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David A. Isaacs and Nathan W. Long are with Aquatic Control (www.aquaticcontrol.com), Seymour, Ind. Russell G. Brown is with the city of Salem Water Works Department (www.cityofsalemin.com), Salem, Ind. William A. Ratajczyk and James C. Schmidt are with Applied Biochemists (www.appliedbiochemists.com), Germantown, Wis. John H. Rodgers Jr. is with Clemson University's School of Agricultural, Forest, and Environmental Sciences (www.clemson.edu/cafls/safes), Clemson, S.C.

Solve Taste-and-Odor Problems with Customized Treatment

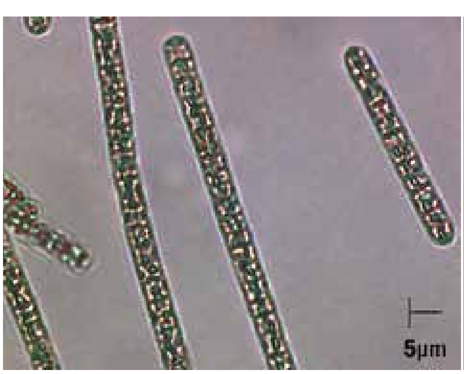
A Salem, Ind., utility devised a generic, widely applicable approach to taste-and-odor control that paved the way to site-specific treatment, resulting in higher quality water and fewer customer complaints. **BY DAVID A. ISAACS, RUSSELL G. BROWN, WILLIAM A. RATAJCZYK, NATHAN W. LONG, JOHN H. RODGERS JR., AND JAMES C. SCHMIDT**

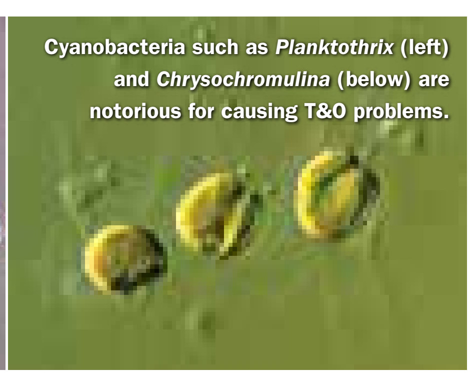
SURFACE WATER is the primary source of potable water for most US citizens. Although about 90 percent of US public water systems obtain water from groundwater, these systems are usually much smaller than those served by surface waters. Constituting about 66 percent of the potable water consumed, surface waters are periodically plagued by taste-and-odor (T&O) problems.

T&O COMPOUNDS

The two most commonly measured T&O compounds in water are geosmin and 2-methylisoborneol (MIB), which are produced primarily by cyanobacteria and actinomycetes that may grow to "bloom" densities before producing T&O compounds sufficient to cause problems for operators.

Geosmin and MIB are naturally occurring terpene alcohols produced by cyanobacteria and filamentous bacteria (actinomycetes) as well as myxobacteria. MIB is a volatile methylated monoterpene with an intense muddy odor that contributes to a musty or earthy smell in water and fish tissue. Geosmin (*trans*-1,10-dimethyl-*trans*-9-decalol)—an aromatic, volatile metabolite with an earthy smell—produces a moist soil odor and odd flavors in drinking water and food. These organic compounds are usually found in ultra-trace levels (a few ppt or less) in surface waters. The human nose can detect geosmin at concentrations as low as 5 ppt or 0.000005 mg/L. Although geosmin and MIB aren't known to be public-health problems, their presence prompts customer complaints and misinterpretation of the odors as a water quality problem.





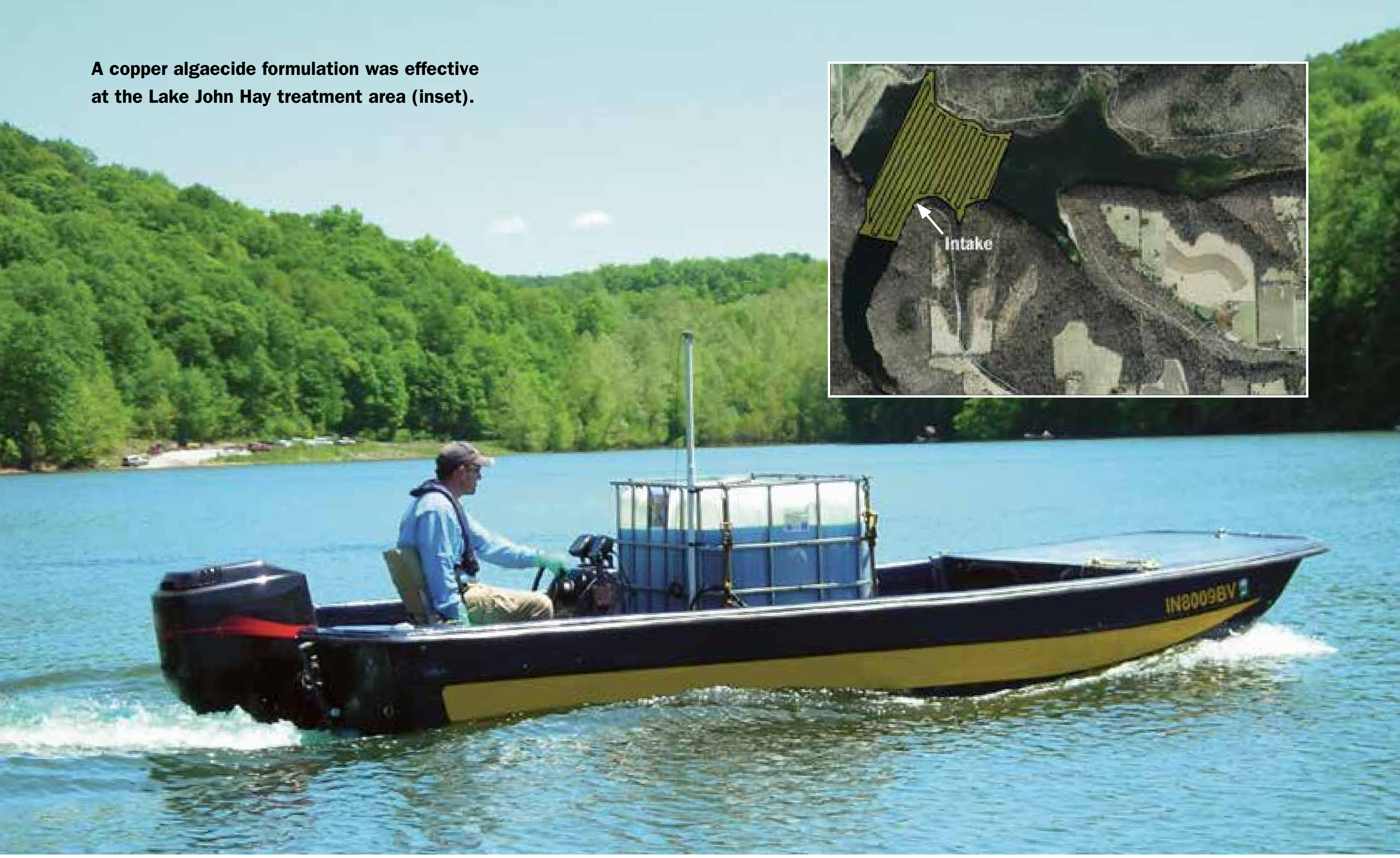
Cyanobacteria such as *Planktothrix* (left) and *Chrysochromulina* (below) are notorious for causing T&O problems.

Cyanobacteria species—including *Oscillatoria*, *Lyngbya*, *Phormidium*, *Planktothrix*, *Anabaena*, *Nostoc*, *Aphanizomenon*, *Synechococus*, *Chrysochromulina*, and *Pseudanabaena*—are common synthesizers of geosmin and MIB. Actinomycetes genera that produce geosmin include *Streptomyces*, *Nocardia*, *Actinobacteria*, *Arthrobacter*, and *Fossombronia*; some also may produce MIB. Several other microbes (e.g., fungi, protozoa, and eukaryotic algae) occasionally generate geosmin and MIB.

TREATMENT APPROACHES

T&O compounds in source water must be treated to produce potable water. Operators must decide whether to treat T&O compounds inside or outside the treatment facility.

Inside control involves dealing with T&O compounds when the source water arrives at the treatment plant. Treatment



A copper algaecide formulation was effective at the Lake John Hay treatment area (inset).

PHOTOGRAPH: AQUATIC CONTROL

may consist of ozonation for oxidizing geosmin and MIB and granular activated carbon for sorption. Outside control consists of managing the density of T&O producers through algaecide application. Water resource managers may need to use both control options. Site-specific considerations include the frequency and intensity of T&O production, logistics, water resource characteristics, availability of water treatment equipment, consumer sensitivity, and costs.

When algae grow to an extent that T&O compounds become a problem, water resource managers are compelled to intervene. Adaptive water resource management considers the following steps:

- Identify what, when, and where the problem is (T&O compounds in source water) and what and where the target algae are (planktonic or benthic as well as horizontal distribution).
- Determine what algaecide will control the target algae and how to achieve exposure (concentration and contact duration).
- Apply the efficacious algaecide to the target algae.
- Monitor the treatment response. Measure algal densities and T&O compound production pre- and post-treatment.
- Analyze complaints and costs for pre- and post-treatment.

Although these steps are generic and widely applicable, they will provide information that leads the way to a site-specific treatment approach.

A CASE IN POINT

Repeated, persistent algal bloom occurrences and production of T&O compounds in Lake John Hay near Salem, Ind., provided an opportunity to evaluate outside treatment and control. Lake John Hay is a 210-acre impoundment located about 6 miles northwest of Salem in the Rush Creek Valley. Owned by Salem

Figure 1. Laboratory Algal Challenge Test Cell Densities

Algal assemblage and densities in Lake John Hay samples were measured pre-treatment and 1, 7, and 14 days after treatment (DAT). *Planktothrix* and *Chrysochromulina* declined significantly the day after treatment.

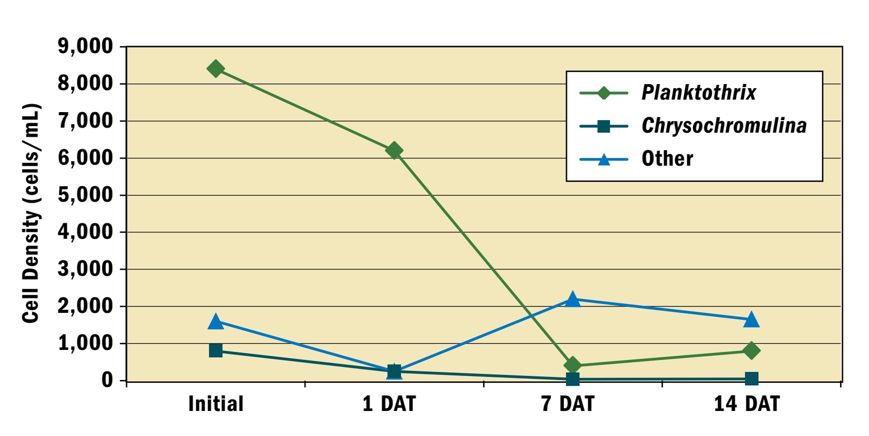
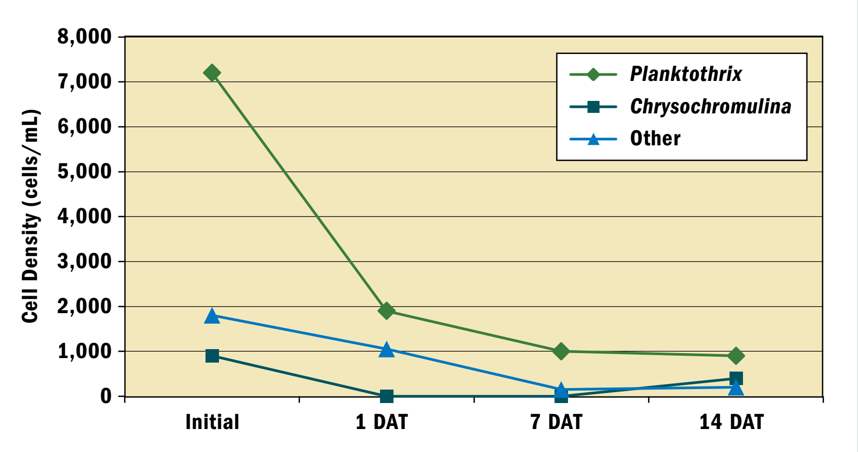


Figure 2. Station 4 Cell Densities

Algal assemblage and densities for the Lake John Hay treatment area were measured pre-treatment and 1, 7, and 14 days after treatment (DAT).



Water Works, Lake John Hay is one of two major water resources supplying Salem, Washington County, and the surrounding area. The reservoir drains an area of 9 mi^2, with normal storage of about 3,050 acre-ft. With an average 14–15-ft depth, much of Lake John Hay is within the photic zone and can support algae and vascular plants. Unrelenting complaints about the finished water's earthy T&O triggered an action plan to alleviate the problem.

The reservoir supports tournament and recreational fishing. However, because the reservoir is a drinking water resource, use of gasoline-powered motors is banned; only electric trolling motors are allowed. The reservoir is also a good place for observing birds and other animals that prefer relatively undisturbed environments.

Identifying the Problem. Water samples collected from several locations in Lake John Hay and examined microscopically identified two primary planktonic T&O producers—*Planktothrix* and *Chrysochromulina*—at densities (9 x 10^3 units/mL) sufficient enough to be the source of the problem. The algae were located in areas surrounding the water intake structure. Geosmin concentrations in excess of the human-detection threshold were also measured at several locations and in sediment samples.

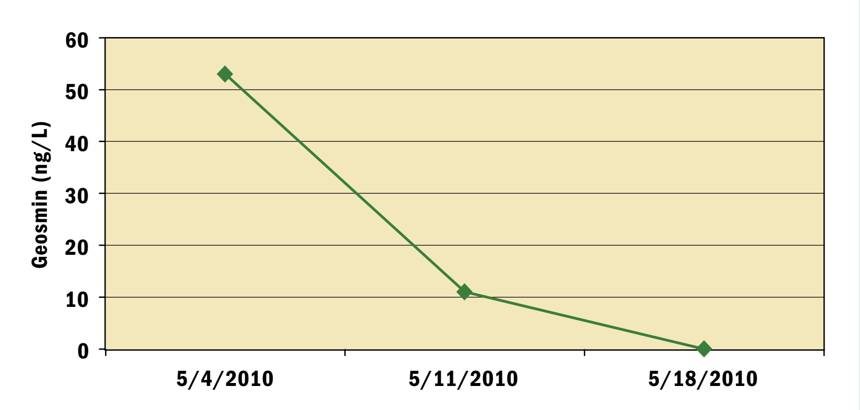
Tests. Laboratory experiments were conducted with three candidate algaecides (two copper formulations and a peroxide formulation) to determine the *Planktothrix* and *Chrysochromulina* responses to treatment. Algae in water samples were exposed to five concentrations with three replicates of each algaecide. Treatment responses were observed and measured for 14 days. Algal cell density, chlorophyll a, geosmin, and MIB were measured in response to algaecide treatments.

Algaecide Application. A 200-µg/L treatment dose of one of the copper formulations effectively controlled the algae. This approach demonstrated that algaecides don't always perform consistently in a given situation and that applying the maximum algaecide concentration specified on the label wasn't necessary in this case. Spectrofluorometer analysis revealed that chlorophyll a was reduced to nondetection levels, and cell densities declined by more than an order of magnitude. Geosmin concentration declined, and MIB wasn't detected.

An initial precision application of an NSF-certified algaecide was made near the lake's water intake structure on May 4, 2010. Precision applications consist of carefully calibrated algaecide delivery pumps as well as Global Positioning System and sonar (depth finder) equipment. The treatment area covered about one-third of the reservoir's surface area, including the raw water intake structure. Two months after the initial treatment (July 27, 2010), a second treatment was

Figure 3. Raw-Water Geosmin Levels

Geosmin concentrations in water samples from the Lake John Hay treatment area were measured before and after treatment with a copper algaecide formulation.



This adaptive water resource management approach improved customer satisfaction with the finished water and decreased the amount of algaecide required to maintain the water resource and its uses.

applied, using drop hoses to inject the algaecide at depth. Algae and geosmin were concentrated about 12 ft below the water's surface. This application method stressed using algaecide to treat the target algae—not just to treat the water.

Treatment Response. Water samples were collected pre- and post-treatment to measure the target algae's response to the algaecide. Cell densities of *Planktothrix* and *Chrysochromulina* declined significantly one day after treatment. MIB wasn't detected, and the geosmin concentration in the vicinity of the water intake structure declined from about 50 ng/L to a nondetectable limit (< 5 ng/L) two weeks after treatment.

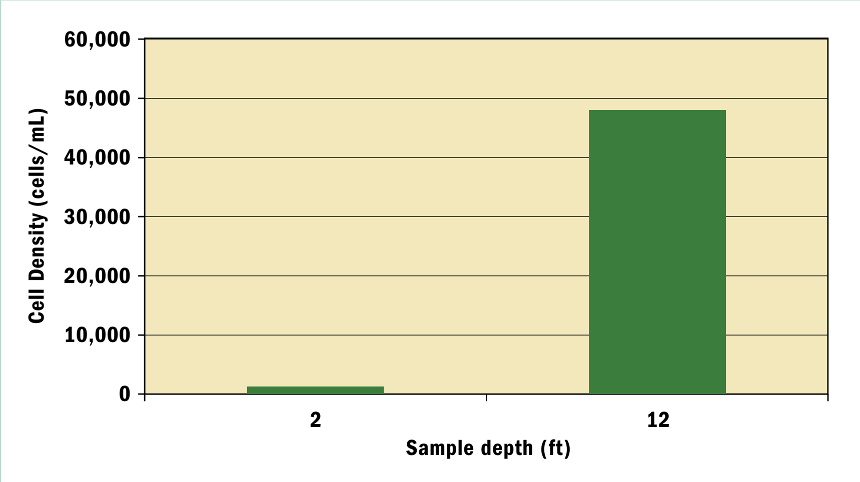
About two months later, but before the second treatment, algal cell densities were approaching 50,000 cells/mL at a 12-ft depth, and geosmin concentrations were > 35 ng/L in the treatment plant's raw water. After the second algaecide application, post-treatment geosmin concentrations were < 2 ng/L in the treatment plant's raw water. Future monitoring will include at-depth algal densities in surface waters, along with geosmin concentrations, water temperature, and dissolved oxygen.

Analysis. Complaints regarding the treated water's T&O were recorded pre- and post-treatment. In the years prior to algaecide treatment, there were complaints during spring and summer months. Geosmin concentrations had been so high that treatment with permanganate and activated charcoal wasn't adequate to reduce concentrations below the odor threshold, even though concentrations had been reduced by > 90 percent. Following the algaecide treatments, complaints subsided, and compliments for a job well done increased.

Treatment costs were also monitored. Initial estimates for treating the raw water supply indicated about a 21 percent reduction in post-treatment costs for producing potable water.

Figure 4. Station 4 Total Cyanophyte Cell Count

Total cyanobacteria cell densities at two water depths in Lake John Hay were measured on July 27, 2010, before water was treated with a copper algaecide formulation.



ADAPTIVE MANAGEMENT

Based on lessons learned from this project, the utility will further refine site-specific treatment protocols and decisions regarding algaecide application. The goal will be to trigger anticipatory treatments to prevent algal blooms and avoid consumer complaints.

This adaptive water resource management approach improved customer satisfaction with the finished water and decreased the amount of algaecide required to maintain the water resource and its uses. Although the case study is site specific, the approach is generic, adaptive, and widely applicable.

Figure 5. Plant Raw-Water Geosmin Levels

Geosmin concentrations in Lake John Hay raw water were measured before and after treatment with a copper algaecide formulation.