

Investigative Sampling Special Study Protocol

Overview:

The Investigative Sampling Special Study can be implemented as a single event (i.e., during a comprehensive performance evaluation (CPE)) or as part of a multi-event long term effort to establish a distribution system optimization monitoring program at a water system that utilize free chlorine as a secondary disinfectant.

Similar to using turbidity as a surrogate for particles and bacteria in surface water treatment plant evaluations, free chlorine residual was identified as a surrogate indicator for water age and disinfection by-product (DBP) formation. Free chlorine residual is easy to measure and provides immediate results. Additionally, free chlorine decay is linearly related to DBP formation. Examples of this relationship, developed from data collected during a pilot CPE, are shown in Figure 1 for total trihalomethane (TTHM) formation and Figure 2 for haloacetic acid (HAA) formation. For TTHMs, the areas with higher free chlorine decay (relative to the water treatment plant (WTP) effluent), and lower measured chlorine residuals, coincided with higher TTHM formation.

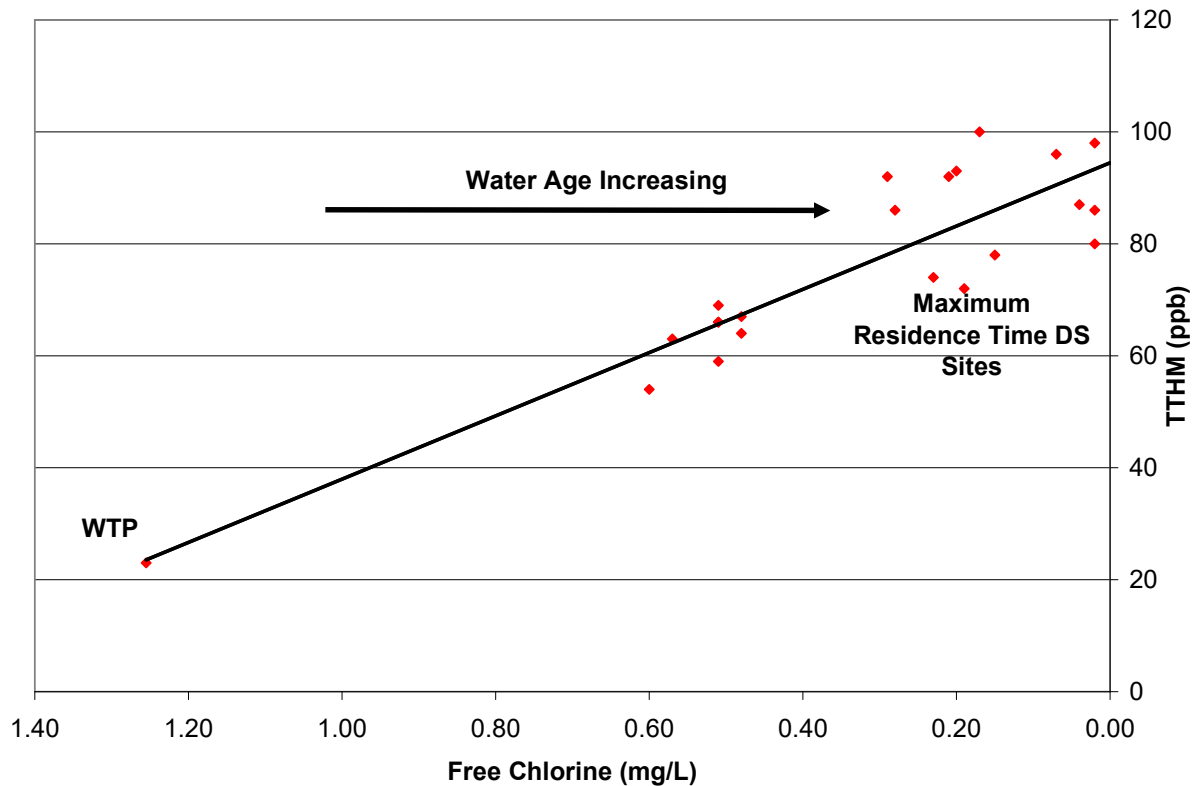


Figure 1: Example TTHM vs. Free Chlorine Decay Relationship

However, this relationship is not as strong for HAA formation due to the biodegradation of HAAs, which is often observed at sample locations with high water age and high free chlorine decay. Biodegradation is the microbial degradation of HAAs by heterotrophic bacteria, which result in lower concentrations of HAAs at high water age locations. If lower than expected (i.e., non-linear formation) HAA concentrations are observed at high water age locations, these data points should be considered outliers, as circled in Figure 2.

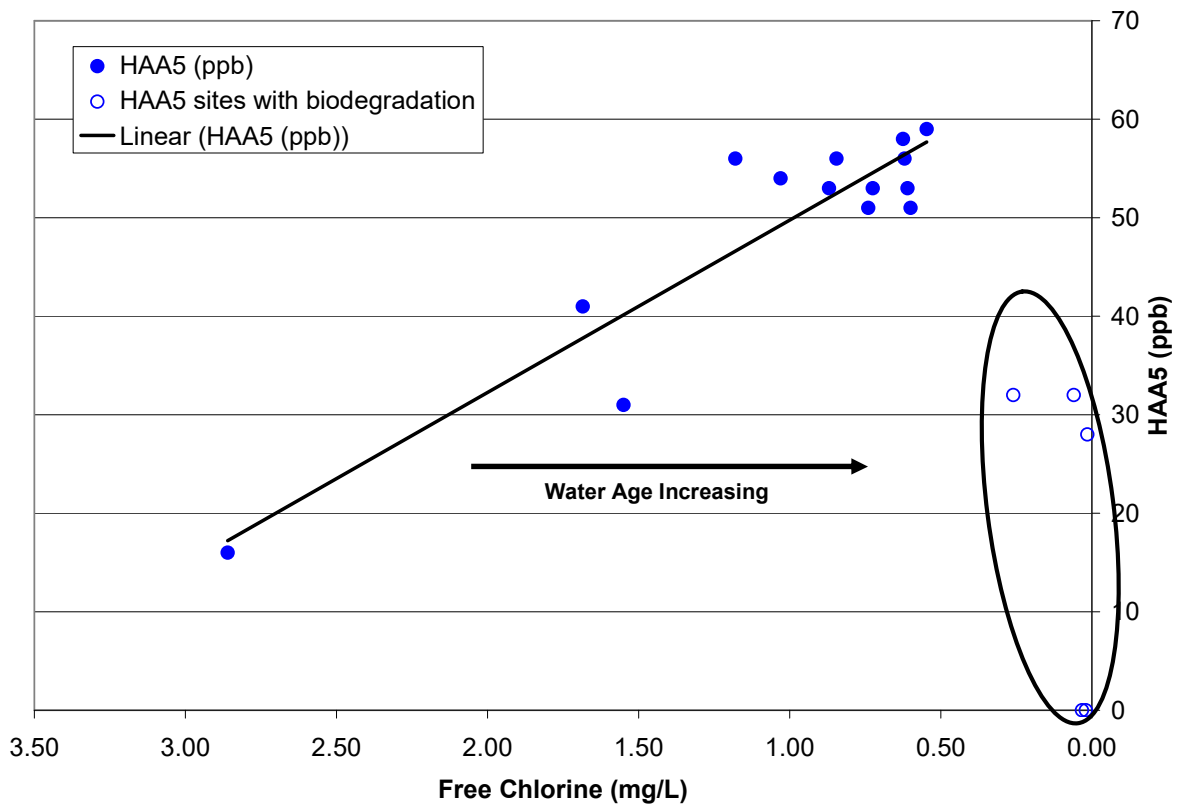


Figure 2: Example HAA5 vs. Free Chlorine Decay Relationship

Overall, the data presented in Figure 1 and Figure 2 support the use of free chlorine as a surrogate indicator of overall water quality. During this special study it will be assumed that low chlorine residual concentrations (relative to the WTP effluent) are indicative of areas of high water age, elevated DBP formation, and increased microbial risk. If DBP samples are not collected due to resource limitations, the general relationship between free chlorine decay and DBP formation may be used to estimate areas of elevated DBP formation. However, the system-specific relationship between free chlorine decay and DBP formation cannot be determined without sufficient DBP samples.

This special study can be used to accomplish various objectives:

- Identify areas of poor water quality (i.e., low chlorine residual, high DBPs) in the distribution system, so that operational changes can be made to improve public health protection.
- Trace water quality from distribution system influent throughout the system to identify specific areas of water quality degradation (e.g., high water age from low consumer demands, increased chlorine demand from pipe material).
- Identify areas of the system to install automated flushing devices to reduce water age (based on chlorine decay).
- Assess the impact of storage tank operations on water quality in the proximity of a storage tank.

Hypothesis:

The hypothesis of this study will vary based on the desired objective of the study (see the *Overview* section, above).

Resources:

- Required Personnel (*divided into two teams*):
 - Four to six (4-6) investigators
 - Two (2) distribution system operators
- Required Equipment (*divided into two teams*):
 - Two (2) distribution system maps that illustrate the location of all of the following (if possible):
 - Treatment plant(s) and/or wells
 - Connections to parent/consecutive systems
 - Water lines with diameters (all pipes $\geq 6"$)
 - Pump stations
 - Storage tanks
 - Booster chlorination stations
 - Regulatory sample locations (DBP and Total Coliform Rule)
 - Pressure zone boundaries
 - Two (2) colorimetric chlorine test kits with necessary instructions for various detection ranges and DPD reagents for free and total chlorine analysis
 - Two (2) pH meters with calibration standards
 - Containers for sample collection (e.g., six 100-mL beakers per team)
 - Two (2) bottles of deionized water
 - Two (2) tap samplers (*see Hydrant & Tap Sampler Design.pdf*)
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 - Two (2) hydrant adapters (2 ½" NST is typical; prior to the special study, confirm thread type and diameter, if the system uses a different thread type an adapter will be needed)
 - Two (2) thermometers (may be included in hydrant/tap sampler design)
 - Two (2) of the following tools: hydrant wrench, pipe wrench, crescent wrench, and screwdriver (confirm type)
 - Safety equipment for each investigator: gloves, safety glasses, first aid kit, traffic vests
 - Two (2) distance measuring wheels
 - Two (2) timers
 - Two (2) sets of pens, markers, and clipboards
 - Two (2) sets of log sheets and Calculated Flush Time Summary information (*see Data Collection Log Sheet.docx and Calculated Flush Time Summary.pptx*)
 - One (1) computer with Microsoft Excel and software capable of creating/modifying maps (e.g. PowerPoint, Streets and Trips, etc.)
 - Field Data Spreadsheet (*Investigative Sampling Data Spreadsheet.xls*)

- Optional Equipment (*divided into two teams*):
 - Two (2) groups of DBP sample sets:
 - Five to ten (5-10) sets of TTHM sample vials with preservative per team
 - Five to ten (5-10) sets of HAA5 sample vials with preservative per team
 - One (1) set of DBP shipping materials (e.g., coolers, ice packs, bags, chain of custody forms, packaging tape, bubble wrap, markers, temperature blank, etc.) per team (if samples will be shipped)
 - Two (2) calculators
 - Two (2) dechlorinators with dechlorinating reagent
 - Two (2) flashlights
 - Two (2) boxes of disposable laboratory wipes
 - Spare batteries (pH/chlorine kit specific)
 - Spare “required equipment” (e.g., chlorine test kit, pH meter, tape, etc.)

Approach:

1. **Locate Sample Sites:** Review distribution system maps and identify sample locations¹ with the assistance of distribution system personnel. If this special study is part of a CPE², the results from the historical data analysis and information from the distribution system “tour” may also be used to determine sample locations. The quantity of sample locations to be identified depends on the time available and objective of the sampling study. During site selection, the following locations should be considered:
 - Distribution system influent locations (i.e., WTP, wells, or connections to parent systems), to provide a reference to compare all other distribution system water quality data (*required*)
 - Areas with frequent customer complaints (e.g., taste and odor, low pressure, color)
 - Regulatory sample locations (DBP and Total Coliform Rule) that have resulted in a violation
 - Areas with aging pipes (e.g., old cast iron lines)
 - Areas with reactive pipe materials (e.g., unlined cast iron, asbestos cement)
 - Areas where water from different sources is blended
 - Storage tanks (while draining):
 - Samples may be collected from in the tank (if taps are installed), from the inlet/outlet, or in the proximity of the tank in the distribution system
 - Poor mixing and/or turnover
 - Operating in series
 - Standpipes (height > diameter; prone to poor mixing)
 - Areas where high water ages is anticipated:

¹ Identify general areas of interest and not specific sites when determining sample locations on distribution system maps. Often times, specific sample sites may not be used for various reasons (e.g., traffic, broken hydrant, etc.).

² If conducted during a CPE, sampling should be limited to one or two areas of the system to identify *evidence* of poor water quality. Ideally, results from this study should convince both managers and operators to pursue distribution system optimization.

- Extremities of the distribution system and/or maximum residence time locations
 - Areas with physical and/or hydraulic dead-ends (i.e., valves or pressure boundaries impede flow)
 - Areas with vacant industrial, commercial, or residential developments
2. **Collect Samples:** Collect samples at the identified sample locations in the distribution system with the equipment identified in the *Resources* section. Assign sample sites to each team, which should consist of two to three investigators and one operator. The investigators should collect samples using the calculated flush time (CFT) approach (Sekhar & Dugan, 2009) with a hydrant and/or tap sampler. Free chlorine residual, total chlorine residual³, DBPs⁴ (if applicable), pH, and temperature measurements should be taken at each sample location. The operator should open hydrants, navigate the team to each sample location, and if needed, facilitate access to sample taps at water system facilities (e.g., pump houses, storage tanks).
3. **Assess Results:** Sample results from both teams should be compiled in the *Investigative Sampling Spreadsheet.xls*. This spreadsheet may be used to determine the relationship between free chlorine with total chlorine residual, TTHM concentrations, and HAA5 concentrations. In addition to tabulating the results in a spreadsheet, the free chlorine, TTHM, and HAA5 data should be plotted on the distribution system map(s)⁵. This allows the results to be spatially interpreted, which enhances the identification of “problem areas” in the distribution system and supports the identification of performance limiting factors (if applicable). If this study is being conducted over multiple days (e.g., during a DS CPE), the results should be plotted daily so that the sample locations can be changed to satisfy the overall objective of the study. An example distribution system map with sample site locations is shown in Figure 3 and a distribution system map with free chlorine data and sampling summary in Figure 4. Similar maps may be made with the DBP data when it becomes available.

³ If the system routinely measures and reports for compliance monitoring total chlorine residual, both free and total residual should be measured at all sample locations. If the system routinely measures and reports free chlorine residual, then total chlorine residual measurements should be collected to compare to free chlorine results at approximately 20% of sample sites.

⁴ If a limited quantity of DBP samples are available, attempt to collect them at sample locations that represent a range of observed free chlorine residual. This will help in determining the relationship between free chlorine decay and DBP formation.

⁵ Both TTHM and HAA5 results will not be available until they are analyzed by the laboratory, which may take several weeks. As a result, only free chlorine residual data may be shown on maps if this data is presented at the exit meeting of a DS CPE.

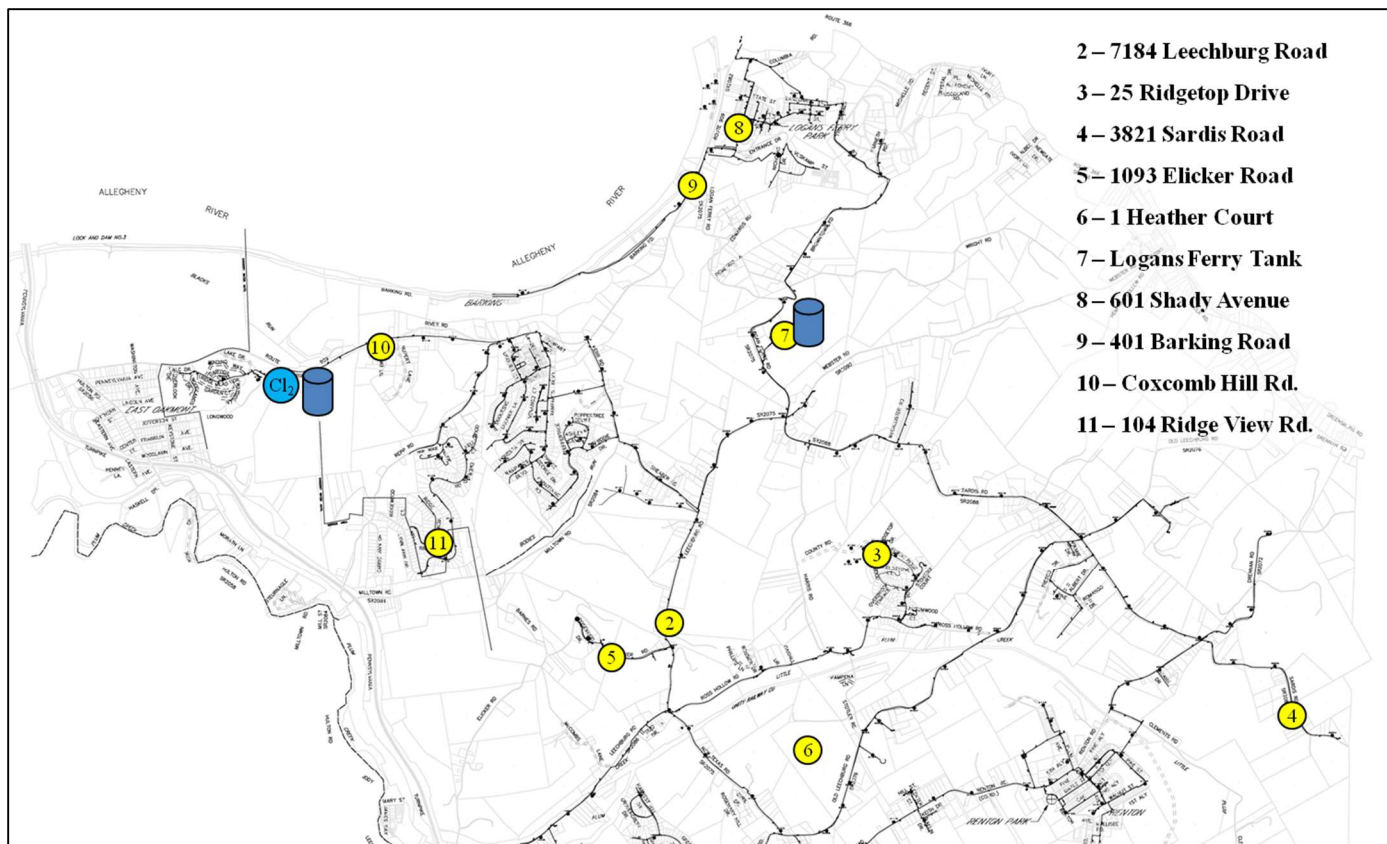


Figure 3: Example Distribution System Map with Site Locations

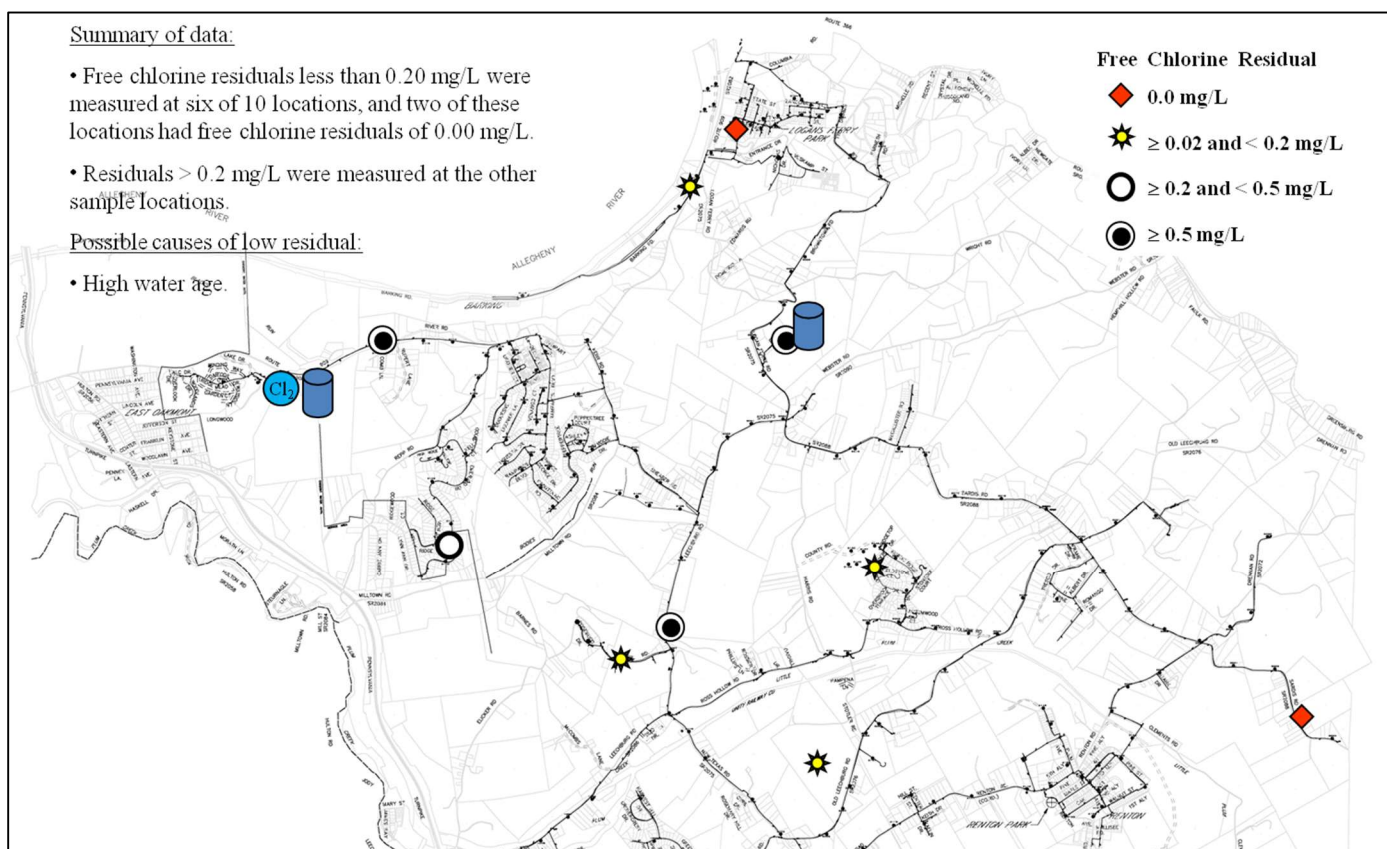


Figure 4: Example Distribution System Map with Free Chlorine Data and Sampling Summary

Duration of Study: The duration of the study can vary based on the objective of the study, the number of sample locations, and the travel time between each sample location. If this study is conducted as part of a CPE, it is typically conducted during the afternoon of Day 1 (Tuesday) and the morning of Day 2 (Wednesday).

Expected Results: The results from this study should identify areas of poor water quality within the distribution system. Specific sites or areas of concern may require further evaluation before operational strategies can be identified to improve distribution system performance.

Summary and Conclusions: This will be developed once the study is complete, but will likely include many of the figures generated above, as well as conclusions supported by the water quality data. It is likely that the investigative sampling special study will reveal water quality sample sites that are more critical than the current compliance sampling sites.

Implementation: Water systems interested in pursuing optimization could use the results of the investigative sampling special study to identify critical sample sites for long-term optimization monitoring. These sites may include some of the same sites identified in this special study or sites in other critical locations. Developing a level of water quality awareness within a system (i.e., compliance and critical locations), can provide an excellent “early warning system” for system-wide distribution system water quality problems.

References:

Sekhar, M., & Dugan, A. G. (2009, January). Collect Representative Distribution System Samples. *Opflow* , 20-23.