Determining the effectiveness of ultrasound to control algae in wastewater treatment lagoons

By **Dennis J. Gregor**

Wastewater treatment lagoons provide an ideal environment for blue-green algae growth as they have high nitrogen and phosphorous concentrations, are relatively shallow, have a small surface area that limits wave action, are designed to have a controlled residence time, and are generally warmer and ice-free for longer periods than natural ponds.

Most lagoons, however, have aeration systems to ensure circulation and oxygenation. The turbulence caused by the aeration systems may reduce algae growth, especially blue-green algae, because these algae optimize growth by controlling their buoyancy with the gas vesicles within their cell wall.

Researchers have demonstrated the effectiveness of ultrasound to control cyanobacteria. A frequent concern with the use of ultrasound is that the ultrasonic vibration could result in cell lysing (i.e., breaking of the cell wall) that could release the microcystin toxins stored within the blue-green algae cell. However, based on demonstrations elsewhere, ultrasound does not result in cavitation (formation of bubbles in the water), and consequently, does not lyse the blue-green algae cells.

The application of ultrasonics to control blue-green and green algae in wastewater lagoons was studied at two locations in Ontario.

Left: *Samples of raw water from cell 4, Essex Northeast Lagoons on March 16, 2021 prior to installation of ultrasound.* ***Right:*** *Samples from the effluent from cell 4 on May 4, 2021.*

TOWN OF SUNDRIDGE

The town of Sundridge, located approximately 50 km north of Huntsville, has two wastewater lagoons. The main, active lagoon is aerated with a series of fine bubble diffusers extending across it. In addition, the lagoon is subdivided into three sections by two impermeable geomembrane flow diversion baffles with limited openings, or windows, for a maximum flow of 0.020 m/sec between each cell.

There was a concern that these impermeable flow diversion baffles might interrupt the ultrasonic signal, or reduce the effectiveness of the ultrasound that was placed in the middle of the lagoon, approximately midway between the two baffles.

These lagoons are regulated under an Environmental Compliance Approval (ECA) issued by the Ontario Ministry of the Environment, Conservation and Parks (MECP). Frequent exceedances of the ECA total suspended solids (TSS) limits were a concern, with algae blooms being the main cause of these exceedances.

Algae also affects the efficiency of the underground Submerged Attached Growth Reactor (SAGR) system that is installed downstream of the lagoon to control ammonia concentrations in the wastewater.

Wastewater system operators sought a cost-effective solution that would control or eliminate the algae blooms, would allow the system to meet its ECA TSS effluent limits, and directly benefit the SAGR operation. Water samples collected on July 14, 2020 confirmed that the algae in the lagoon were predominantly the green algae Chlorophyceae *(Chlamydomonas sp.)* and Cyanophyceae *(Pseudanabaena sp.)*.

Both types of algae are now controlled by ultrasound, using a solar powered SonicSolutions (now Water IQ) Dual Band (DB)® ultrasonic unit, which was installed on August 18, 2020 in the main treatment lagoon.

TOWN OF ESSEX

MECP sets effluent limits under an ECA for the spring discharge from the Town of Essex's four wastewater lagoons. They provide treatment prior to effluent discharge during spring freshet into the Puce Drain. Extremely poor water quality in Cell 4 of the lagoons led to a decision to test the effectiveness of ultrason-

ics to control algal blooms in the lagoon.

A lagoon water sample collected on March 16, 2021, and analyzed by ALS Environmental Laboratories, demonstrated that algae in the lagoon were dominated by Chlorophyceae *(Chlamydomonas sp.),* Chlorophyceae *(Unidentified)* and Cyanophyceae *(Aphanothece sp.).* The MECP agreed to an extension of the discharge window to May 15, 2021, to allow time for the ultrasound, installed on March 31, 2021, to control algae in the lagoon.

ULTRASOUND TECHNOLOGY AND HOW IT WORKS

The SonicSolutions ultrasound is a patented ultrasonic and biofilm control device that has four ultrasound sources (piezos), and uses two bandwidths with over 2,000 ultrasonic frequencies. This allows it to cover 360 degrees with a radial range of 400 metres, or an area of 50 hectares (ha), for the control of blue-green algae. It has a range of 150 metres (7 ha) for the control of green and diatom algae, and a range of 60 metres (1.1 ha) for aerobic bacteria.

The surface area of the Sundridge lagoon is approximately 3.5 ha, while Cell 4 in Essex is approximately 6 ha. Accordingly, all blue-green, green and diatom algae theoretically will be treated throughout the treatment lagoon, along with aerobic bacteria within a portion of each lagoon.

The treatment of aerobic bacteria is important for ultrasonic applications in wastewater lagoons because it minimizes the colonization of the transducer heads. This would impair the unit's effectiveness and require frequent cleaning.

As a result, the ultrasound units were able to operate for the entire period of the demonstration (two months at Sundridge and five months at Essex), without maintenance of the in-water units. As there was no AC power supply directly available at either location, both sites were DC powered (24 V) systems with 200 W solar panels and two 12 V Group 27 Absorbed Glass Mat (AGM) batteries.

A Morningstar Corporation ProStar 15-amp, 12/24 V solar charge controller was used to manage the solar panels and protect the batteries. The DC power source located onshore provided power to the ultrasound head via a submerged 150 m cable.

The SonicSolutions system has been tested extensively in CanDetec's facility and has a peak pulsed power demand of less than 3 amps at 24 V. At this low power output, it has no visible vibration effect, even in small water containers (60 L) and does not induce cavitation. While controlling a large number of algae species, ultrasound does not control weeds and filamentous forms of algae that look more like vegetation due to their structure.

With respect to blue-green algae, the absence of cavitation does not lyse (break apart) the cell wall. Lysing potentially releases the toxins produced within

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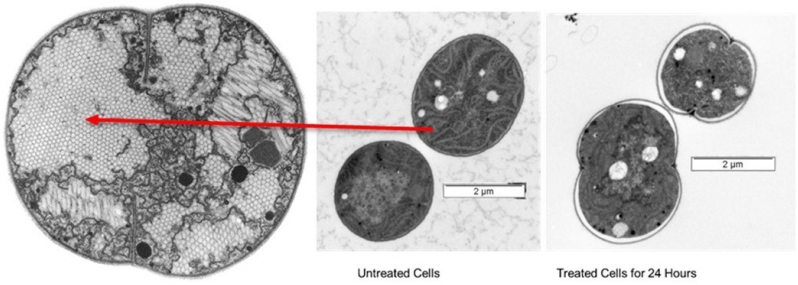

Transverse section of a dividing cell of the bacterium (Microcystis sp.) showing hexagonal stacking of the cylindrical gas vesicles at x31,500 magnification (Walsby, 1994) and transmission electron microscopy images of ultrasonic damage to vesicles showing loss of gas to outer cell wall which is permeable to the internal gas after 24 hours of exposure (Huang and Zimba, 2020).

the cell. Rather, ultrasound stops the growth and reproduction of the algae by disrupting the integrity of the internal gas vesicles. The disruption of these vesicles results in the loss of the ability of the algae to control its movements in the water column.

Vertical movement of the cells is necessary to permit access to sunlight and food sources. This loss of buoyancy causes the algae to sink out of the photic zone, resulting in a loss of light within approximately three to four days, with overall decay of the algae population occurring over a period of several weeks.

Other forms of algae, such as green algae, are also affected by ultrasound. Through the disruption of the internal cell fluid, green algae will die off in three to four weeks due to their inability to grow and reproduce. As noted above, the effective range for green algae is more restrictive, at a radius of about 150 metres.

Anaerobic bacteria are not directly affected by the ultrasound, but their growth and colonization is minimized.

SAMPLING AND ANALYTICAL ANALYSIS

Water samples were taken periodically at both Sundridge and Essex's lagoons throughout the demonstration projects to document algae populations and effectiveness of the ultrasound. All samples were collected for the enumeration of cyanobacteria and commonly for phytoplankton and microcystin. Samples were preserved (if appropriate) and shipped refrigerated to ALS Environmental Laboratories in Winnipeg for analysis.

The analysis of total microcystin using the Enzyme-Linked Immunosorbent Assay (ELISA) with a detection limit of 0.10 for MECP or 0.20 µg/L for ALS, never exceeded the detection limit on a total of 11 samples. The MECP further noted, based on their analysis of a sample from Cell 4 final effluent collected on May 4, 2021 at Essex that: *"No algal mat, cyano bloom or algae bloom [was] (sic) found…"* and *"The sample contained extremely deteriorated material. There were numerous bacterial cells and debris observed in the sample. The sample also contained numerous extremely small algal cells which were not identifiable due to poor condition…."*

RESULTS

The results for all sampling events for both Sundridge and Essex Cell 4 are summarized in Figure 1. The Sundridge figure demonstrates the reduction in cell counts of the microcystis *Cyanophyceae* and Total Cyanobacteria, which is comprised mostly of *Cyanophyceae.*

The direct effect of the ultrasound resulted in the reduction of the Total Cyanobacterial cell count by more than 1,300 times (from 2.09 million on August 18 to 1,600 by October 28, 2020). Most of this reduction was achieved in the first 30 days of operation (from 2.09 million on August 18 to 4,420 by September 21, 2020, or a reduction of almost 500 times).

Aphanizomenon *(Cyanophyceae)*, which was not present in the July sample, doubled between start-up in August and the first sample on September 21. Thereafter, Aphanizomenon was significantly controlled, with cell counts declining from 2,440 cells/ml in September to 300 cells/ml and 0 cells/ml on October 6 and 28, respectively. It is

not surprising to see some species increase after the installation of the ultrasound, likely as a result of the loss of competition for nutrients and light from the originally dominant algae in the water column.

Although it was expected that the overall benefits of the ultrasound would be limited by the impermeable membranes that ran across the Sundridge lagoon, this turned out not to be the case. The ultrasound signal could be detected at strength around the entire lagoon, including near the outlet structure.

The ability of the ultrasound signal to pass through the membranes is likely due to the fact that they are thin, stretched, and directly contacted by water on both sides. This allows the signal to propagate through the membrane. This means that a single ultrasound unit is capable of treating this lagoon, and others that may have similar membranes.

The Essex Cell 4, dominated by the single species Aphanothece *(Cyanophyceae sp.)*, was reduced from over 14 million cells/ml to 9.4 million cells/ml, 14 days after the ultrasound was installed, and to 3.1 million cells/ml in the 34 days following installation.

The ultrasonic treatment did not result in measurable microcystin toxins in the effluent after four weeks of treatment. The MECP provincial officer overseeing the site, stated in email correspondence on August 18, 2021, after reviewing data from the May 2021 discharge *"…that the ultrasound treatment was effective in preventing a bloom to form downstream in the river. Based on these positive results from the spring discharge, we support the use of the ultrasound treatment in the lagoons on a permanent basis."*

In addition to the control of blue-green algae, ultrasound will reduce the total suspended solids concentration and the pH in wastewater effluent. The low base cost of the ultrasound technology, combined with low power requirements that can be readily accommodated through on-site solar systems, and minimal maintenance requirements, makes SonicSolutions ultrasonics an excellent choice to effectively manage wastewater lagoons and other water resources that are impacted by blue-green and green algae blooms. ■

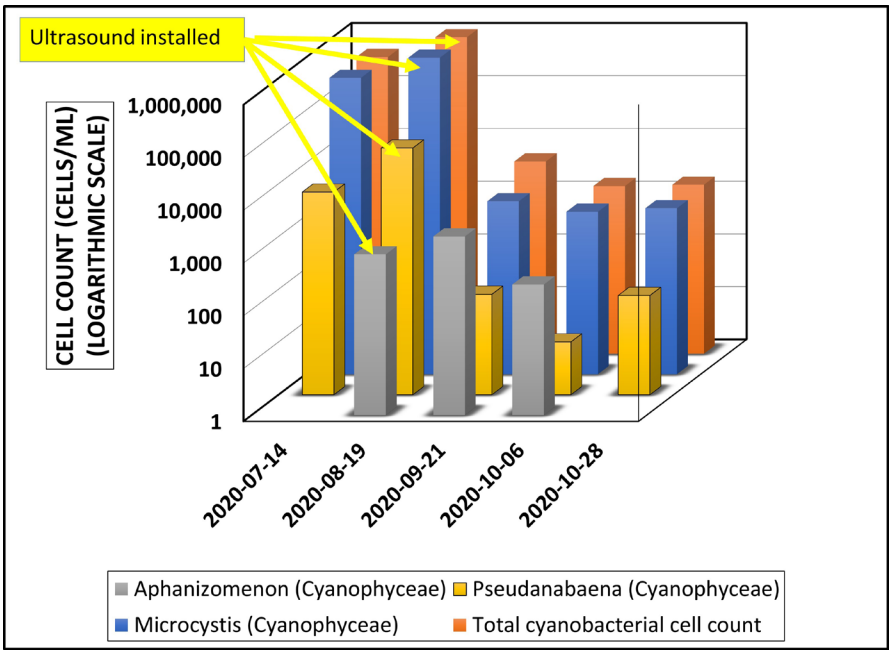

Figure 1. Cell counts of algal species and total cyanobacteria in Sundridge wastewater lagoon in the summer of 2020 with ultra-sound treatment commencing on August 19, 2020 and Total Cyanobacteria count for Essex Cell 4 with ultra-sound treatment commencing on March 31, 2021. A single species, Aphanothece (Cyanophyceae) predominated (>98%) in this cell throughout the demonstration and thus only the Total Cyanobacteria count is shown

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References are available upon request.

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