

Report for 2001MA3341B: Monitoring Disinfection Byproducts in Drinking Water: Strategies for Small Utilities

There are no reported publications resulting from this project.

Report Follows:

Monitoring Disinfection Byproducts in Drinking Water: Strategies for Small Utilities

Problem and Research Objectives

To develop and test several strategies for non-compliance monitoring of THMs and HAAs in small to medium sized drinking water systems using free chlorine as a residual disinfectant. Over the next decade, small drinking water systems will have to comply with the new stage 2 federal regulations for minimizing disinfection byproducts (DBPs). These contaminants are costly to measure and their concentrations are highly dependent on source water quality, physical conditions, and engineering parameters. Reliable and cost-effective control of DBPs requires good knowledge of the relationship between system operation and DBP concentrations throughout the system. Currently only large water systems have the resources to measure their own DBP concentrations. This leaves small systems at the mercy of commercial laboratories, with almost no chance of managing their system in 'real time'. The combination of staffing limitations and the forementioned disengagement between utility and data analysis leaves small systems with little opportunity to develop their own in-house expertise at controlling DBPs. The end result of this project will be new set of tools that can empower small utilities to better manage their THM monitoring and control.

Methodology

Our first activities were to test out some of the simple analytical tools that were proposed for this work: UV absorbance measurement, chlorine residual titration, and the Fujiwara-based colorimetric THM test (Hach's THM Plus). The students were trained in the use of these tests in the laboratory, and they developed strategies for field use.

Early in the summer of 2001 we identified Northampton as the test site for the medium-sized utility. Several meetings with the Northampton Department of Public Works staff followed, and we were given access to key information on their system (e.g., pipe network, past water quality data, operational practices). Tighe & Bond also assisted in providing us a nearly-working hydraulic distribution system input file.

With the assistance of Boston Water and Sewer Authority, we were able to secure a 1000-pipe version of Haested Methods's WaterCAD program, just sufficient to accommodate Northampton's 926-pipe system. Following several months of discussions between Northampton, UMass and Tighe & Bond, we were able to formulate a reasonable water demand file and run the full program. Since then we have modeled chlorine residuals throughout the system and have graphical and tabular outputs that were generated to compare with field data.

In addition to the laboratory activities and computer modeling, there were four major field sampling events. These occurred on October 2, 2001, October 16, 2001, February 5, 2002 and June 28, 2002. In each case, samples were collected from the raw water sources, and up to 20 separate locations in the distribution system. At the time of collection, field measurements for chlorine residual, temperature, and pH were made. The samples were brought back to the UMass laboratory for analysis of TOC, DOC, UV absorbance, haloacetic acids, trihalomethanes and other neutral extractable byproducts. In addition, several bulk raw waters samples were collected on the second, third and fourth field sampling dates. These have been subject to an

extensive set of kinetic experiments that involve chlorination under varying conditions with analysis of byproducts by gas chromatography.

Extensive data analysis followed each of the field sampling events. Laboratory kinetic experiments provided data for use in calibration of a kinetic model. These types of models constitute one of the major strategies proposed in this work for assessing and managing disinfection byproduct (DBP) concentrations. When combined with the hydraulic model (which estimates water age), the kinetic model is used to predict concentrations at specific locations. These are then tested against the field data to determine predictive accuracy.

The next major field effort will involve one of several resin extraction protocols. These are currently being developed in the laboratory. Options being investigated include use of hydrophobic (reverse phase) resins, hydrophilic (normal phase) resins and anion exchange resins. Each will be tested for retained (following elution) and unretained TOC and UV absorbance.

Principal Findings and Significance

- The concept of using a hydraulic model with a chemical water quality model has shown itself to be viable in the Northampton system. Predicted chlorine residuals based on laboratory data and modeled hydraulic retention time matched well the actual measured concentrations in the system. This leads one to conclude that both models (hydraulic and chemical) are effective at describing the data, and that there are no overwhelming “pipe effects” in the Northampton distribution system. Since, we have not even had to adjust the node demands to reflect the real heterogeneous use pattern that exists in Northampton, this also suggests that demand allocations need not be highly spatially resolved. Nevertheless, there was at least one sampling campaign (February 2002) where model predictions could have benefited from a pipe wall demand term. Future testing will better clarify the need for this model add-on.
- During warm weather, HAA biodegradation occurs at locations where the chlorine residual drops below 0.2 mg/L. During the cold weather, biodegradation cannot be detected even under conditions of no detectable chlorine residual. HAA biodegradation is one process that cannot be accurately studied in laboratory systems. Information of this type could form the basis of an empirical approach to modeling this process.
- At certain times of the year, there is a substantial drop in TOC at long residence times. This was not expected, and may reflect excessive levels of biodegradation or possibly chemical degradation in the “dead ends”. This may be another key in understanding the HAA degradation puzzle.
- In several locations, pH was seen to drift upward with increasing residence time. This seemed to be associated with the presence of asbestos cement piping. Increasing pH will result in higher levels of THMs and lower levels of trihaloacetic acids. For this reason, pH modeling and/or monitoring is quite important.
- Delta-UV₂₇₂ (change in absorbance at 272 nm) showed a weak positive correlation with TTHM level, but not with the HAAs. Additional refinements in the methodology may show this correlation to be stronger in future tests. The Delta-UV₂₇₂ correlation has been proposed as a useful surrogate for the formation of a wide range of disinfection byproducts.

- A colorimetric THM test method used in the field failed to produce data exhibiting the same strong correlation with water age, as noted for the GC-based THM data. Some exceptionally low values were recorded for the colorimetric method, which were largely responsible for the poor correlation. This test may require more operator experience; so future testing will likely prove decisive.
- Raw water samples chlorinated in the laboratory showed slightly lower DBP levels than those chlorinated by the full-scale plant and held in the laboratory. The latter samples matched the distribution system samples better (based on the modeled retention times). The reasons for this are not clear.

Publications Resulting from this Research

None yet, but at least one is planned for the *Journal of the American Water Works Association*.

Students Supported

Three students in Civil & Environmental Engineering: Bree Carlson (MS student), Shem Kellogg (BS student), and Narayan Venkatesan (MS student).