Controlling Nitrification Within Pinellas County's Ground Storage Tanks

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In 2000, the Pinellas County Department of Environment and Infrastructure (DEI) installed a passive mixing system in each of its distribution system ground storage tanks (GSTs) to prepare for conversion to chloramines for secondary disinfection. These installations were completed in an attempt to reduce future potential nitrification issues in the GSTs. Conversion to chloramines occurred in 2002, and after gaining experience using GST passive mixers, DEI has been able to easily control nitrification in the GSTs at one pump station, but has encountered challenges in the GSTs at four others. The pump station in which control of GST nitrification has been easier is one that could be classified as having a high GST throughflow with a high incoming total residual chlorine (TRC) concentration. The other pump station GSTs typically have a lower throughflow and a lower incoming TRC concentration. Passive mixers can only impart mixing energy when they are active (i.e., they are filling a GST). Due to the system configuration and operating constraints, the primary strategy used to promote a more uniform water quality and reduce the potential for nitrification within these challenging GSTs has been to artificially increase throughflow by recirculating water through, or by flushing water downstream of, these pump stations.

To control nitrification in the distribution system and GSTs, DEI has increased system flushing and performs annual chlorine maintenance in which the system is switched from chloramines to free chlorine. The DEI flushes an estimated 255 mil gal of water per year. In summer and fall 2009, the system experienced the earliest reoccurrence of nitrification after chlorine maintenance in the beach community areas. This early onset of nitrification in the system was likely linked to low customer water consumption resulting from water-use restrictions brought on by early drought conditions and possibly from a localized decrease in population. For this reason, and because of future system demand reductions resulting from some wholesale users further developing their own water supplies, DEI authorized Jones Edmunds & Associates Inc. in 2010 to study the system and develop improvements to reduce nitrification in the system and system flushing requirements. The study found that the best way to control nitrification was to control TRC (Jones Edmunds, 2010). Figure 1 presents the TRC distribution at various nitrification conditions for the data collected during a 2008–2009 DEI nitrification study and reanalyzed in the 2010 study. The median TRC concentration of all non-nitrifying samples was 2.5 mg/L, and this data analysis indicates that the system needs to maintain TRC above 2.0 mg/L to limit the occurrence of medium and severe nitrification episodes (nitrite > 0.04 mg/L). However, to better control nitrification in the distribution system, DEI has established a goal of maintaining a minimum distribution system TRC of 2.5 mg/L.

The recommendations in the 2010 study included improving water quality in the GSTs by improved mixing and TRC boosting at some pump stations. None of the samples presented in Figure 1 was found to be nitrifying when the TRC concentration was 3.0 mg/L or higher. Since the GSTs contain large volumes of water for later use, DEI is considering establishing a higher TRC target (e.g., 3.0 mg/L) in the GSTs.

The DEI is implementing many recommendations presented in the 2010 study. However, before implementing the recommendation to improve mixing within some GSTs using active mixers, DEI and Jones Edmunds wanted to verify that any active mixers would perform as needed. In addition, DEI and Jones Edmunds

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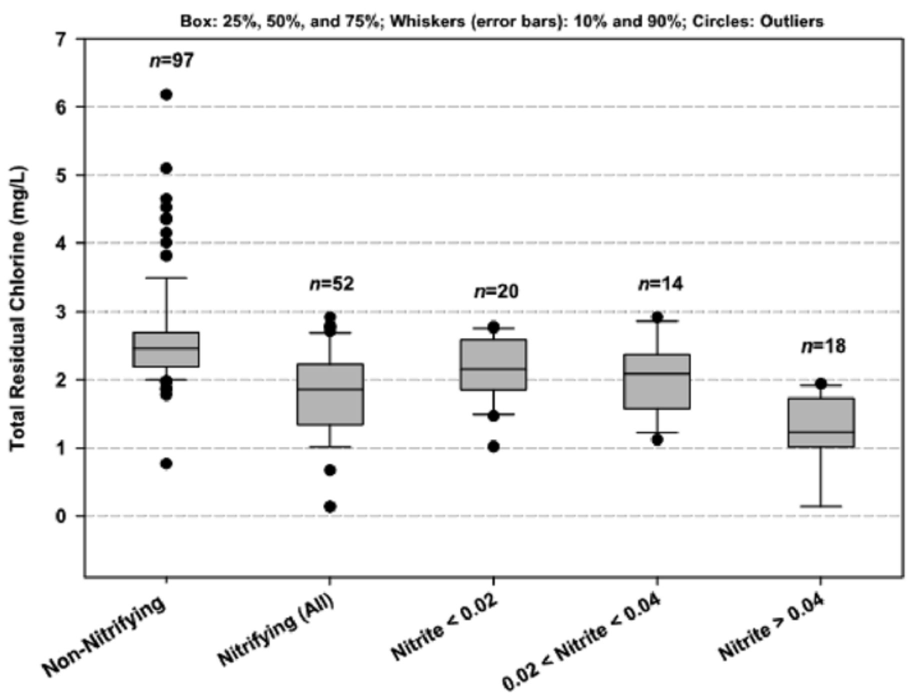

Figure 1. Nitrification Study TRC Distribution at Various Nitrification Events (2008–2009)

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wanted to use the results of this verification effort to help validate the performance guarantee requirement to which any potential active mixers would subsequently be held. For this reason, DEI authorized an active mixer demonstration test at one of its pump stations. Due to logistical reasons and the GST cleaning and inspection schedule, the demonstration test occurred at North Booster Pump Station (NBPS).

Active Mixer Demonstration Test Procedure and Timeline

The active mixer demonstration test involved isolating two GSTs at the NBPS. An active mixer was installed in the southeast (SE) GST, and the southwest (SW) GST was used as a control tank. The test timeline and general testing procedures are as follows:

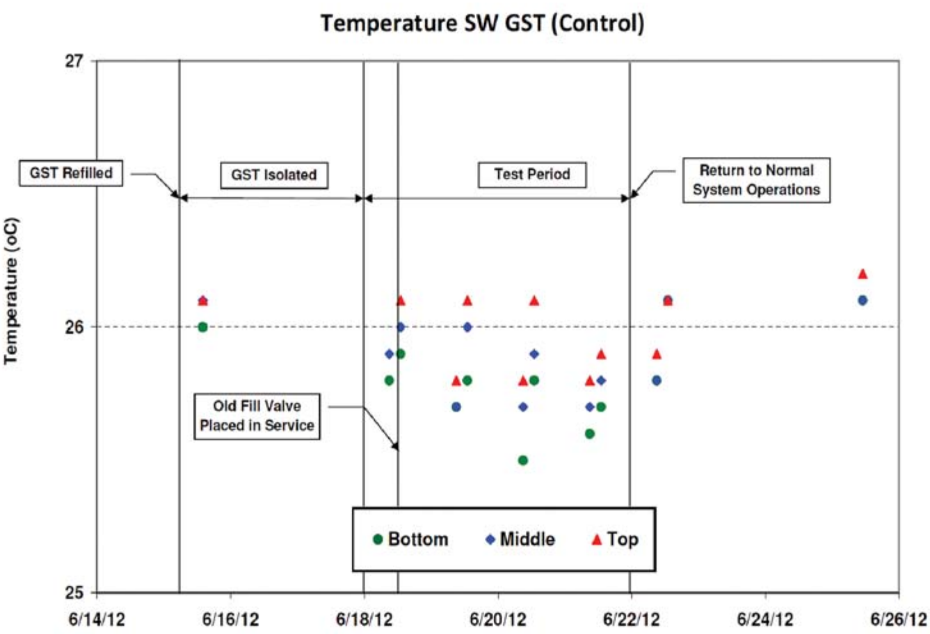

Figure 2. Recorded Temperature Readings in SW Control Tank

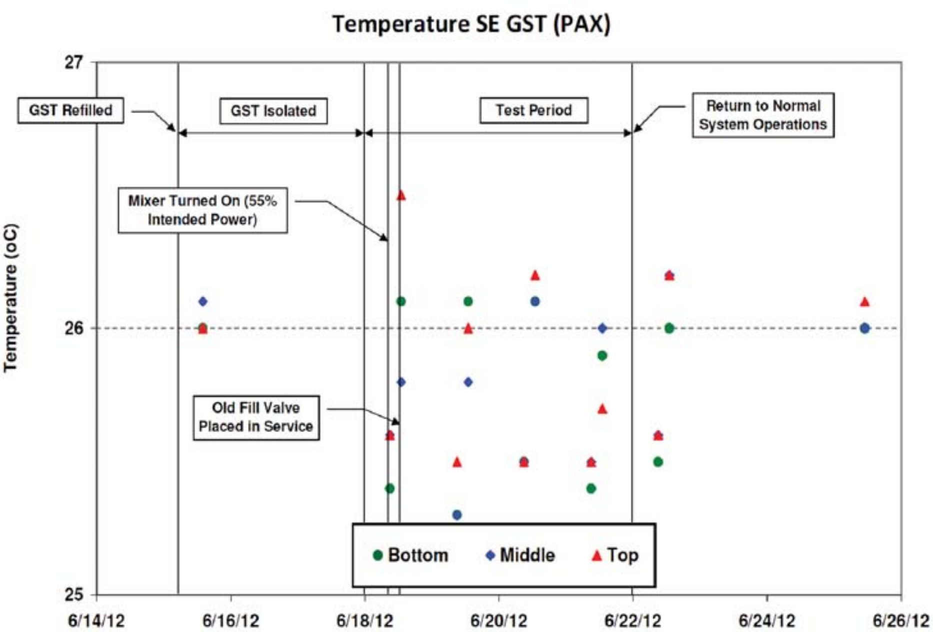

Figure 3. Recorded Temperature Readings in SE Actively Mixed Tank

- The SE and SW GSTs were isolated from the system by closing the inlet and outlet valves and then draining them before June 12, 2012.
- A PAX PWM-400 active mixer was installed in the SE GST on June 12, 2012.
- The SE and SW GSTs were refilled on June 15, 2012.
- The SE and SW GSTs were isolated from the system (inlet and outlet valves closed) after refilling through June 18, 2012, to promote the occurrence of stratification over the weekend.
- The SE and SW GST outlet valves were opened, the system operations were switched to using an older fill valve, and the active mixer was turned on at 50 percent power on June 18, 2012. This configuration created a worst-case, fill-and-draw situation in which the inlet is the outlet. This arrangement typically results in the most challenging mixing condition.
- The SE and SW GST inlet valves were opened and system operations switched back to using the new fill valve on June 22, 2012. In this configuration, the inlets and outlets were separated by 180 degrees and water enters the GSTs through the passive mixing systems. The active mixer was left at 50 percent power.
- Temperature, TRC, and other parameters (e.g., pH, nitrite) were measured and recorded at different levels in the GSTs from June 15-25, 2012.
- On June 26, 2012, the power setting for the active mixer was found to be at 50 percent, less than intended for a 5-mil-gal GST, and was increased to 90 percent, the intended setting.

Discussion of Results

Review of the collected data and results of the active mixer demonstration test indicate that the temperature and TRC readings provided the most meaningful information for evaluating GST thermal and chemical stratification. Figures 2 through 5 present charts of recorded temperature and TRC readings at the bottom, middle, and top of the SW GST (control tank) and SE GST (actively mixed tank). Thermal or chemical stratification was deemed to have occurred when a consistent temperature or chemical concentration profile pattern with depth was observed between successive readings. Typically, thermal stratification is identified in aboveground GSTs when warmer, less-dense water layers are at the top of the GST and cooler, denser water layers are at the bottom of the GST. The SW GST (control tank) experienced mild thermal stratification (range: 0.1 to 0.3°C) over the test period (Figure 2). The SE GST (actively mixed tank) did not experience thermal stratification over the test period (Figure 3). Although temperatures varied along the depth of the SE GST for most measurements, well-defined temperature layers did not persist. This is evidenced by the times when recorded temperatures at the top of the SE GST were lower than those at the middle and bottom. The SW GST (control tank) experienced significant chemical stratification of nearly 1 mg/L of TRC over the test period (Figure 4). The SE GST (actively mixed tank) did not experience chemical stratification over the test period (Figure 5).

Conclusions and Recommendations

Based on the active mixer demonstration test results and previous studies, the following conclusions and recommendations are provided:

- Incomplete mixing can lead to thermal and chemical stratification issues in a GST. Test data indicate that with the occurrence of thermal stratification (i.e., warmer water located higher in the GST), the TRC of the warmer water is less than the TRC of the cooler water. As a result, it can be concluded that incomplete mixing and tank stratification are the major reasons that nitrification issues are typically first revealed in the upper levels of a GST.
- Temperature is often used to determine if a GST is stratified. The test results indicate that having simultaneous mild thermal stratification and significant chemical stratification is possible. Since one of the primary improvement objectives is to maintain uniform TRC distribution throughout water depth to reduce the likelihood of nitrification within the GST, using temperature data as the only parameter to evaluate GST mixing is not sufficient for this system. The process performance guarantee and subsequent testing to verify that any installed mixing system meets the guaranteed performance should be focused on maintaining TRC uniformity throughout water depth.
- Although the data were limited, they appear to show that an active mixer installed in a GST with the worst-case inlet/outlet condition (i.e., the inlet is the outlet) and operating at 55 percent of intended power can provide mixing results equivalent to a passive mixing system installed in a GST in which the inlet and outlet are separated, significant throughflow is provided, and the mixing valves are submerged/operable.
- Maintaining acceptable GST water quality requires more than simply controlling stratification through mixing; drinking water quality parameters, such as TRC, disinfection byproducts (DBPs), and others within their regulatory limits, must also be maintained. A common starting point to attempt to do this is simply to control the amount of GST throughflow. When the amount of GST throughflow becomes unreasonable or the quality of the incoming water is not sufficient to sustain the GST water quality, additional treatment may need to be considered. When evaluating alternatives, the additional energy costs associated with throughflow beyond what is needed to meet the water system's hydraulic needs should be considered in the water quality alternatives evaluation.
- The DEI does not have a DBP issue, and maintaining somewhat longer retentions times in the GSTs is not expected to result in exceedances of the U.S. Environmental Protection Agency Stage 1 and 2 DBP rules. However, maintaining longer retention time

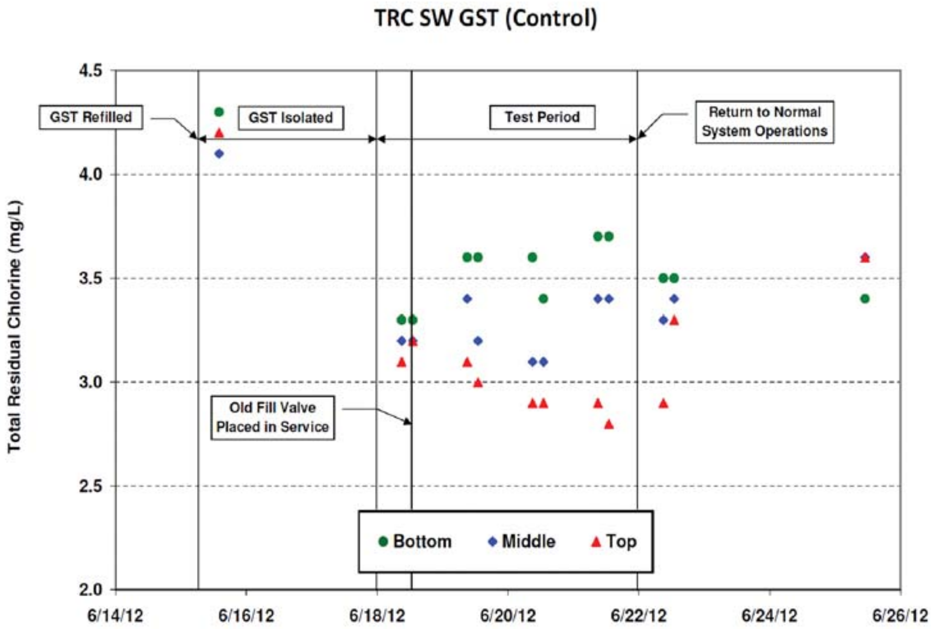

Figure 4. Recorded TRC Readings in SW Control Tank

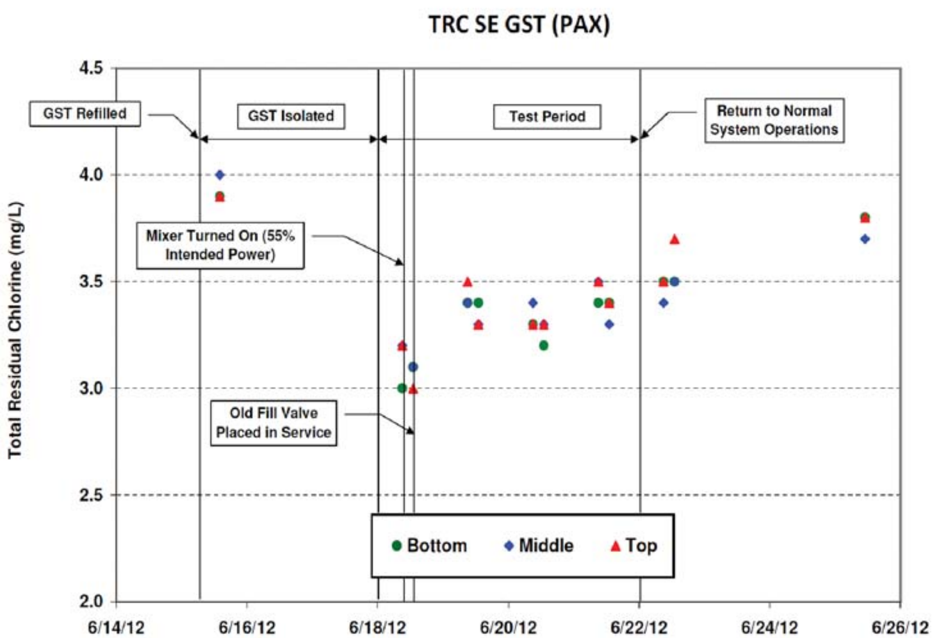

Figure 5. Recorded TRC Readings in SE Actively Mixed Tank

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can reduce TRC in the GSTs. Maintaining a minimum target TRC value throughout the water depth is critical to reducing the nitrification episodes in the GSTs. Figure 6 presents the expected TRC within a nearly full, completely mixed 5-mil-gal GST based on an inlet concentration of 4 mg/L for various throughflows and the range of bulk TRC decay coefficients measured in the system over the years. The inlet concentrations and/or reasonable throughflows for the GSTs at four pump stations do not appear adequate to maintain a target TRC value high enough to control nitrification within these GSTs during warmer months. For this reason, TRC boosting within these GSTs should be considered. During major distribution nitrification episodes, not enough free available ammonia may be in the water to combine with chlorine to boost TRC at some pump stations; therefore, the TRC boosting systems at some pump stations may need to include both chlorine and ammonia addition to be effective when most needed.

- The test results demonstrated that the active mixer installed in the SE GST appears to have met or exceeded its performance guarantee during the testing period, despite operating at 55 percent of intended power.

The following items should be considered when establishing mixing goals, selecting mixers (passive or active), and establishing GST throughflow strategies:

Uniformity

The type of uniformity (e.g., temperature, TRC, or other) to be maintained within a GST should first be determined. Once a uniformity goal is established, research should be performed on each mixing system being considered to evaluate past success at achieving the desired uniformity. If actual data are not available that demonstrate the mixing system has successfully achieved the desired uniformity, or if a need exists to first verify that a mixing system will be successful in a site-specific GST before proceeding with a permanent installation, a mixer demonstration test could be performed. For this project, the contracting requirements for the mixer demonstration test stipulated that if the mixer did not achieve the sought-after mixing uniformity, the mixer would be removed by the supplier and the supplier would be reimbursed a predetermined amount for its effort during the demonstration test. This protected DEI from purchasing a mixer that may not have been capable of achieving the uniformity goals.

Modeling

Hydraulic- and water-quality-extended period modeling of the distribution system is recommended for establishing 1) the throughflow needed at each GST to satisfy the system's hydraulic needs, and 2) the additional throughflow required for sustaining good water quality, assuming the GST is completed mixed. Sometimes, local treatment may also be needed to fully meet the water quality goals.

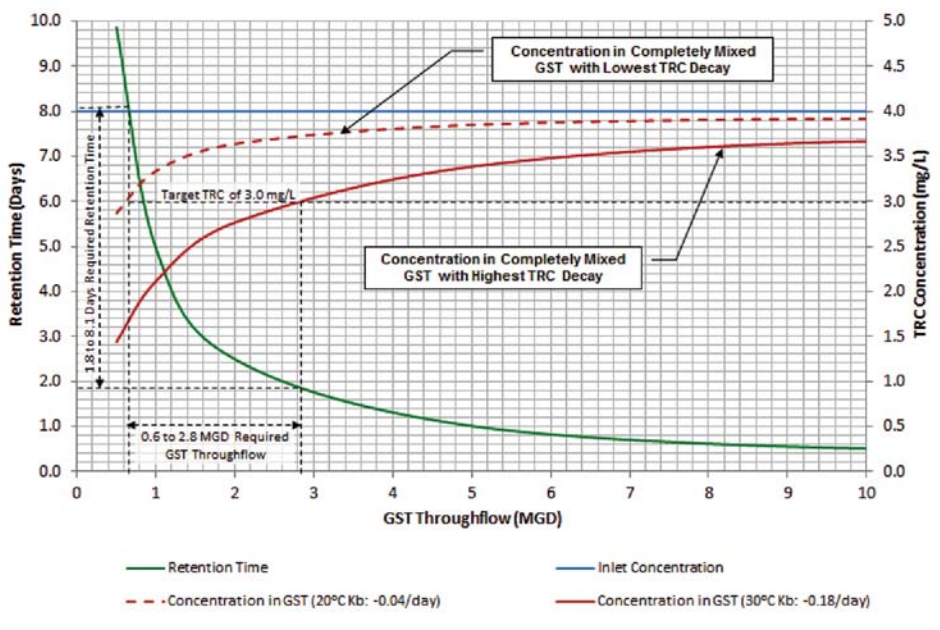

Figure 6. 5-Mil-Gal GST Retention Time and TRC Concentration Versus Throughflow

For passive mixing systems, the additional throughflow needs to be evaluated to determine if it is sufficient for a passive mixer to maintain destratified conditions within the GST. During this effort, the impact of buoyant jets on the passive mixing time needs to be considered, as buoyant jets could have a significant impact on the passive mixing time. If the passive mixing system requires additional throughflow to mix the GST beyond what is necessary to sustain water quality in a completely mixed GST (due to buoyant jets or for other factors), this additional throughflow also needs to be determined.

Cost Analysis

If multiple mixing systems are being evaluated and each satisfies the mixing goals, a present-worth cost analysis of the capital, and operation and maintenance costs, should be performed to determine which system has the lowest overall cost. The energy costs associated with the GST additional throughflow needed for each mixing system, beyond what is required to satisfy the hydraulic needs of the system, should be considered in the cost analysis.

Process Guarantee

The contract documents should include a mixing system process guarantee that is specific to the project's mixing uniformity requirements. In addition, a mixer demonstration test should also be required to prove that the process guarantee has been met before considering the installation is successfully complete and ready for payment. If the mixing system fails to satisfy the process guarantee, the supplier could be required to either make modifications necessary to satisfy the mixing requirements or remove its mixing system from the GST.

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References

- Jones Edmunds. (2010). *Upgrades and Improvements to Water Distribution System Final Report.* Prepared for Pinellas County Utilities, Fla., October.