American Water Works Association
Opflow
Water Quality

https://doi.org/10.1002/opfl.1454

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Eliminate Taste-and-Odor Events With Cost-Effective Algae Control

Using a savvy approach focused on biological monitoring and management helps water utilities implement cost-effective algae control.

BY FRANCES BUERKENS, TRICIA KILGORE, AND HUNTER ADAMS

THE WORLD OF biological analysis has three rules of thumb: Change is constant, nothing is linear, and everything is interconnected. Stepping into this realm is daunting, but enterprising US water quality managers have made the leap. In doing so, they've earned public confidence and saved their utilities money while providing high-quality drinking water. Treatment technologies like ozone are highly effective at disinfection and degrading organics, thereby eliminating most biological concerns that create taste-and-odor (T&O) issues. However, such technologies often come with a bond-worthy price tag that remains inaccessible to most utilities. Developing a savvy biological approach involves more scientific finesse but offers tremendous value by allowing utilities to monitor and improve water quality before raw water enters the treatment plant.

CONSIDER THE COSTS

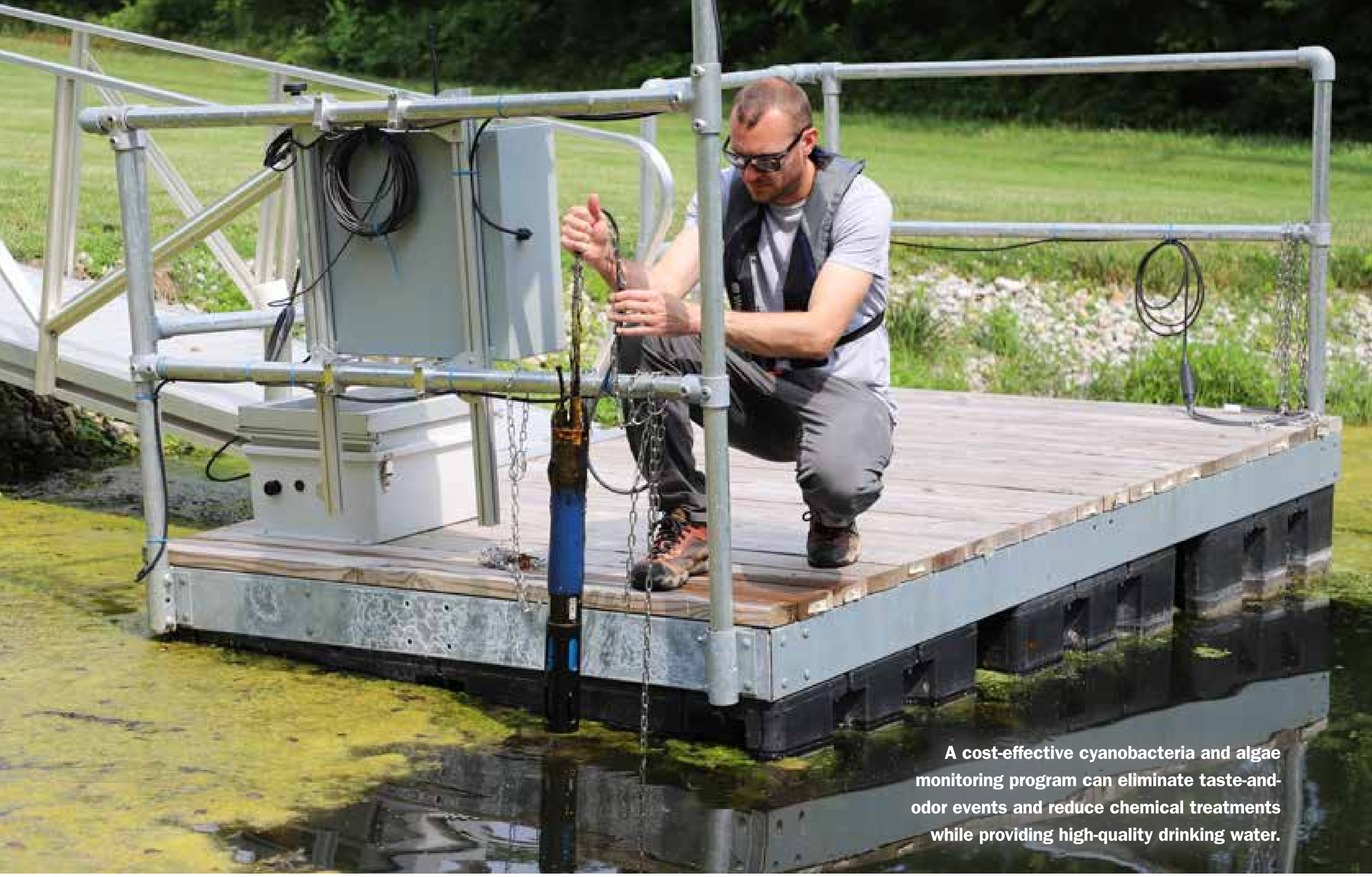
Each time a new monitoring program is evaluated, utilities face two proverbial million-dollar questions: How much does it cost to install? How much does it cost to operate and maintain? Beaufort-Jasper Water & Sewer Authority (BJWSA) in Okatie, S.C., tackled these questions with assistance from the engineering firm Hazen and Sawyer. The BJWSA team implemented a cost-effective cyanobacteria and algae monitoring program that has eliminated T&O events for more than six years.

Implementing ozone would have cost BJWSA at least $10 million per treatment plant, bringing its total to $20 million. Operating the system would cost approximately $1 million each year. Although ozone treatment systems effectively address T&O compounds, the cost is unapproachable for most utilities. BJWSA adopted a different approach. Because the utility owns and controls its two reservoirs, it developed an algae control plan focused on biological monitoring and management of its 330 mil gal of raw water storage. BJWSA invested in monitoring equipment, spending less than $400,000 on a FlowCam Cyano semi-automated flow-imaging microscope from Yokogawa Fluid Imaging Technologies (www.fluidimaging.com), gas chromatograph–mass spectrometer (GC-MS), reservoir sondes from In-Situ (www.in-situ.com), handheld probes from YSI Xylem (www.ysi.com), and training for existing staff. The utility spends less than $10,000 each year on service, supplies, and telemetry for the monitoring equipment.

To detect and mitigate algae as quickly as possible, BJWSA collects weekly samples at 13 locations in its raw water canal, reservoirs, and treatment plants, then analyzes them for 2-methylisoborneol (MIB), geosmin, nutrients, dissolved oxygen (DO), pH, chlorophyll, phycocyanin, algae, and cyanobacteria. Before bringing analysis in-house, MIB and geosmin samples were outsourced to the tune of $200 per sample. Not only did this cost more, results took days to arrive, rendering the data useful only as a historical snapshot. Bringing MIB, geosmin, organism identification, and cell counting analysis in-house paid for itself quickly, as the cost of GC-MS and the monitoring equipment were recovered in less than two years.

BIOLOGICAL MANAGEMENT

Monitoring for cyanobacteria and algae enables utilities like BJWSA to determine if, when, where, and how much to treat. BJWSA spends approximately $60,000 a year on reservoir treatments to address the six to eight algal blooms that occur annually. Copper sulfate is used discriminately on the reservoirs, and powdered activated carbon (PAC) adsorbs MIB and geosmin in the plant. Smaller blooms are adequately addressed just with PAC. But treatment approaches can vary, depending on local conditions. For example, the City of Wichita Falls, Texas, has a monitoring program that parallels BJWSA's program. Because cyanobacteria thrive in hot conditions, the Texas utility increased PAC use after its algae program was implemented. Although PAC increases costs, customer satisfaction is at an all-time high.



A cost-effective cyanobacteria and algae monitoring program can eliminate taste-and-odor events and reduce chemical treatments while providing high-quality drinking water.

PHOTOGRAPH: YSI XYLEM

One of the most frequent culprits of algae issues for BJWSA and the City of Wichita Falls is the cyanobacteria *Anabaena*. The organism is persistent and needs only days—sometimes just a few hours—to wreak havoc. It has a habit of making itself known on holidays in Beaufort-Jasper. A 2013 Christmas bloom led to hundreds of T&O complaints, which inspired the weekly monitoring program BJWSA has today. A 2017 Father's Day bloom tested the limits of the operators and its system. While the team's water operations leaders were attending AWWA's annual conference in Philadelphia, settled water turbidity tripled, followed by increases in filter turbidity, to create a rare and potentially serious event.

The villain was *Anabaena*, which released a substance that seemed to prevent coagulation but had no taste or odor this time. Raw water chlorine was turned on to facilitate turbidity removal. In doing so, the process lysed *Anabaena* cells, releasing phycocyanin, cyanobacteria's dominant pigment, which turned the utility's basins tropical blue. Operators poured alum on individual filters to decrease turbidity, only to see rates spike again. One by one, the filters fell below Partnership for Safe Water goals and regulatory limits.

Down to a single filter, BJWSA prepared for a boil-water notice. It's not uncommon for filters to clog if algae and cyanobacteria concentrations are high, but this event threw a wrench in coagulation and flocculation, which in turn upset the filters. After taking the reservoir offline and feeding high alum doses (more than 100 mg/L) for a day, the coagulation process returned to normal. Thanks to thoughtful master planning, system redundancy exists, and water was sourced from the utility's other treatment plant and wells during the event.

Although the team identified and mitigated the utility's largest bloom in history in record time (less than a week), BJWSA expanded its raw water monitoring plan to include additional indicators of cyanobacteria and algae, including field-deployed and handheld sondes to track chlorophyll and phycocyanin as well as monitoring equipment to determine the type and concentration of cyanobacteria present. The earlier a bloom is detected, the easier it is to address issues, including T&O, process failures, and cyanotoxins.

This scenario exemplifies the dynamic nature of biological management. Without in-house monitoring protocols and a fundamental understanding of cyanobacteria and algae, BJWSA couldn't have responded to the event in less than a week. Temporary loss of its primary reservoir and treatment plant could have shut down operations or at least required a boil-water notice. Monitoring cyanobacteria and algae is key to mastering the art of biological management, preparing water quality operators to respond effectively when needed.

CONSTRUCTING WETLANDS IN RESERVOIRS

Although algaecides effectively kill algal and cyanobacteria blooms, there are concerns about the enduring implications and ongoing operating expenses of chemical treatment processes.

Algaecides don't address the cause of the bloom; they merely treat the symptom. Copper sulfate carries additional risks to the utility. Treated cells lyse, releasing compounds that are difficult to remove from the water, including MIB, geosmin, or cyanotoxins, which can create a T&O or toxin event—or, in BJWSA's case, a process upset.

Conditions in the Savannah River, the utility's source water, continue to worsen over time, which has increased the number of blooms. Instead of increasing copper sulfate use, BJWSA is working with a consultant and researcher to manage biology with biology using a novel phytoremediation system that involves constructing floating wetlands in reservoirs. Native plants will take up nutrients, while the wetland will form a shade cover that blocks sunlight and adds oxygen to the water. The result will minimize the conditions for algal growth, which decreases the need for chemical treatment.

Algal blooms exhibit the remarkable ability of these organisms to exploit their environment. The conditions that promote growth—light, temperature, and nutrients—are well-known by the scientific community. There are two basic ways to limit algal growth conditions: limit nutrient inputs or maximize nutrient uptake. Wetlands are nature's long-established tool for cleaning and filtering water. However, urban expansion, agricultural nutrient runoff, and wetland draining practices make it nearly impossible for these natural systems to do their job. These conditions compromise the quality of water coming into the reservoir, creating more work for utilities.

Utilities can either increase algaecide use or seek alternatives, such as wetland construction, to create a balanced ecosystem capable of supporting a healthy watershed. Improving the quality of raw water enhances finished water quality. Even with a wetland to treat the cause of algal blooms, chemical treatments may still be required. The goal for chemical treatment is to be strategic, minimizing the quantity and frequency of use. This approach is informed by continuous biological monitoring efforts, determining when, where, and how much to treat. How can a utility manage a reservoir without algaecides? In Colorado, the cities of Westminster, Northglenn, and Thornton have done so for 20 years. Their replicable process is described in "Colorado Reservoir Remains Chemical-Free for 20 Years," page 19.

Managing a reservoir without algaecides starts with monitoring the biological and chemical characteristics that drive water quality metrics. To accomplish this task, utilities should track temperature, pH, chlorophyll, and phycocyanin levels with field-deployed sondes. Remotely collected data provide a baseline of the reservoir's behavior and health. The monitoring equipment is used in conjunction with sondes to identify and enumerate the cyanobacteria and algae that produce cyanotoxins and cause T&O events.

Knowing which organisms are present and in what abundance is critical to diagnosing the problem. Cyanobacteria populations can change in a matter of hours, so data should be collected at least every other day during bloom season. T&O and toxin testing via GC-MS and liquid chromatography–tandem mass spectrometry (LC-MS/MS) come next, particularly when MIB and geosmin or toxin producers are detected in abundance. An October 2020 *Opflow* article, "Tackle Taste and Odor With Proactive Water Quality Monitoring," dives deep into the subject, discussing the benefits (and challenges) of these methods.

AN INTEGRATED APPROACH

Operators throughout North America are adopting effective water quality monitoring programs, yielding excellent results. The City of Wichita Falls implemented its monitoring program in 2016 and eliminated customer complaints. Through its monitoring efforts, the city's environmental laboratory has developed the experience to know what triggers algae events in its area. Thanks to this intimate understanding of the behavior of the city's reservoirs, the team was able to reduce summertime monitoring from five days to two to three days per week.

The lab uses an integrated approach, including thermal profiling, DO, and pigment detection by sondes; algae/cyanobacteria enumeration and classification by FlowCam; T&O compound monitoring by GC-MS/ECD; cyanotoxin monitoring by quantitative polymerase chain reaction (qPCR); dipsticks from Eurofins Abraxis (http://abraxis.eurofins-technologies.com); and toxin confirmation and quantification by LC-MS/MS. Decisions are based on data generated by these tools, including source switching and chemical treatment at the source and/or in-plant.

The city has seen unusual spikes from time to time, but thanks to this comprehensive management approach, it's been able to detect spikes early and make data-driven treatment decisions. Most important, it's developed a solid historical baseline and now has a better understanding of its reservoirs. That baseline was difficult to establish at first, but long-term data collection fosters a comprehensive understanding of each reservoir's dynamics. When graphing data, including pH, temperature, DO, chlorophyll, phycocyanin, organism identification, and cell counts, it can be difficult to determine whether there's a trend and what its implications might be. Each piece of the toolkit is supported by others. No single method stands alone. This methodology integrates the microbiology and analytical labs, which creates a redundancy that reduces the likelihood of failure. At this point, the City of Wichita Falls is confident in its methods as well as its ability to maintain a winning streak. It has

All of these utilities are paving the way for others to learn how to better mitigate T&O events, manage cyanotoxins, and reduce chemical treatments while providing high-quality drinking water and bolstering public confidence in their water systems.

been more than four years (1,491 days) since its last customer complaint.

LEADING BY EXAMPLE

Algae and cyanobacteria are complicated. Variable data in biological analyses are to be expected, requiring sound judgment. The ability to interpret these data comes with experience, particularly because each reservoir is unique. Utilities can use this to their advantage by enhancing monitoring programs that use data to inform treatment decisions, allowing algaecides to be used strategically and cultivating native plants to improve water quality. Instead of wasting time and money to fight nature, successful programs attempt to understand and optimize natural processes. Treatment methods and results vary based on the ecological conditions each reservoir faces, and proactive management has shown to be a critical piece of the solution. Given patience and diligence, these skills can be learned. These industry leaders have proven that it can be so. All of these utilities are paving the way for others to learn how to better mitigate T&O events, manage cyanotoxins, and reduce chemical treatments while providing high-quality drinking water and bolstering public confidence in their water systems.

WATER MANAGEMENT

COLORADO RESERVOIR REMAINS CHEMICAL-FREE FOR 20 YEARS

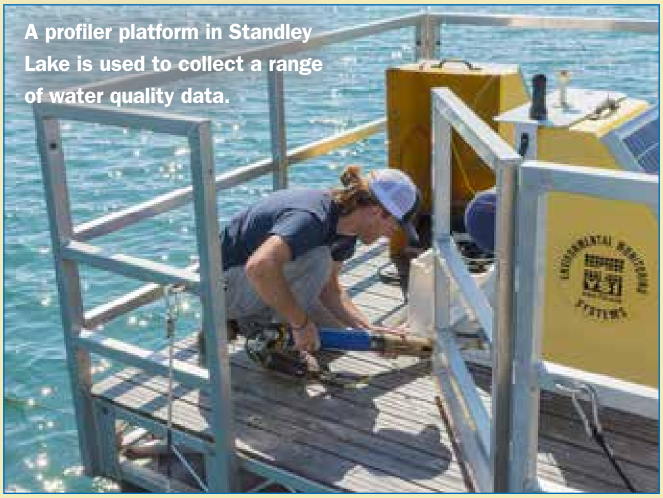
By Frances Buerkens, Yokogawa Fluid Imaging Technologies (www.fluidimaging.com), Scarborough, Maine, and Kelly Cline and Eric Scott, City of Westminster, Colo. (www.cityofwestminster.us)

The Colorado cities of Westminster, Northglenn, and Thornton are role models for affordable, effective water management. Their water systems have operated without chemical treatment for algal blooms for 20 years thanks to an automated observation network that collects data from as far as 60 miles upstream of Standley Lake down to the raw water taps in three water treatment plants.

The utilities use probes from YSI Xylem (www.ysi.com) to monitor pH, turbidity, oxygen reduction potential (ORP), fluorescence, dissolved organic matter, temperature, and conductivity, which can be used as proxies for nitrogen and phosphorus levels. These parameters are collected remotely every 15 minutes and loaded to lab computers. When water enters the reservoir, a YSI Xylem buoy profiles every meter to identify where algae and cyanobacteria are blooming. That alerts technicians where to collect samples. Further analysis is conducted within five hours, using a FlowCam Cyano semiautomated flow-imaging microscope from Yokogawa Fluid Imaging Technologies (www.fluidimaging.com) to determine which algae are present and how much of each genus, defining whether a taste-and-odor event or cyanotoxin event is likely.

Although most utilities rely on chemicals to treat blooms, these cities take a different approach. If a bloom happens in the upper part of the reservoir, the cities switch intakes. Small blooms are mitigated by treatment operators who use innovative oxidation treatment processes. When there's runoff after a rainstorm, the diversion of raw water from Clear Creek to the reservoir can be shut off, stopping the nitrogen and phosphorus inflow that feeds algae. Limiting nutrient intrusion in the reservoir renders treatment unnecessary. Spending less on chemicals means the cities can spend more on prevention and testing.

This proactive methodology is driven by customer expectations. In the 1960s, a poorly managed watershed rendered the water discolored and odorous, spurring what became known in national media as the



A profiler platform in Standley Lake is used to collect a range of water quality data.

PHOTOGRAPH: ERIC SCOTT, CITY OF WESTMINSTER, COLO.

"Mother's March" on City Hall. Additionally, public distrust of chemicals required a thoughtful approach. Although many utilities don't treat aesthetic issues, the outcry motivated the program in place today.

The cities succeeded in this chemical-free approach thanks to the conservation of land in the watershed as well as stakeholder collaborations to reduce road salt and nutrient inputs upstream. The cities also merged land-use plans with water data to ensure the water supply will neither run dry nor fall below water quality standards even as the population expands.

The program's weakness is that it requires a cross-trained team, shared monitoring, and documented standard operating procedures. Thanks to redundancy, teams rotate tasks and share monitoring efforts. This is critical during extreme events like COVID-19 as well as routine events such as vacation or sick days. By structuring a monitoring plan that maximizes the technology's effectiveness, the cities have proven that an eco-friendly approach to reservoir management is possible without chemicals, can reduce long-term operating costs, and can keep customers happy.