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Lake Houston SolarBee Project Report

by

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A. The Problem: For several years the City of Houston has experienced significant taste and odor events at the Northeast Water Purification Plant (NEWPP). The plant intake draws water from the west shore of 12,000-acre Lake Houston, near the south end of the lake but still far upstream of the dam. The plant draws 20 MGD from Lake Houston from about October to May, and 40 MGD from about May to October.

The months when the taste and odor problems have been most severe have been June, July and December. The cause of the taste and odor appears to have been MIB (2-methylisoboneol) and geosmin produced by blue-green algae (cyanobacteria), and possibly some sulfides produced by algae or other decaying organic material at the bottom of the lake. MIB and geosmin are usually the most concentrated in the epilimnion (upper waters above the thermocline) where the blue-green algae have access to sunlight for photosynthesis. But MIB and geosmin can be transported into the hypolimnion (bottom waters of the lake) through (a) nightly convective mixing, where a layer of surface water gets transported to the bottom of the lake each night due to evaporative cooling of the surface, and/or (b) strong wind mixing that breaks the stratification, common in large shallow lakes such as Lake Houston, and/or (c) the slow decomposition of dead blue-green algae cells that have fallen to the bottom of the lake in the past.

The intake pipe for the NEWPP is 6.5 ft diameter, and extends about 200 ft from shore into Lake Houston. The water enters the pipe through eight (8) horizontal intake screens manifolded together; each screen is 4 ft diameter x 6 ft long. The centerline of all eight screens is about 15 ft below the surface of Lake Houston and about 7 ft above the bottom of the lake at that location. The bottom of the lake where the screens are located slopes upward on the shore side of the screens, and is fairly flat in the other direction. This region of the lake is far removed from the old river channel.

B. SolarBee, Two Alternative Methods of Deployment: SolarBee, Inc. has developed portable long-distance, low-energy, solar-powered SolarBee™ circulators to improve water quality in lakes and reservoirs. The large machine most commonly used in lakes, the SB10000v12, pumps 3,000 gallons per minute (4.3 MGD) up its intake hose, and creates 7,000 gallons per minute (10 MGD) of induced flow, for a total of 10,000 gallons per minute (14.3 MGD) leaving the machine. Water enters the SolarBee horizontally from a fixed depth in the lake (there is a 1 ft opening between the intake hose and the bottom plate beneath, so water comes to the machine laterally), and a specialized dish that distributes the flow radially outward from the machine at the lake's surface. Since 2001, SolarBees have solved reservoir water quality problem in about 160 US lakes (out of 170), including over 60 municipal drinking water reservoirs.

SolarBees can be deployed in two different ways, depending on the problem to be solved:

(1) *blue-green algae control*: With this application the machine intakes have a shallow setting to mix and treat just the top portion of a stratified reservoir. Warm water is drawn into each machine from just above the thermocline (usually 1-2 meters deep in Lake Houston when the lake is stratified), and pushed out equally at the surface in all directions from each machine. Since all the water being pumped and mixed is warm water of nearly the same density, long-distance mixing is accomplished allowing for maximum spacing at about 30-35 acres per machine (700 ft radius, 1400 ft between machines). This horizontal and vertical epilimnetic mixing disrupts the ability of the blue-green algae to form blooms and dominate the lake, thus preventing MIB and gesomin problems.

(2) *hypolimnetic oxygenation*: With this application the machine intake is set deep into the relatively cooler hypolimnion, typically deeper than the depth of the intake to the water treatment plant, to draw the deep anoxic water out of the hypolimnion (which can be odorous with MIB and gesomin from dead algae, and/or with sulfides from any decaying organic material) and replace it with oxygenated water (which usually has no odors) from above the epilimnion. Machines are usually installed in the deep areas of the lake without regard to surface acre spacing.

<u>C. The Type of SolarBee Equipment Installed at Lake Houston</u>: It was not immediately known whether the SolarBees would be more effective if they were installed for <u>algae control</u> (shallow 6 ft deep intakes, machines spread out at 30 acre spacing each, best for MIB and geosmin caused by live algae) or for <u>hypolimnetic oxygenation</u> (deep intakes, machines located without regard to systematic surface acre spacing, best for MIB and gesomin caused by decomposing dead algae on the bottom of the lake). Normally, the equipment must be configured for either one type of treatment or the other. However, since Lake Houston has a rather flat bottom in the region of the NEWPP intake, it was determined that if the machines were all equipped with adjustable-length intake hoses, and spaced equally at 30-acre spacing. With this approach, either treatment method could be selected at any time with the same set of equipment by simply adjusting the intake setting of each machine. Accordingly, in April 2006, SolarBee Inc. installed (20) SB10000v12 machines, each with long adjustable intake hoses, at equal 30-acre spacing near the NEWPP intake.

<u>D. From April 2006 to early September 2006, the SolarBees were set for Hypolimnetic Oxygenation</u>. Initially, the SolarBees were all set for hypolimnetic oxygenation (see the attached chart showing the initial deep hose setting). The primary reason is that in prior years, the beginning of the taste and odor problems seemed to correspond to when the treatment plant switched from 20 MGD to 40 MGD. It seemed logical that if the source of the odors was MIB and geosmin produced by living algae, then the odors would have been present at 20 MGD as well as at 40 MGD, and there would not have been a change in odors when the plant increased its

flow to 40 MGD. On the other hand, if the unpleasant taste and odor was caused by dead algae and/or sulfides accumulating in the lake's sediments and bottom waters, then it made sense that the higher flow rate would create more problems because of how the treatment plant's 8 intake screens are configured; all 8 horizontal screens have openings in all directions, including sides facing downward to the lake bottom (about 5 ft below the bottom of the screens), as well as sides facing toward the shore where there is a slight upward slope of the lake bottom. So, higher flow rates could be expected to pull more anoxic bottom water into the plant creating more taste and odor issues.

The estimated flow rate of the SolarBees in removing odorous water from the zone between the thermocline and the lake bottom was: 20 machines x 4.3 MGD of hypolimnetic water per machine = 86 MGD of water transported from the hypolimnion to the lake's surface by the SolarBees. Before the SolarBees, the only turnover of this water was the 40 MGD that the treatment plant was taking. With the SolarBees, the total withdrawal rate from the hypolimnion increased to 86 + 40 = 126 MGD, or triple the prior turnover rate. This deployment provided sufficient circulation to keep objectionable amounts of odor-causing compounds from building up in the cooler hypolimnetic water and getting into the water treatment plant.

The hypolimnetic deployment was a good choice as there were no taste and odor complaints in the summer of 2006. NEWPP operations were apparently smoother than in past years during these critical warm months, and the hypolimnetic manganese problem apparently was relieved with the higher turnover rate of the hypolimnion in the vicinity of the plant intake. However, late June pH values above 9.0 in the 600-acre region where the SolarBees are deployed (SolarBee testing, 6/24/06) suggest that algae apparently were not being adequately controlled in the epilimnion. Nevertheless, the absence of taste and odor events during this time indicates that living algae apparently were not the cause of these problems.

<u>E. From Early September 2006 to the Present (February 2007), the SolarBees have been set for Algae Bloom Control</u>. In early September 2006, the SolarBees' deployment was switched from hypolimnetic oxygenation to algae bloom control by only raising the intake plate on each machine to 6 ft deep. The thinking was that some of the worst taste and odor events have occurred annually in December when the plant operates at a low flow rate of 20 MGD. So in December, when whole-lake mixing normally occurs, the taste and odor problems were more likely to be caused by living algae getting mixed throughout the water column than by compounds released from decomposing dead algae being pulled up off the bottom.

The decision to raise the SolarBee intake hoses for better algae control during the fall and winter months appears to have been a good one (though it still is not certain the change was necessary) as there were no taste and odor problems in the fall of 2006 or through most of January 2007. Data that provided information on fall algae control, and other important lake characteristics, were provided by the USGS. In late summer 2006, the USGS installed three barges equipped with monitoring instrumentation into Lake Houston: one at Site A located upstream of the SolarBee 600-acre treated zone, one at Site B within the treated zone ("treated zone"), and one at Site C downstream of the treated zone.

Periodic USGS data from the fall 2006 and early winter 2006-2007 indicate:

1. For much of the fall, algae control, as indicated by pH, was achieved in the treated zone. Site A had no pH data, but in the treated zone the pH usually was in the 8.0 to 8.5 range compared to 9.5 - over 10.0 at site C.

2. In the fall, water warmed up as it traveled through the lake.

3. For much of the fall, water mixed more thoroughly throughout the water column in the SolarBee treated zone. Even though the SolarBee intakes were set at only 6 feet deep, there was little temperature change down to 16 feet deep, probably due to nightly thermal-driven mixing. Average water column temperatures at Site B varied only 0.4 °C top to bottom, compared to 1.6 °C and 1.3 °C for Sites A and C, respectively.

3. For much of the fall, average conductivity was significantly less at Site B, averaging 145 μs/cm as compared to 165 μs/cm for Site A and 177 μs/cm for Site C. This may indicate better precipitation of dissolved solids for some reason at the treated zone, or it may indicate that there are springs or creeks supplying lower total-dissolved-solids water entering the lake near the treated zone.

4. In mid-October there was a flushing event that brought in low-pH water throughout the lake.

5. Even throughout most of December, Sites A and C were stratifying daily, with a relatively hard stratification of 1 °C to 4 °C gradient located 1 ft to 3 ft deep. This type of stratification helps blue-green algae by promoting favorable surface water stagnation. In contrast, the treated zone did not develop this daily stratification.

6. By January 15, 2007, Lake Houston appeared to be totally de-stratified and mixing top to bottom at all times of the day.

7. It was mentioned in one of the conference calls that there may have been a minor taste and odor event at the end of January or early February. No details are available and this has not been verified.

<u>F. In the future, should the SolarBee hoses be set for Algae Control or for Hypolimnetic Oxygenation</u>? From April 2006 to September 2006, it was demonstrated that a hypolimnetic oxygenation setting (deep intake) of the SolarBees could prevent summertime taste and odor events and manganese problems. From September 2006 to February 2007, it was demonstrated that a blue-green algae control setting (shallow intake) could prevent the severe December taste and odor problems. So it appears the City would have several options to consider:

1. Try a hypolimnetic oxygenation setting year-round. Due to the shallowness of Lake Houston, there is a fair probability that this setting could solve all problems all twelve months of the year.

2. Lower all SolarBee intakes every March and raise them every September.

3. Increase the number of machines from 20 to perhaps 30, and then have half the units set for hypolimnetic oxygenation and half set for algae control. Some fine-tuning may be required for the first year or two with this approach. However, ultimately this is most likely the best approach as it also builds in some additional security with the increased number of machines.

Please call Joel Bleth, 701-225-4494 or 866-437-8076 for any questions. Thank you!