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Cyanotoxin Response Leads to Successful Resilience Planning

Although Salem, Ore., had a well-designed monitoring and treatment process in place, an algal bloom with historic consequences led the city to implement immediate mitigation measures and establish a long-term strategy for meeting future water quality challenges.

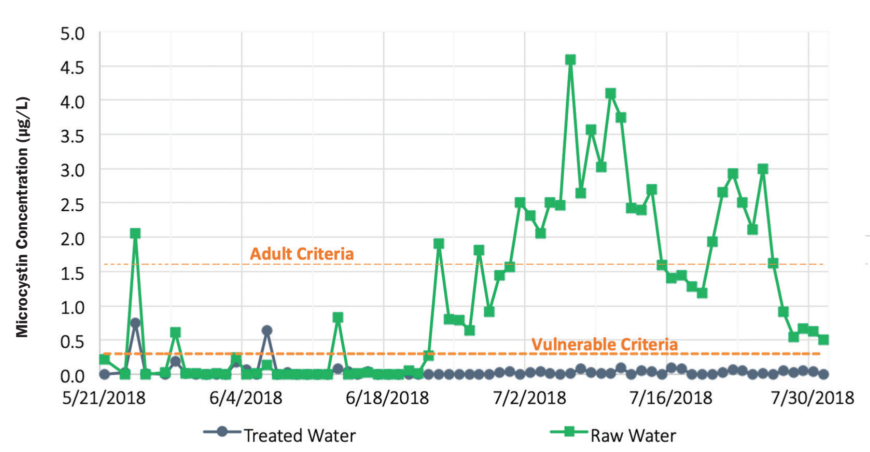
BY CHRISTOPHER JOHNSON, JASON DAVIS, AND TIMOTHY SHERMAN

IN 2018, the City of Salem, Ore., experienced one of the longest do-not-drink advisories in US history because of an algal bloom in Detroit Reservoir; one advisory was issued on May 29 and lifted on June 2, with a second issued on June 6 and lifted on July 2. The bloom produced cyanotoxins that ended up in the North Santiam River, Salem's water source.

In the past, Salem's rigorous watershed water quality monitoring program, coupled with slow sand filtration at the city's Geren Island Water Treatment Plant (GIWTP), had been effective in removing cyanotoxins from the raw water. However, in 2018, cylindrospermopsin and microcystin were detected in the raw water much earlier in the season and at higher concentrations than in previous years—7.0 and 2.1 µg/L, respectively. As a result, GIWTP struggled to reduce the concentrations to below the recommended health advisory levels. Figure 1 shows the challenges the plant had in reducing microcystin to below the advisory level for vulnerable populations early in the season.

Figure 1. Microcystin Concentrations at the GIWTP Intake and Point of Entry to the System

In the spring and early summer of 2018, the plant had trouble reducing microcystin below the advisory level for vulnerable populations.



FAST-TRACKING EMERGENCY TREATMENT MEASURES

Immediately following the do-not-drink advisory, Salem expanded its public outreach efforts to keep the public informed of developments while aggressively implementing near-term treatment enhancements to resolve the immediate situation. In parallel, planning also began for long-term improvements to mitigate the risk of future cyanotoxin and other possible events.

The near-term approach started with developing potential mitigation strategies, which were refined based on what could be implemented within a few weeks. The immediate treatment strategy became clear: Feed powdered activated carbon (PAC) into the plant's inlet channel and install solar mixing units to increase contact between the PAC and cyanotoxins. To minimize solids loading on the slow sand filters, chemical and

PHOTOGRAPH: CAROLLO ENGINEERS

hydraulic mixing systems were used to help coagulate the particles before settling in an existing basin.

Because of Salem's difficult situation, equipment and chemical procurement progressed in parallel with testing to prove the solution and refine chemical dosing recommendations and operational requirements. Testing included phases with increasing capacities, beginning at bench scale followed by pilot scale (1.5 gpm), demonstration scale (using one cell of an existing slow sand filter at 10 mgd), and ultimately full scale (at 40–50 mgd). The first bags of PAC, PAC feed equipment, and channel mixers arrived on site within weeks of detecting elevated cyanotoxin levels.

TESTING FROM BENCH TO FULL SCALE

Every opportunity was used to gather as much cyanotoxin removal data for GIWTP as possible. Bench tests performed by Carollo's Water Applied Research Center (Water ARC) were used to evaluate the efficacy of the near-term treatment strategy shown in Figure 2: PAC adsorption, two-stage biological filtration enhanced by acetic acid, and later chlorine oxidation. The laboratory confirmed that PAC removed cyanotoxins but was difficult to settle upstream of the slow sand filters, indicating that using the existing roughing filters for two-stage filtration would be needed to protect the slow sand filters from the additional solids loading. Tests also showed that chlorination oxidized cyanotoxins, but it required doses greater than those typically used in the GIWTP-treated water. Therefore, the city added sodium bisulfite following oxidation to reduce the chlorine residual to the desired level.

Following bench testing, the laboratory conducted pilot testing on the impacts of PAC on cyanotoxin removal as well as the operational challenges associated with removing PAC and coagulation chemicals using two-stage slow sand filters. For years before the cyanotoxin episode, GIWTP used a pilot facility at the site to better understand and test slow sand filtration operating parameters. This pilot equipment was quickly repurposed to test new chemicals and their role in cyanotoxin removal. PAC, coagulants (alum and polymer), and acetic acid were used as pretreatment for the pilot filters.

As previously mentioned, PAC was used to adsorb the cyanotoxins, and the coagulants were added to help remove the PAC. Before the cyanotoxin episode, pilot testing had shown that extended use of two-stage filtration reduced the biodegradable dissolved organic carbon (BDOC) levels, which are a "food source" for the biological layer, called a "schmutzdecke," in the slow sand filters. These low levels of BDOC would eventually starve the schmutzdecke, and filter performance would suffer. Recent work with the pilot facilities indicated that a small dose of acetic acid helped keep the schmutzdecke healthy, which improved biological filtration and helped with biological removal of cyanotoxins. However, if doses of acetic acid were too high, the schmutzdecke could develop too fast and require cleaning too often; therefore, the right balance in feeding acetic acid was critical.

Several months of bench and pilot testing were fast-tracked into several long weeks. The test results were scrutinized by operators and engineers, and adjustments were made to prepare for demonstration-scale testing on one filter. Once it was determined how one filter performed, the new approach (PAC and use of a roughing filter) was applied at full scale to all of the filters. City operators, engineers, and management put in long hours to review the data and make necessary process changes to use the new facilities for cyanotoxin treatment.

OPERATIONAL READINESS

During the 2019 algal bloom season, Salem measured raw water microcystin concentrations close to those seen during the 2018 season. However, as shown in Figure 3, cyanotoxins in the distribution system remained below advisory limits, and no advisories were required because the city had implemented a detailed monitoring and response plan using the lessons learned in 2018, along with the new near-term improvements for feeding PAC, acetic acid, and higher doses of chlorine.

These efforts resulted in an effective system that successfully treated the high levels of microcystin throughout the summer. The PAC system removed 50% or more of the toxins, with the rest removed by a combination of physical and biological filtration. The additional chlorine provided a multibarrier approach, oxidizing any cylindrospermopsin or microcystin that made it past other treatment methods. This near-term strategy has served Salem well while it implements a long-term, more sustainable, and effective solution: a new ozone facility that will produce high-quality water for years to come.

Operations staff reconfigured the pilot facility to test powdered activated carbon.

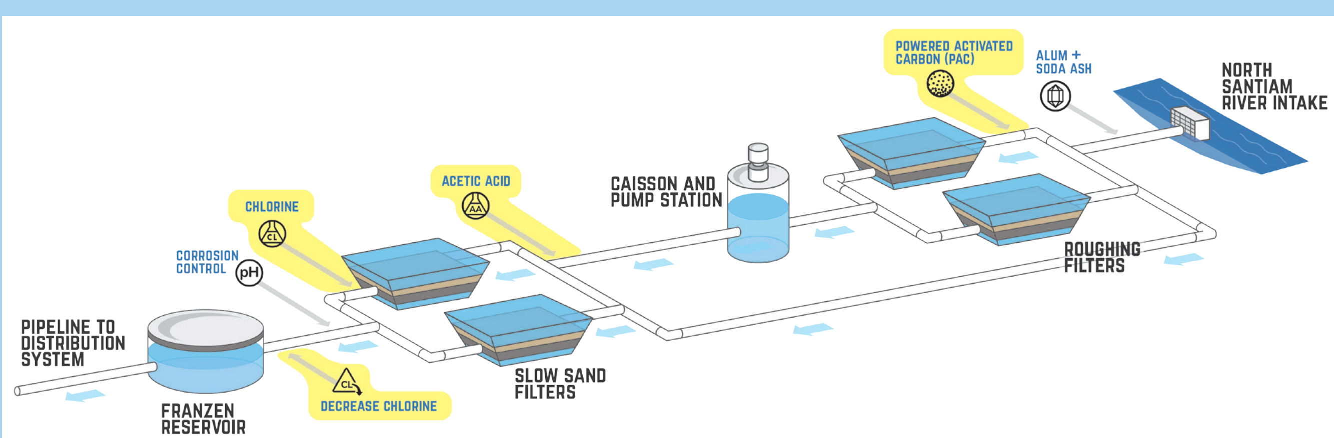
PHOTOGRAPH: CAROLLO ENGINEERS

PREPARING FOR THE FUTURE

For more than 80 years, GIWTP had a history of reliable operation through myriad changing climate and river conditions, but the latest cyanotoxin

Figure 2. Near-Term Treatment Strategy (Highlighted)

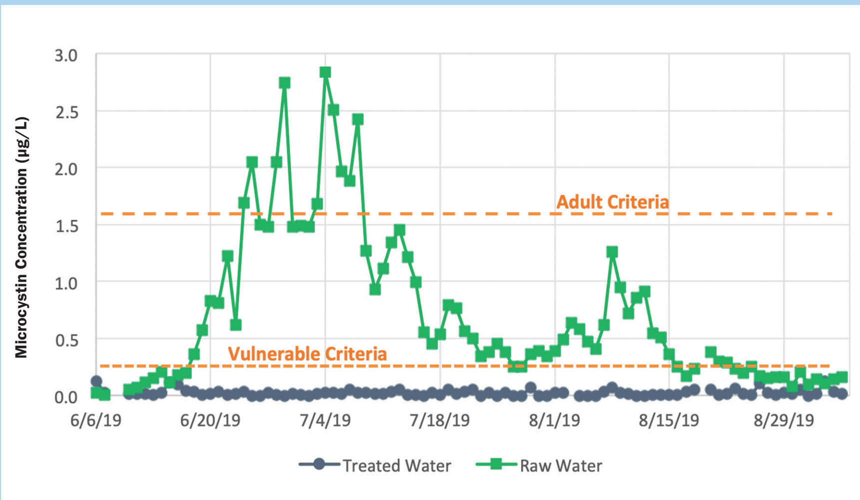
Bench tests were used to evaluate the efficacy of the near-term treatment strategy.



The city quickly implemented multiple short- and long-term strategies for dealing with cyanotoxins and looked forward to other possible challenges.

Figure 3. Near-Term Solution Works Throughout 2019 Cyanotoxin Season

The PAC system removed 50% or more of the toxins, with the rest removed by a combination of physical and biological filtration.



episodes forced Salem to take a hard look at a more permanent, long-term solution for such challenges. The city selected ozone as the long-term solution through a rigorous review of previous on-site testing; cyanotoxin treatment success at other facilities; and outside, independent reviews of testing to date. Ozone is multifaceted when it comes to treatment benefits, including destruction of cyanotoxins, oxidation of organic carbon and dissolved metals (enhancing their removal through filtration), and overall taste-and-odor reduction.

The ability to reduce organic carbon levels is important because organic carbon contributes to the formation of harmful disinfection byproducts. Organic carbon levels and levels of dissolved metals have been historically low in the North Santiam River but could increase after wildfires in the local watershed. Because of Salem's foresight in selecting ozone as the long-term solution for cyanotoxin treatment, the city will gain an additional tool in treating organic content and dissolved metals in the raw water if those levels increase as a result of wildfires.

The $50 million ozone treatment facility is expected to be online in spring 2021, providing an added layer of protection for Salem and increasing the reliability and resilience of its water supply. The facility will be operational just in time to help plant operations staff treat cyanotoxins and any residual effects of wildfires.

Wildfires in the West have become progressively larger and more destructive. This trend is expected to carry into the future, posing a significant threat to property and the environment as well as to surface water supplies. By using ozone, Salem will have the technology in place to continue to deliver safe, clean water to its customers, even as it anticipates these future challenges.

Although Salem was originally affected by a significant algal bloom, the city quickly implemented multiple short- and long-term strategies for dealing with cyanotoxins and looked forward to other possible challenges, including increased organic carbon and metals. These sustained efforts resulted in a robust system that successfully treated high levels of microcystin, and the new ozone facility will produce high-quality water for years to come. Such proactive planning can serve as a model for western utilities interested in preparing for future changes in source water quality and protecting water supplies for the long term.

Once it was determined how one filter performed, the new approach (PAC and use of a roughing filter) was applied at full scale to all of the filters.

PHOTOGRAPH: CAROLLO ENGINEERS