LG SONIC
Leading in ultrasonic algae control

Control Algae in Drinking Water Reservoirs

Contents


Figure 1: Drinking water reservoir.

1. Algae Problems in Drinking Water

Excessive cyanobacteria (blue-green algae) and green algae growth in a water reservoir for drinking water can have negative consequences for the water quality. The water turns green, sand filters can clog, and some algae can produce geosmins and MIB, giving the water an 'earthy' and 'molty' taste, which can result in customer complaints. In addition, cyanobacteria may produce toxins that can cause serious illness in humans consuming the water. Therefore, an algae problem is often unwanted, and algae control is desired.

In Drinking Water Plant reservoirs and other water bodies algae growth can occur. Algae cells need light, water, carbon dioxide and nutrients, which are naturally occurring in water, in order to grow. An algal bloom is a rapid increase or accumulation in the population of algae in freshwater or marine water systems. Excessive algal growth can result in the occurrence of several algae related by-products, such as toxins, MIB, and geosmins. These by-products can have a serious impact on the water quality.

What is Causing Algae Problems in Drinking Water Reservoirs?

Nutrient buildup in a lake or reservoir can be due to irrigational run-off, pollution from industries, and a general build-up of organic material at the bottom of the lake or reservoir. Especially in the summer months, when the water temperature increases, the concentration of algae can grow exponentially. Water in raw water reservoir is often stagnant, the lack of circulation of the water can cause the algae to over-compete other organisms in the ecosystem and thus create massive algae blooms.

"Excessive algae growth can be caused by nutrient pollution, high temperatures, low turbidity, and/or slow-moving water."

In order to deal with these by-products, water treatment plant (WTP) operators often use copper sulfate in a raw reservoir to control the algae. Additionally, Activated Carbon filters are used to remove geosmins, MIB, and Toxins from the final product. Removing algae from the water treatment plant is expensive and time consuming (e.g., the removal and cleaning of the sand filters).

The objective of this white paper is to give a complete and in-depth overview of the causes and possible interventions to control algal blooms in drinking water (raw water, intake) reservoirs.

Where to Deal with Algae Related Problems within a Water Treatment Process?

In general, it is safe to say that an excessive growth of algae in a drinking water system has a negative impact on the water quality and needs to be reduced. Every drinking water treatment plant is different; however, when algae if found growing within the water source, it causes problems in almost all treatment processes.

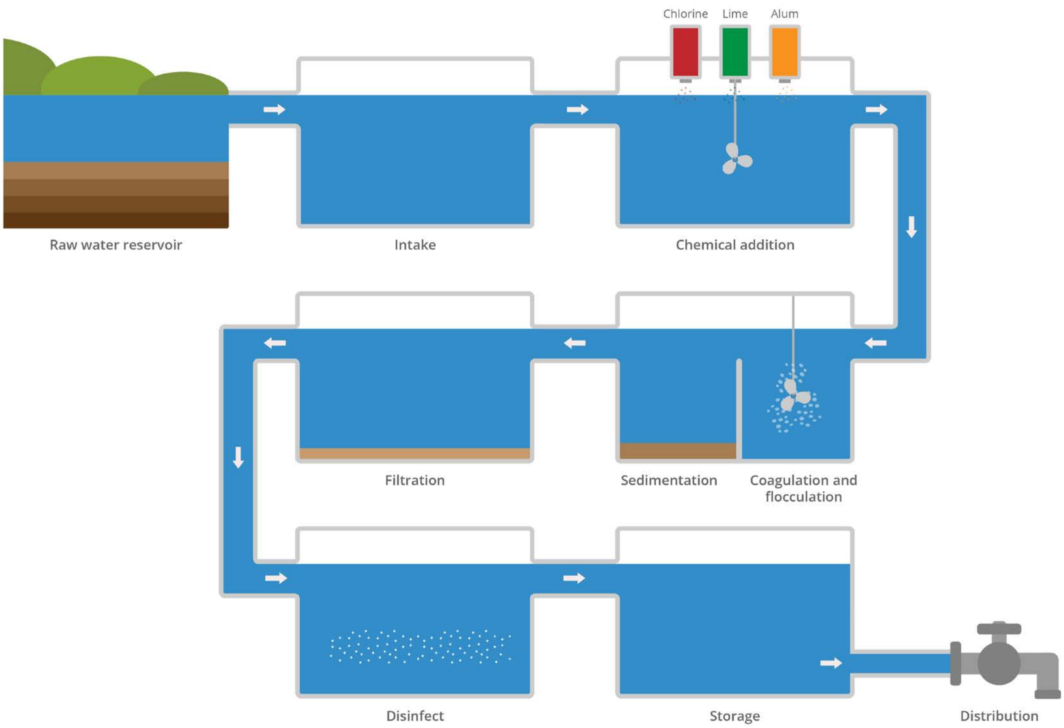

Figure 2: Drinking water treatment process.

At a typical drinking water treatment plant, raw water is taken from a river, from the groundwater, from a raw water reservoir or a combination of all of those.

The first step in the drinking water treatment plant is the flocculation/coagulation step. During this step, small particles are removed from the water. These small particles form aggregates in the presence of coagulant or flocculants and sink to the bottom of the clarifier (sedimentation tank). This step is often followed by a sand filtration step. The water treatment process is often finalized with an Activated Carbon step.

Algae growth can cause problems at several stadia in this process, depending on the type and place where algae growth occurs. It is important to tackle the problem at the source of the algal bloom, in order to prevent a direct impact on the entire treatment system:

- Most of the time, the source of the algae growth is at the intake, e.g., raw water reservoir, river. When the algae grow here, treatment of algal by-products or the algae itself can be cumbersome and impractical.

- In some situations, algae growth may also occur within the water treatment plant itself. Most common places of algae growth are, for example, in sand filters where they cause fouling of the filter bed.

"For effective algae control, it is important to tackle the problem at the source, which is often the raw water reservoir."

2. Can Algae Problems be Prevented?

The most rational answer in order to prevent the occurrence of algal blooms is to create better policy control of nutrient loads (such as N and P) that end up in freshwater or marine water bodies causing highly eutrophic conditions and algal blooms consequently. However, this is a long-term solution dependent on regulatory measures that normally take years before enforcement is properly in place and even longer for visible improvements to be seen. Hence, it is more important to check the possibilities of what can be done in the short term as an early warning measure and to react properly to Harmful Algal Bloom (HAB).

A preventive measurement that can be taken is the real-time monitoring of essential water quality parameters and algae indicators. Real-time monitoring of water quality parameters related to phytoplankton dynamics such as Chlorophyll-a, phycocyanin, Temperature, DO, pH, Turbidity, and Redox is essential for short-term forecasting of potentially harmful algal blooms. These parameters provide direct and indirect information about the concentration of algal biomass in a waterbody. This testing is best done where the algae growths are beginning, which is in most of the cases would be the raw water reservoir, river or another water source. Once a bloom is predicted, it is easier to anticipate the effects and determine whether it might by-pass the reservoir.

“Prediction of algal blooms can help treatment plant operators to better deal with the negative side effects of these blooms.”

Figure 3: Drinking water reservoir.

3. Options to Control Algae in Drinking Water

In order to treat and control the growth of algae in drinking water systems that are already infected by algae, current solutions that are commonly used include the following four main methods:

1 Chemicals

Chemical intervention involves treating the water with a variety of additives, such as alum, lanthanum, or any other products that precipitate or sequester the ionized orthophosphates. Aquatic herbicides used to treat algae are called algaecides and are often copper-based compounds, such as copper sulfate, copper chelate communes or the chemical Endothall. Care must be taken in the use of algaecides because they can cause algal cell rupture, which can result in intracellular toxins being released into the water reservoir. A rapid decay of an algal bloom may result in the release of high concentrations of algal toxins into the water. In addition, the potential long-term effect of chemicals on the ecological balance of the entire lake is a serious factor that needs to be considered.

2 Aeration

Aeration is used to increase the level of oxygen in the water. Aeration is an environmentally friendly technique to maintain and rejuvenate water bodies. To eliminate chemical use and create a healthy ecosystem, aeration systems can be used. It is important to maintain healthy levels of dissolved oxygen in your pond because the oxygen aids in the breakdown of decaying vegetation and other nutrients that find their way into the water. This breakdown of the bottom silt is carried out by microorganisms where the water meets the soil. The decomposition is carried out by both aerobic and anaerobic bacteria. Aerobic decomposition requires a continuous supply of oxygen and proceeds more rapidly as dissolved oxygen concentrations are near saturation levels. The primary end result of aerobic bacteria decomposition is carbon dioxide. Anaerobic decomposition is slower than aerobic decomposition, and the end products are organic compounds such as alcohols and foul-smelling organic acids.

The disadvantages of this technology are the high costs for maintenance (labor costs) and energy use. Since aeration does not kill the algae directly, the efficiency of this technology against algae is not always certain.

3 Mixing

The main function of mixers in a reservoir is destratification, which is a process in which the water is mixed to eliminate stratified layers (Epilimnion, Metalimnion, Hypolimnion) and make it less favorable for algae growth in certain layers.

To control algae effectively, it is usually advised to circulate Epilimnion and Metalimnion to keep iron, manganese, and anoxic odors that commonly occur in the Hypolimnion layer away from the surface water.

The disadvantage of the mixing or circulation of water is often the high maintenance required to the systems regarding wear and tear, and the fluctuating results the systems can have on algae blooms.

4 Ultrasound

Ultrasound are sound waves with frequencies higher than the upper audible limit of human hearing (22 kHz). At specific frequencies, these sound waves can be used to control algae growth.

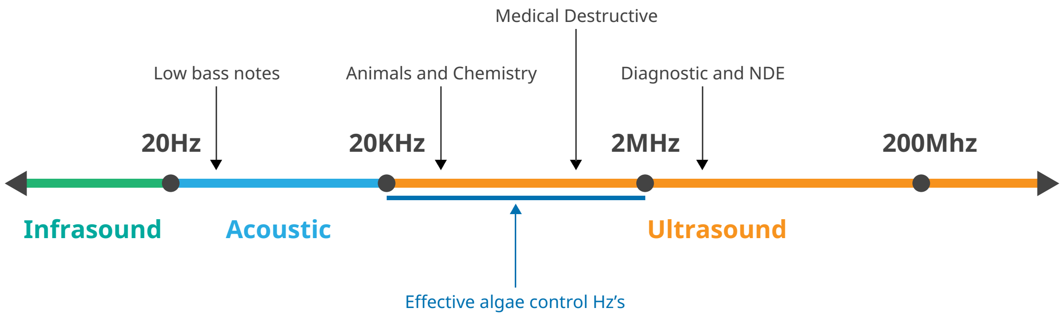

Figure 4: Sound frequencies.

Cyanobacteria use gas vesicles for buoyance and depth regulation. During the day, algae are photosynthesizing in the top layer, using carbon dioxide and dissolved nutrients from the surrounding water to produce oxygen and polysaccharides. At night, the cyanobacteria cells empty their gas vesicles (vacuole) to sink to the bottom and use oxygen and nutrients to produce biomass.

Ultrasound waves create a sound layer in the top layer of the water. The sound layer has a direct impact on the buoyancy of the algae. The algae cells will sink to the bottom and are unable to photosynthesize and eventually die due to a lack of light.

Controlling algae with ultrasound is a well-established technology that has existed for many years. It is an environmentally-friendly technology that is harmless to fish and plants. It is, however, important for the efficiency of the technology that specific frequency programs be used, based on the type of algae that requires controlling. Due to the adaptability of algae during seasons within a lake, the ability to change these ultrasonic frequencies is of importance for long-term algal control.

Summary of different methods

The presence of cyanobacteria is a severe and global problem. When it comes to lakes or bigger ponds, the current methods used to control algae all have their advantages and disadvantages. While some methods are environmentally unfriendly (Algaecides), other methods are expensive (Aeration). The next chapter will explain the concept of combining real-time water quality monitoring, web-based software, and ultrasound technology as a new method to monitor, predict, and control algal blooms in intake reservoirs.

Algacide	Aeration	Mixing	Ultrasound
• Effective • Fast results	• Increased oxygen levels at the bottom improve the ecological balance of a lake • Environmentally friendly	• Prevents stratification • Environmentally friendly	• Environmentally friendly and cost-effective • Can be used for large water surfaces
• Can be harmful for the environment • Needs frequent dosing for long term effect	• No direct effect on algae • Expensive	• High in maintenance • Reduced efficiency depending on the water quality	• Can control up to 90% of the algae • Takes some weeks before you can see the results

Figure 5: Comparison of the different methods to control algae.

Figure 6: The LG Sonic MPC-Buoy algae control solution installed in Zoetermeer, the Netherlands.

4. LG Sonic Ultrasonic Algae Control

There are various ultrasonic algae control solutions available to treat smaller water areas (up to 200 meters/650ft). The algae control devices comprise floating systems with transmitters that emit ultrasound waves underwater in order to control common types of algae. For larger water surfaces such as drinking water reservoirs, there are products available based on solar powered buoy constructions, for example, the MPC-Buoy.

1. Ultrasonic treatment range

A common principle of effective ultrasonic treatment of lakes and reservoirs is that the entire surface area should be covered by ultrasound. Most ultrasonic products require power from shore and can consequently only be placed close to the waterside, making treatment of lakes wider than 400 meters difficult. LG Sonic developed a solar-powered system that is capable of monitoring and controlling toxic algal blooms in large water bodies. The systems can be anchored in the middle of a lake, treating the water with a range of 500m in diameter. Multiple systems can be installed to treat larger water areas. There are no limitations to the size of lakes that can be treated with the MPC-Buoy.

2. Effectiveness in treating different algae species

Within a body of water, physicochemical parameters, water flow, and micro-organisms present can differ. The type of algae can vary and even change during the season. To use ultrasonic waves effectively, it is important that very specific ultrasonic frequencies be used, based on the present type of algae in the water. Not all providers are capable of controlling different algal species specifically or use different frequency programs to respond to changes in algal population. LG Sonic incorporated water quality sensors to measure algae indicators (such as Chlorophyll-a, Phycocyanin) and other relevant parameters such as the temperature, DO, pH, Turbidity, and Redox. This monitored data is delivered real-time through radio, GPRS, 3G to a web-based software. By using a web-based software, a clear overview of the water quality is provided which allows for predicting an algal bloom a few days ahead. LG Sonic monitors the water quality in real time, and an algorithm can determine the most effective ultrasonic parameters based on the received data. The system is able to modify the ultrasonic program to the specific water and algae conditions, resulting in more effective control of the algal blooms.

Figure 7: The MPC-Buoy combines online water quality monitoring and ultrasound technology to effectively control algae.

3. Use of cavitation

Some ultrasonic algae control solutions aim to use cavitation to kill algae, which is a phenomenon where high-power ultrasound causes the formation of micro-bubbles that implode, causing intense heat, local high pressure, and the generation of hydrogen radicals. This process can destroy cells and will result in the release of algal toxins into the reservoir. Furthermore, the required power consumption for this technique in order or treat even a small volume is high, making this technology unsuitable for lake or even pond treatment. For many years, it was thought that cavitational ultrasonic sound was needed to kill algae and that it only killed algae in very close proximity to the transducer. Later it was discovered that low-intensity ultrasound could also be used to control algae, even though it relies on a completely different mechanism than technologies based on cavitation. The LG Sonic products are not based on cavitation; the LG Sonic technology uses low-power ultrasound to control algae growth. This prevents the release of algal toxins into the water.

4. Maintenance

It is important to keep the ultrasonic transmitter head clean in order to maintain the system's efficiency. The LG Sonic transmitters are equipped with an automatic cleaning system, the Aquawiper™, to prevent damage to the ultrasonic transmitter, providing effective treatment with minimal maintenance. Many ultrasonic algae control systems do not have an automatic cleaning system. They need to be unplugged from the power source, taken out of the water, cleaned, and then put back in the water at least bi-weekly, resulting in high maintenance costs.

LG Sonic products provide an environmentally friendly solution to effectively control algae in drinking water reservoirs, and other applications by using ultrasound technology.

"Over the last decade, more than 10,000 LG Sonic products have been successfully installed in 52 different countries."

How does Ultrasonic Algae Control work?

Within a body of water, physicochemical parameters, water flow, and microorganisms present can differ. The type of algae can vary and even change during the season. To use ultrasonic waves effectively, it is important that specific ultrasonic frequencies be used. LG Sonic uses scientifically proven ultrasonic frequencies to control many types of algae. The size of an algae cell, its morphology, and the general water quality determine the frequency necessary to control algae. It is therefore very important to monitor the water quality (Chlorophyll a, Phycocyanin, Turbidity, DO, pH, Redox, temp) to predict an algal bloom and to identify what kind of algae is growing and effectively base the ultrasonic treatment on that.

The MPC-Buoy provides a complete overview of the water quality by collecting the following parameters every 10 minutes: Chlorophyll α (green algae), Phycocyanin (blue-green algae), pH, Turbidity, Dissolved Oxygen, and Temperature. The collected data is delivered in real time via radio, GPRS, or 3G to a web-based software platform. Based on a developed algorithm, LG Sonic is able to modify the ultrasonic program to the specific water conditions and predict an algal bloom a few days ahead. Depending on the information received, the ultrasonic program can be modified to address the water conditions and type of algae present. In this way, it is possible to eliminate existing algae and prevent the growth of new algae.

The ultrasonic sound waves create an ultrasonic pressure in the top layer of the water. This ultrasonic sound barrier prevents the algae from rising to the surface and absorbing light for photosynthesis. Therefore, algae are no longer capable of growing further. The algae will die while the cell wall remains intact, preventing the release of toxins from the algae into the water. The algae will sink to the bottom of the water reservoir, where it is degraded by the bacteria present.

The University of Portsmouth, UK; UNICET Catania, Italy; and BOKU, Austria found that LG Sonic units are safe for fish. LG Sonic devices have been tested to determine their effect on zooplankton, and no negative effect was found.

“For effective ultrasonic algae control, it is important to adapt the ultrasonic parameters to the specific water conditions.”

Algae Control during a Harmful Algal Bloom

In all water bodies, a basic level of algae is present. These algal concentrations belong to the normal lake ecology and are important for the ecological balance within the water. However, when a specific algal type starts growing exponentially, it can suffocate other organisms within the water that are important for a balanced lake ecology. Results can be seen as a reduced light penetration into the water column and increased pH, which in turn leads to a reduced growth of plants and hence reduced levels of dissolved oxygen in the deeper layers of the lake. The balance within a lake shifts even more as aerobic bacteria in the soil start to die, and nutrient digestions are taken over by anaerobic bacteria, causing a deterioration of the water quality, and eventually massive deaths of fish and other aquatic organisms, creating an imbalance in the lake. Thus, several factors favor the blooming of specific algae, leading to the shifting of the balance of the lake.

Ultrasonic algae control, in general, does not alter the basic level of algae present in a lake very much. However, due to the direct effect of the ultrasound on the vertical distribution of algae in the water column, the ultrasound directly influences the capability of an algal species to form a bloom. In general, these blooms can be reduced by 70 – 90% in concentration, compared to no treatment. Figure 8 shows the effects of ultrasound on the general algal composition of a waterbody.

“Algal blooms can be reduced by 70 – 90% in concentration, compared to no treatment.”

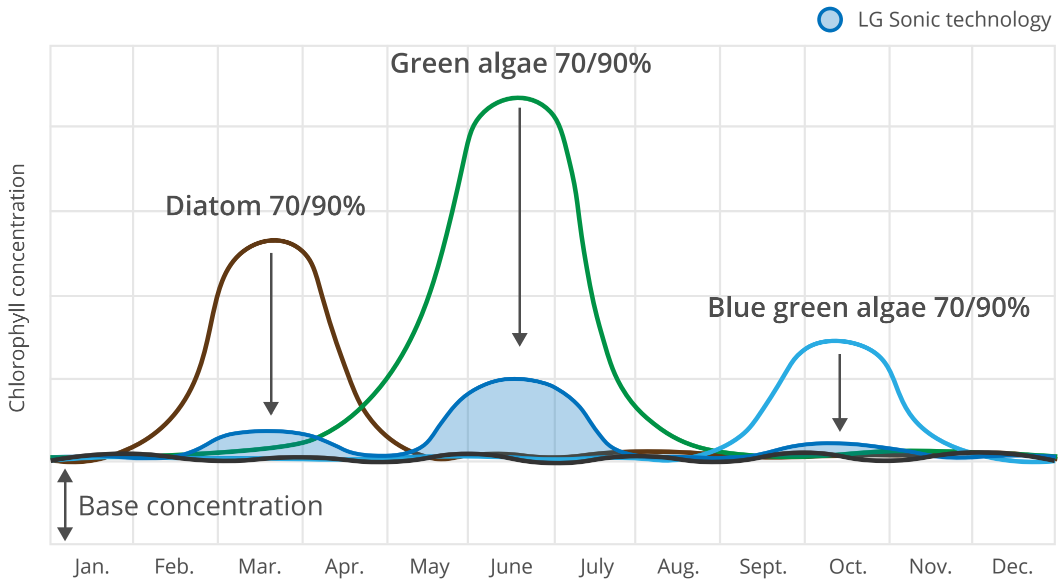

Figure 8: The effect of ultrasound on algae.

In order to minimize the algal growth, it is crucial to stop the algal growth at its source. In Drinking Water facilities, it is highly recommended to place a floating, solar-powered ultrasonic algae control system, named the MPC Buoy, in the Raw water reservoir (the intake water) as in most situations this is the place where an algal bloom originates. The MPC-Buoy can effectively eliminate 70 - 90% of the existing algae and prevent the growth of new algae. By handling the problem at the source, the intake of algal cells and their potential by-products (toxins, geosmins, MIB) into the water treatment plant is reduced, resulting in less operational problems within the plant itself.

In some situations, it is advised to place another ultrasonic algae control device within a sand filter. As the retention time is relatively long at this stage of the treatment, algae may grow on the filter medium causing the system to clog. By placing an LG Sonic e-line within the sand filter, the fouling of the filter bed will be reduced, resulting in longer filter runs.

“By handling the problem at the source, the intake of algal cells and their potential by-products (toxins, geosmins, MIB) into the water treatment plant is reduced, resulting in less operational problems within the plant itself.”

Which type of Algae can be Controlled in a Drinking Water Treatment Plant?

Algal growth occurs in three basic forms: planktonic, filamentous, and macrophytic.

Planktonic algae are single-celled, microscopic algae that float freely or in colonies in the water. When these are extremely abundant or “bloom,” they can turn the water green. Less often, they can turn the water to other colors, including yellow, brown or red.

Filamentous algae occur as fine green threads that form floating mats, which are often moved around the water surface by wind. These algae are also commonly found attached to rocks, submerged trees, other aquatic plants, and boat docks. Filamentous algae are single-celled algae that form together into long hair-like mats.

Macrophytic algae resemble true plants in that they appear to have stems and leaves. A commonly-occurring macrophytic algae is called Chara or musk grass (due to its strong musky odor.) Chara feels coarse to the touch because of lime deposits on its surface, earning it another common name — stonewort.

Figure 9: Planktonic algae.

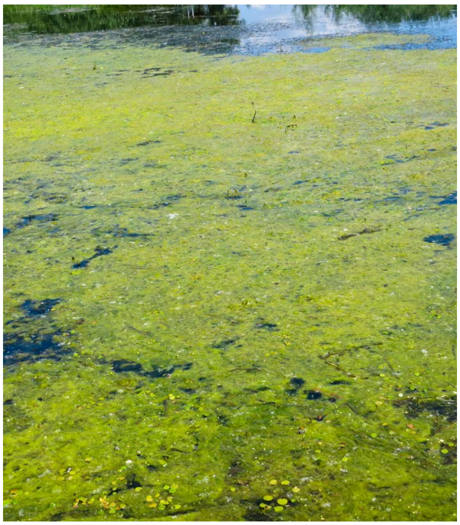

Figure 10: Filamentous algae.

Figure 11: Macrophytic algae.

The ultrasound can control common types of planktonic and filamentous algae (e.g., cyanobacteria, diatoms, green algae). The most common green-blue algae species found in drinking water plants that can be controlled by ultrasound are the following:

Microcystis spp (Microcystis Aeruginosa)

A freshwater blue-green algae (cyanobacteria) can become a harmful algal bloom. Microcystis spp can produce neurotoxins and hepatotoxins. Microcystis spp is characterized by small cells often together in colonies and contain gas-filled vesicles. This algae specie is able to form a large surface bloom and is capable off out-competing all other phytoplankton species because (as many blue-green algae) they can regulate their buoyancy.

Anabaena spp

Anabaena is a filamentous cyanobacterium that grows naturally in different kinds of waters. Anabaena exhibits a filamentous morphology, string like cells, attached to each other. Anabaena is able to fixate nitrogen from the surrounding environment by its heterocysts. Anabaena is common all over the world, can produce toxins, and is often associated with the production of MIB.

Oscillatoria spp

Oscillatoria is a filamentous cyanobacterium that makes a wave-like (oscillation-like) movement. Oscillatoria grows in a diversity of waters, including the open sea, fresh standing water, and even hot springs. Some species are capable of secreting algal toxins, and it is often associated with the production of geosmins (especially when in benthic stage).

Aphanizomena spp

Aphanizomenon is a filamentous blue-green alga that lives mostly in brackish and fresh waters. Aphanizomenon is very small and can cause dense blooms. They can move through the water column by its small vacuoles and by gliding. Aphaxnizomenon can become dominant in a water body, due to its ability to induce phosphate-limitations for other phytoplankton species. Trichomes of Aphanizomenon species can be grouped together like sheaths of wheat and form ‘rafts’ visible to the naked eye. Other Aphanizomenon species live solitary.

Ultrasound can control most common types of algae (e.g., cyanobacteria, diatoms, filamentous algae).

American Water Case study:

Ultrasonic Treatment of Algae in a New Jersey Reservoir

Figure 12: The algae control solution for large water surfaces, the MPC-Buoy.

AMERICAN WATER

"Extensive testing conducted during 2014 showed that the buoys had a significant impact on the algae, reducing algal counts, raw water turbidity and total organic carbon in the water."

In 2014, American Water, America's largest publicly traded water and wastewater utility company, installed four buoys in a drinking water reservoir. An extensive study indicated that the ultrasonic system resulted in an improvement in the water quality, reduction of chemical consumption by more than 20%, and a payback time of 1.8 years.

The Challenge: Address Episodic Taste and Odor events

In 2014, American Water installed four buoys in a drinking water reservoir at the Canoe Brook water treatment plant in Short Hills, New Jersey. The primary objective was to reduce algae concentrations with secondary objectives to reduce the concentration of taste and odor-causing compounds (geosmin and MIB) in the reservoir water and also to increase the efficiency of the plant by decreasing chemical doses and increasing filter run times.

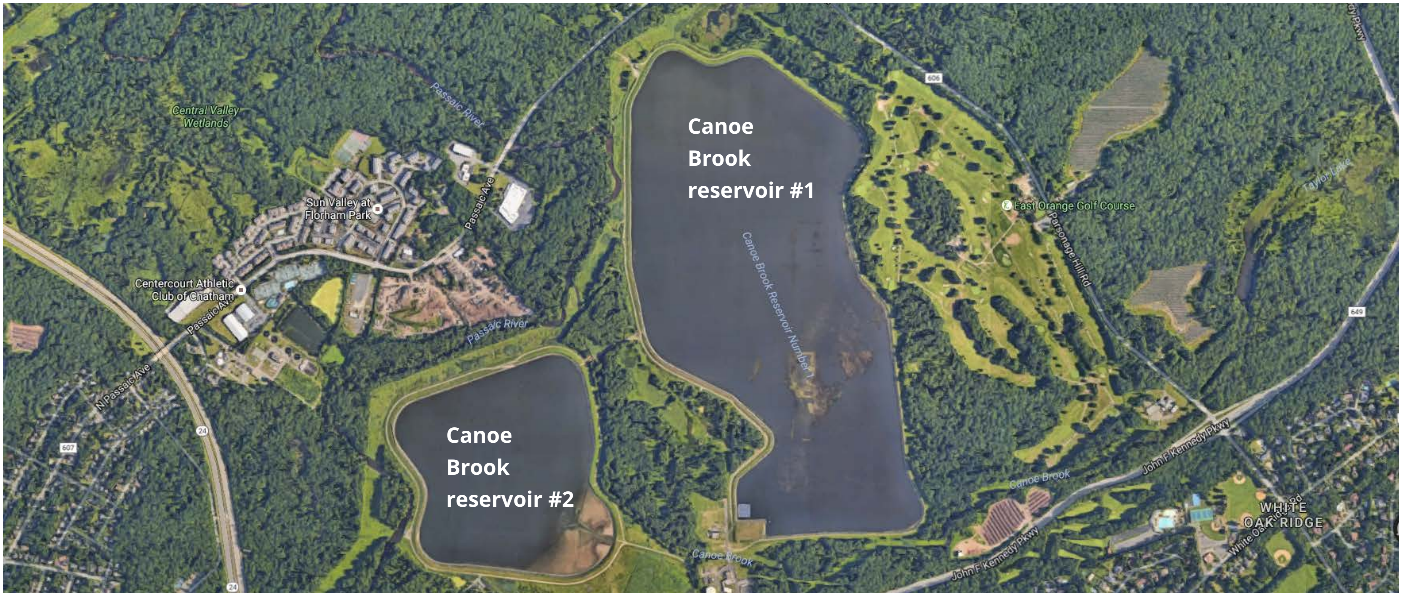

Figure 13: Overview of the Canoe Brook water reservoirs.

The Solution: The Solution: Monitor, Predict and Control Algal Blooms

As an alternative to copper-based algaecides, the use of ultrasonic treatment can be used to control algae. For this project, four MPC-Buoys were purchased and installed to control algal growth.

Different parameters are used to continuously measure the water quality. The data are separated into two groups – optical data (including turbidity, chlorophyll, and phycocyanin) and water quality data (including temperature, pH, Redox, and dissolved oxygen). The collected data is delivered in real time via radio, GPRS, or 3G to a web-based software (MPC-View) which allows users to visually follow the water quality and the progress of the ultrasonic treatment. Employees of LG Sonic receive water quality data to verify the current status of the lake, modify the ultrasonic program, and prevent new blooms. As shown in the figure below, the optical data do not show any clear trends until early September, approximately 10 days after the inlet to Reservoir #2 was closed. At that point, the phycocyanin and chlorophyll concentrations rapidly rose. After the second ultrasonic program change on September 9, the chlorophyll and phycocyanin levels dropped almost immediately.

Similar to the optical data, the water quality data (Figure 14) showed a rapid improvement in water quality after the second ultrasonic program change. Unlike the data collected at the intake, these improvements were almost immediate and are likely related to the water quality at the point of highest ultrasonic energy intensity.

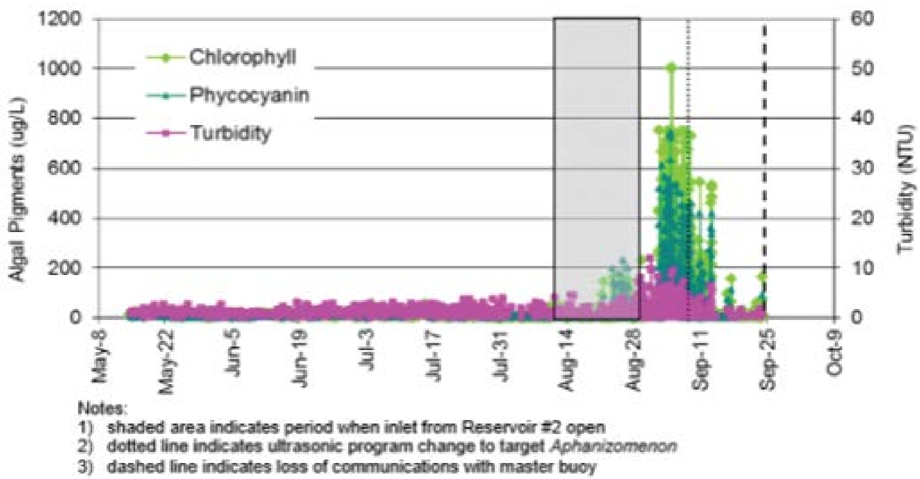

Figure 14: Algae parameters from the Canoe Brook reservoirs.

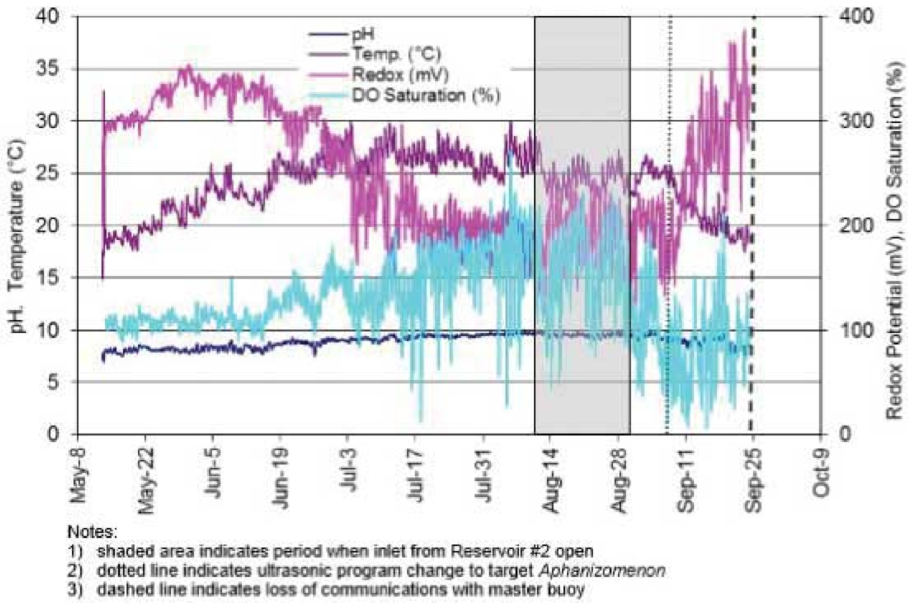

Figure 15: Water quality data from the Canoe Brook reservoirs.

The Technology: Control Algae by using Ultrasound

By using ultrasonic pressure, algae and cyanobacteria are controlled. Because of the tuneable emitter, a single device is capable of treating the range of algae that may be present in a water body, including cyanobacteria (blue-green algae), green algae and diatoms. The effective diameter of treatment using these buoys is approximately 500 meters (the effective area is approximately 50 acres). Because the algal cells are not lysed, metabolites (including T&O compounds, pigments and toxins) are contained within the cells and are not released into the water. The LG Sonic devices created an ultrasonic pressure in the top layer of the water. This ultrasonic sound barrier prevents the algae from rising to the surface and absorbing light for photosynthesis. The algae sink to the bottom of the reservoir.

Prior to installation of the buoys these diatoms show full colonies with thick branches. After only several days of treatment, the colonies are broken, thinner, and possibly show signs of predation by fungi (seen as the circular dots on the branches of the colonies).

The Results: Reduction of Chemical Consumption, Odor, and Taste Problems

Extensive testing conducted during 2014 showed that the buoys had a significant impact on the algae, reducing algal counts, raw water turbidity and total organic carbon in the water. This improved water quality, enabled the plant operations staff to reduce coagulant consumption by more than 20 percent and reduced the concentration of undesirable T&O-causing compounds in the raw water entering the plant. As a result of the treatment, the concentrations of taste and odor compounds entering the plant were lower than in previous years. Additionally, the lower algal loads required significantly lower alum doses to treat (~20% lower dosage), which in turn resulted in improved DAF effluent turbidity (37% lower), lower combined filter effluent turbidity's (19% lower), longer filter runs (127% better), and higher unit filter run volumes (83% higher) as compared to the same time period in 2013. Reduced chemical use resulted in lower filter effluent turbidity and significantly increased filter run lengths over the same period in 2013, all while pumping approximately 20 percent more water than the previous year.

"Extensive testing conducted during 2014 showed that the buoys had a significant impact on the algae, allowing the plant to reduce chemical consumption by more than 20 percent, and reducing the concentration of undesirable taste and odor causing compounds in the treated water delivered to customers".

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Lisa Brand has a bachelor degree in microbiology at Leiden University and in 2007, a radiation hygiene diploma at the Technical University of Delft. She has throughout experience analyzing and improving water quality. She worked in Africa developing a water quality monitoring program and designing new techniques for water purification. As a coordinator in 2 European Funded projects under the 7th Framework, Lisa has gained experience in Financial- and Technical management.

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