growth control mechanism by means of ultrasound

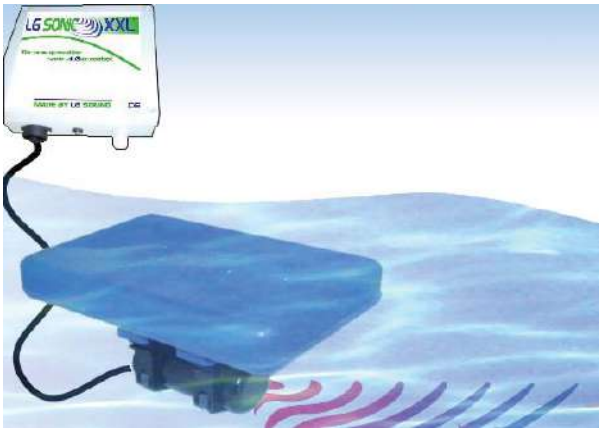
The ultrasound produced these devices are target to different types of algae such as unicellular algae, colonial forming algae, filamentous algae and cyanobacteria.

Eukaryotic algal cells and ultrasound

Each Eukaryotic (unicellular and filamentous) algal cell has one or more relatively big cell compartment(s), the vacuole(s). This compartment can occupy about 70-90% of the cell volume and can have different functions. Lipids, water, starch, pigments, other nutrients and some biochemical components can be stored in this vacuole. Some of these cellular compartments also function to maintain the fluid balance (turgor). These specific ultrasound frequencies can negatively affect the membrane (tonoplast) of the vacuoles and cause the detachment of the cell membrane from the cell wall. Other cell components can also be affected by these ultrasounds forces. All these are lethal to the algae cells.

Blue-green algal cells and ultrasound

Blue-green algae (cyanobacteria) are bacteria (prokaryotic organisms) capable of photosynthesis and nitrogen fixation. Most of them have small cell compartments (gas vesicles). These gas vesicles are small and hollow, air filled structures of a cylindrical shape that provide buoyancy to these cyanobacteria. Each cyanobacteria cell can contain up to 5000 gas vesicles. The gas vesicles enable the bacteria, after periods of water mixing, to float up from the deeper water layer back into the eutrophic zone, where light for photosynthesis is provided, or to reach deeper nutrient-rich layers by sinking when the loose the air form there gas vesicles. Therefore, these organisms have means to overcome spatial separation of nutrition and light. The ability to regulate their buoyancy is discussed as a major advantage over other phytoplankton species and may partly explain the enormous success of the toxin-producing species in the field.



The produced ultrasound forces will fracture these gas vesicles, thus causing the blue-green algae to sink and (eventually) die. Furthermore, some cyanobacterial types (strains) are able to produce toxins. Older and senescent blooms tend to release toxins into the water as the cells break open (or via treatment with copper sulphate). Cyanobacteria can produce a wide array of neurotoxins, hepatoxins, cytotoxins and skin irritants. In addition, many genera, such as Anabaena, can produce multiple toxins. By reducing the amount of the cyanobacteria, reduction of the produced toxins will be achieved. Thus, used for anti algae and growth inhibition purposes, the ultrasonic water treatment system can have an outstanding effect on the reduction of toxins by the control of toxic cyanobacterial growth. In several scientific publications, scientists showed that degradation of these toxins can be achieved at lab scale by certain ultrasound forces.

Biofilm control by means of ultrasound

Biofilm: Many industrial and professional applications use water. Whether streaming or stagnant, algal growth and biofilm formation may occur, which can damage the installations and reduce the efficiency. Many methods to control biofilm formation involve chemical treatment which is expensive, damages the circuit or lowers the water quality. Ultrasound treatment can inhibit the formation of biofilm on an environmentally friendly, cost effective manner without inducing damage to the installation in which the treatment is being applied. A biofilm can grow on different types of substrates which can be found in water. When temperatures are high, for eg, in cooling towers, a matrix of different microorganisms such as bacteria, fungi, protozoa and algae can grow very rapidly.

The formation of biofilm

Biofilm consists of communities of microorganisms, which develop on surfaces in natural and artificial environments. Under certain conditions, many bacteria can be induced to produce Extracellular Polymeric Substances (EPS) which include polysaccharides, proteins, and nucleic acids. EPS are the "cement" of biofilm. Subsequently, other microbial aggregates settle in the pore spaces of the EPS, thus helping in the further formation the biofilm. Some of the bacterial species that can produce EPS are Pseudomonas, Burkholderia, Aeromonas, Pasteurella, Pantoea, Alcaligenes and Sphingomonas. Microalgae can also contribute to biofilm formation by the production of exopolysaccharides (EPS) under certain stressed conditions. In particular, surface adherent biofilm and bacteria living within protozoa pose potential health problems that are unrecognised by conventional laboratory culture methods. A host is required for Legionella pneumophila multiplication, but in the absence of a host, L. pneumophila can survive within a biofilm layer (sessile Legionella) and yet others will be suspended in the water (planktonic Legionella). Mostly, protozoa serve as host cells for the intracellular replication of certain Legionella species in a variety of environmental settings.

The disadvantages of biofilm formation

Even a small layer of biofilm within a pipe reduces the diameter of the pipeline. This means that less water can be pumped around the circuit but also the hydraulic pressure needs to be increased to still cope with the system/industrial demand. This can result in higher energy costs and lower performance efficiency of the cooling tower. A biofilm consists for 85-95% of stagnant water, this can function as a insulating layer around the grids and pipes, thereby reducing the cooling efficiency of the tower. A Biofilm can contain several bacteria who can produce corrosive chemicals. For eg, anaerobic sulphate reducing bacteria. These bacteria produce sulphuric acid which can cause corrosion of metal pipes. Also the so called iron-oxidising bacteria can cause corrosion of metal, resulting in expensive repairs of leaking pipes. Biofilm can be a host for the pathogenic Legionella bacteria. These bacteria can become aerosol and infect humans when they inhale them causing severe pneumonia.

Ultrasound treatment

The produced ultrasound attacks most of the unicellular and blue-green algae as well as certain bacteria responsible for the formation of the biofilm. Further algae (and other micro organisms) growth will be inhibited, the biofilm will slowly deteriorate, thus enabling easy cleaning and removal/maintenance operations. Legionella control strategies should also include the control of cyanobacteria, which enhance growth and improve the survival of Legionella in an aquatic reservoir which subsequently enhance the chance that Legionella bacteria will be present in formed aerosols. The ultrasound makes the environment in the water

less favourable for the Legionella bacteria to multiply and/or attached to surfaces including post formed biofilm surfaces to help in the formation (or further formation) of biofilm.

Reduction of other micro organisms

In the irrigation, ultrasound treatment seems to suppress and control the growth of funguses such as Pithium, Fusarium and Phytophthora. Pithium (ed. P. insidiosum) are plant pathogens that produce motile oospores. Organisms of this genus are sometimes called aquatic fungi, but they really are not considered to be true fungi. These organisms may now actually be placed into a new Kingdom, Kingdom Stramenopila. They are often studied as part of medical mycology due to their ability to produce a chronic granulomatous process in which one sees hyphal structures. The disease is sometimes called "swamp cancer" due to its association with water exposure. Fusarium are parasitic type of fungus which can affect plants and animals. Furthermore, they can produce mycotoxines (trichothecenen and fumonisines) which can cause food contamination. The growth of another plant pathogen Phytophthora (ed. Phytophthora infestans) can be suppress and control. Phytophthora belongs to the water-funguses, Oömycetes. The usually infect dycotile plants. In other applications (inlcluding irrigation), ultrasound treatment can also suppress and control the amount of E.coli, Enteroccocus and total coliforms.

About the Author

Duddy Heviandi Oyib is Manager big/special projects and chief biologist of LG Sound. He has done MSc in molecular cell biology, medical biology and microbiology. LG Sound produces and worldwide markets the newest generation of ultrasonic algae control units.

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