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Use of Continuous Recording Water-Quality Monitoring Equipment for Conducting Water-Distribution System Tracer Tests: The Good, the Bad, and the Ugly

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Abstract

An emerging and innovative technology that is a possible alternative to manual sampling is the use of continuous recording water-quality monitoring equipment (CR-WQME) for collecting multiple ion-specific tracer data. Advantages of using CR-WQME include the ability to record continuously water-quality events (including unplanned events) during a tracer test at small time intervals of 15 minutes or less. This recording provides real-time data when using hand-held logger equipment to query the CR-WQME at each sampling location. Also, the labor needed to conduct the test is reduced. Disadvantages could include the cost of multiple ion-specific sensors and units for large or complex systems, the effort required to calibrate the equipment by setting up a test-site water-quality laboratory, and the reliability of the equipment for long-term monitoring events. In this paper the authors assess the use of CR-WQME in conducting a tracer test at a military installation in North Carolina. Using results obtained from the tracer test, the authors found that CR-WQME is an emerging and innovative technology that still requires refinement and the use of some grab samples to provide quality-assurance and quality-control procedures during the tracer test. However, CR-WQME is an excellent option when designing and conducting multiple parameter tracer tests for water-distribution system model calibration activities.

Introduction

The use of water-distribution system models for analyses and assessments of contamination events—including historical, current, and future events—requires a calibrated water-quality model. Conducting tracer tests by injecting a conservative compound into the distribution system (e.g., calcium chloride) or shutting off an additive compound (e.g., sodium fluoride) and collecting concentration data at selected sampling locations can provide the information required to calibrate a water-quality model. Spatially large water distribution-system networks can be complex and could have unknown or variable operational characteristics. Collecting water samples ("grab samples") to capture a unique water-quality event, such as the passing of a tracer's peak concentration at a sampling location, can be cost and labor intensive. Also, the tracer front and peak can be missed during the test if a sudden or unplanned change in operational characteristics occurs.

Description of Tracer Study

An ongoing epidemiologic study at U.S. Marine Corps Base, Camp Lejeune, North Carolina, requires the use of calibrated water-distribution system models to assess present-day conditions and historical exposures. To obtain calibration data, a tracer test was conducted. The source of sodium fluoride (NaF) at the Holcomb Boulevard water treatment plant (WTP) was shut off at 1600 hours on 22 September 2004. The fluoride concentration in the distribution system was recorded at nine monitoring locations (Figure 1) and allowed to diminish to background levels (~ 0.2 mg/L) through dilution by non-fluoridated water. At 1200 hours on 29 September 2004 the NaF source at the WTP was turned back on and fluoride concentrations in the water-distribution system were recorded until the conclusion of the test on 12 October 2004.

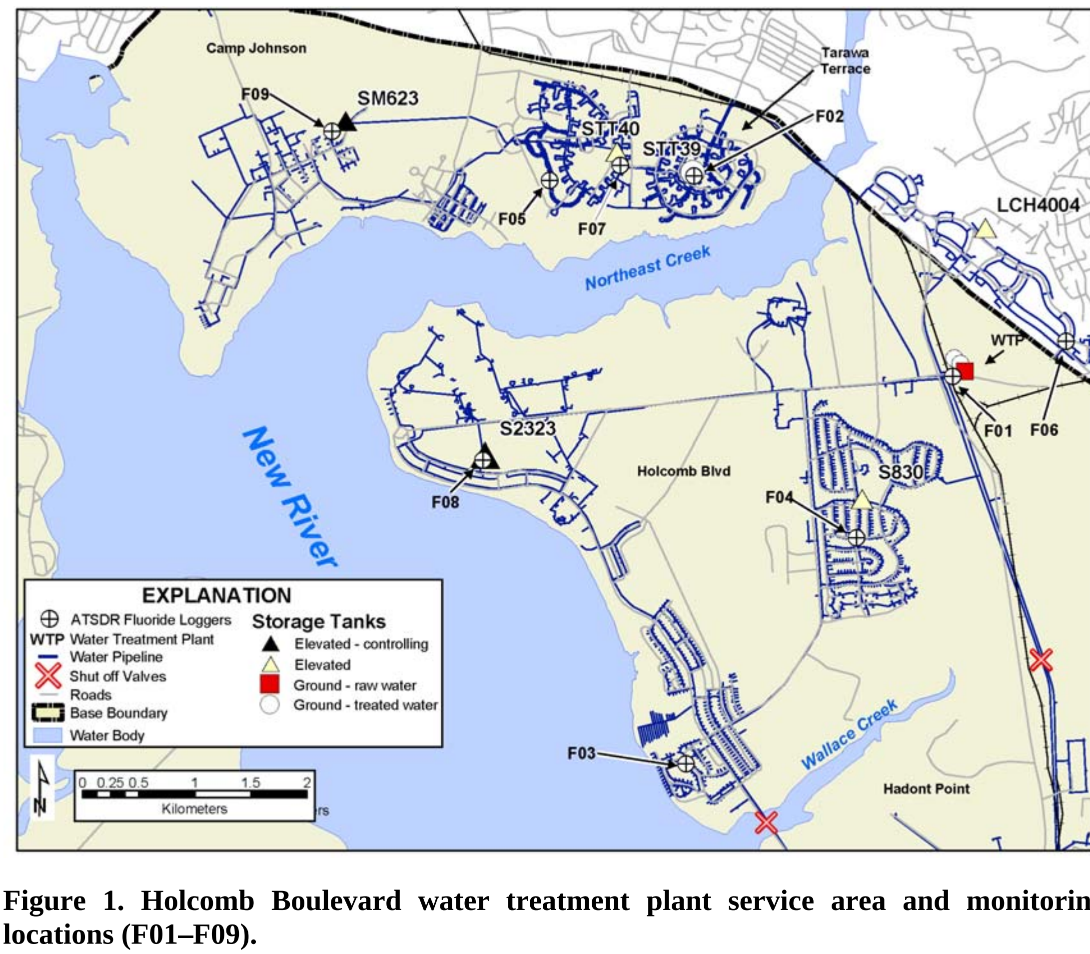

Figure 1. Holcomb Boulevard water treatment plant service area and monitoring locations (F01–F09).

Continuous recording water-quality monitoring equipment (CR-WQME) was placed on the distribution side of the WTP (logger F01, “source location”; Figure 1), at the Tarawa Terrace treated water reservoir (ground storage, logger F02), at controlling elevated storage tanks (loggers F08 and F09), and at 5 hydrants located in family housing areas in the Holcomb Boulevard WTP service area (loggers F03, F04, F05, F06, and F07). Fluoride concentrations were recorded using 15-minute intervals. In addition to the CR-WQME, nine rounds of water samples were collected at each monitoring location for quality assurance and quality control (QA/QC) purposes. For analyses, the samples were split so that 25 mL of the grab sample water were analyzed at the Holcomb Boulevard WTP water-quality lab, and the remaining 225 mL of water were analyzed by the Federal Occupational Health laboratory in Cincinnati, Ohio.

Continuous Recording Water-Quality Monitoring Equipment (CR-WQME)

To record continuously the fluoride concentration, the HORIBA W-23XD dual probe, multi-parameter, water-quality monitoring system was used. This system consisted of a dual–probe ion detector and a flow cell that fits the double probe W-23XD (Figure 2). The probe and flow cell are housed in a plastic protective container—a standard 5-gal (18.9 L) water jug (Figure 3). Distribution-system water passes through the flow cell by attaching a Dixon A7893 hydrant adapter kit to the sampling location hydrant. The adapter kit is configured with a 1/4 NPT brass “T” and two 1/4-in. (6.4 mm) ball valves on each side of the brass “T” (Figure 3). One valve was used to control flow into the flow cell, and the other valve was used to turn water on and off when obtaining grab samples from the hydrant. The complete configuration, consisting of the HORIBA W-23XD probe, flow cell, and 5-gal (18.9 L) plastic protective water jug, was secured to the hydrant by means of a chain and lock. During the test, a continuous discharge of water came from the flow cell and the plastic protective container (approximately 1–2 gpm [3.8–7.6 L/m]). To monitor and download fluoride data, the HORIBA water-quality control unit was attached to the sensor probe using a cable (Figure 4). With the configuration described above, the data logger continued to record data while real-time data values were observed using the HORIBA water-quality control unit.

The Good

The good aspect of using the CR-WQME was that it required only three people to conduct a field test that lasted 12 days. To start the test, one person calibrated the loggers while a second person deployed the loggers at the selected monitoring locations (Figure 1). A third person was used to collect grab samples for QA/QC. Once all of the loggers were installed at the selected monitoring locations and one round of grab samples was taken, two of the field test personnel returned to their office—located about 500 miles (805 km) away—while only one person was required to remain on site. The field person collected one round of QA/QC samples in the morning and one round in the afternoon. Fluoride concentrations from the grab samples from the WTP water-quality lab were reported to the two test personnel who were stationed back in the office. The field person also used the water-quality control unit (Figure 4) to obtain real-time concentration values and to assess the status of the CR-WQME. When field data (logger readings and QA/QC grab samples) indicated that fluoride concentrations had decayed to background levels, the one on-site test person communicated with WTP personnel to turn the fluoride back on. Thus, the CR-WQME provided a means by which a long-duration field test could be conducted with just three people, and only one person in the field, thereby reducing the labor costs associated with the test.

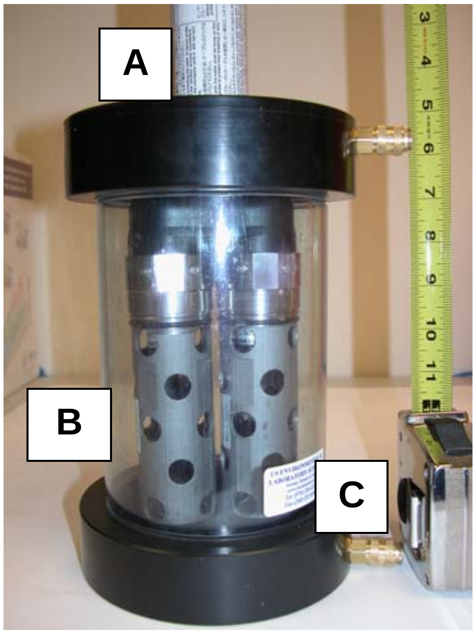

Figure 2. Photograph showing (A) HORIBA W-23XD dual probe ion detector, and (B) flow cell, and (C) Rectus 21KANNMPX, ¼ NPT brass connectors.

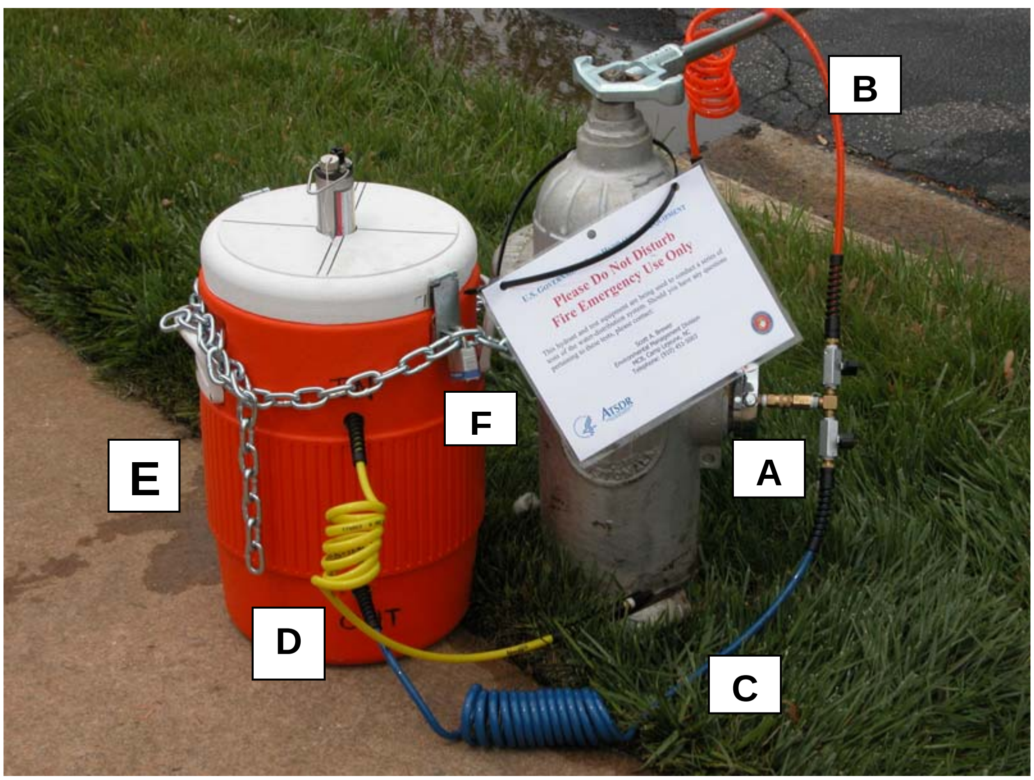

Figure 3. Photograph showing: (A) hydrant adapter kit configuration, (B) Rectus PSCH0605-16, orange hose for collecting grab sample, (C) Rectus PSCH0610-3, blue hose for supplying flow cell with hydrant water, (D) Rectus PSCH0605-5, yellow hose for discharging water from flow cell, (E) 5-gal protective plastic water jug housing the HORIBA W-23XD dual-probe ion detector and flow cell, and (F) chain and lock for securing equipment to hydrant.

Figure 4. Photograph showing HORIBA W-23XD water-quality control unit and cable attached to dual probe ion detector housed in a protective plastic 5-gal water jug

When compared with grab sample data at all but one of the monitoring locations, good results were obtained using the CR-WQME. Because of space limitations, only two graphs of data are shown (Figure 5). Logger F01 was located on the main transmission line going from the Holcomb Boulevard WTP to the distribution system (Figure 1). This logger represents the source conditions for fluoride in the Holcomb Boulevard WTP service area. The data collected by the CR-WQME (solid line), and the QA/QC grab samples analyzed at the WTP water-quality laboratory, and the FOH water-quality laboratory strongly agree. Logger F08 was stationed at a controlling elevated storage tank. Therefore, the water level in the tank fluctuates based on demand. The graph for logger F08 clearly shows the draw and fill cycle of the tank. When the fluoride concentration in the distribution system reached a near–background level of about 0.2 mg/L on September 28, the elevated storage tank still contained water with a fluoride concentration of about 0.8 mg/L. Additionally, the correlation between the continuously recorded data and the QA/QC grab sample data is also very strong.

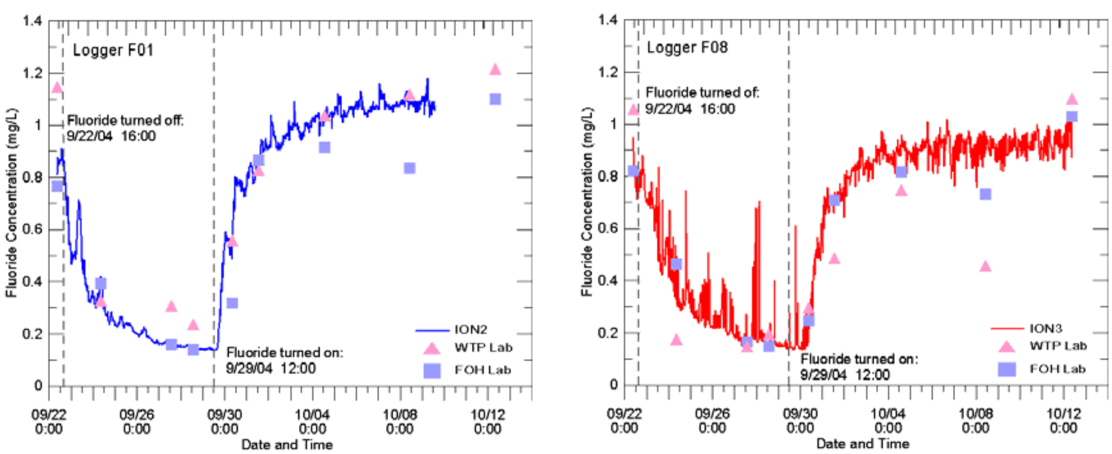

Figure 5. Graphs of fluoride concentration for loggers F01 and F08

The Bad

When using CR-WQME, two situations still require improvement and technical enhancement: the equipment-logger calibration procedures and the occurrence of calibration "drift" during the test. The authors' experience with using the specific equipment described here is that approximately 1-hour per ion-specific parameter is required to calibrate the equipment. For one parameter this might not be an issue. However, if in addition to fluoride concentration, one wanted to gather continuous data for pH, temperature, conductivity, and chloride, it could have taken up to 5 hours to calibrate each logger. One technique the authors devised to shorten the calibration time was to calibrate each parameter for all loggers at the same time by placing all loggers in a water bath (Figure 6).

Another issue that must be confronted when using CR-WQME is the issue of logger calibration "drift." Because the CR-WQME is connected to a hydrant, it is not possible to re-calibrate the loggers while the test progresses. If calibration drift becomes significant, the data collected by the CR-WQME may not be useful. To determine when logger calibration drift becomes significant and continuously recorded data becomes unreliable, at the present time, grab samples must still be obtained while continuously recording data. Thus, at the present time, requiring the collection of grab samples increases the cost of the test (in terms of labor and water-quality laboratory analyses) and limits the long-term usefulness of CR-WQME. Results from data logger F04 (Figure 7) clearly show logger calibration drift occurring after about 10 days. Continuously recorded data on the graph show a marked departure from the QA/QC grab sample data.

Figure 6. Photograph showing use of a water bath for calibrating multiple loggers.

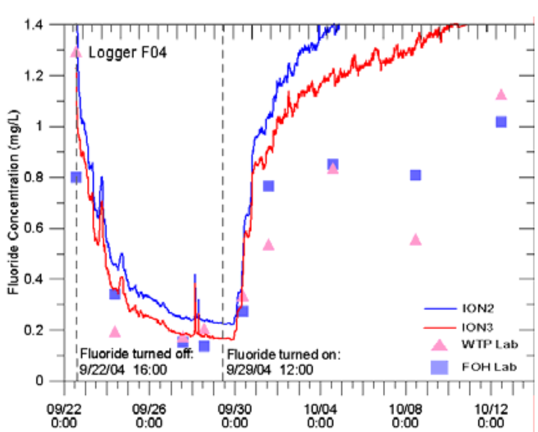

Figure 7. Graph of fluoride concentration for logger F04 showing departure of continuously recorded data (solid lines) from grab sample data (symbols) after about 10 days.

The Ugly

The most pressing and time-consuming issue pertaining to the use of CR-WQME that the authors encountered was reliability of the ion-specific sensors used to measure concentrations in the distribution system water. To test the reliability of the fluoride ion sensors, several of the loggers were equipped with two sensors (e.g., logger F04 in Figure 7). As shown in Figure 7, both sensors ("ION2" and "ION3") produced consistent and reliable results. In other loggers, however, such good results were not observed. In fact, some of the sensors were completely unreliable. Examples of this condition are shown in Figure 8 for loggers F05 and F07. Logger F05 was equipped with two fluoride sensors; the sensor identified as "ION3" shows a marked and complete departure from the sensor identified as "ION2" and from grab sample data. Results for Logger F07 show that continuously recorded data generally followed the trend of declining fluoride, as did the grab sample data; nevertheless, recorded data from this sensor also appear to be unreliable. Thus, without the use of more than one sensor or grab sample data for QA/QC, concentration data at these monitoring locations would not be reliable for analysis of the water-distribution system or for model calibration purposes.

Because the use of CR-WQME is still an emerging technology, the number of vendors supplying the equipment might be limited. As such, the cost of the equipment described here, is still high. Thus, if one conducts a test in which 10–20 locations might be required to monitor and characterize a water-distribution system properly, the purchase of that many CR-WQME could be cost prohibitive at this point in time.

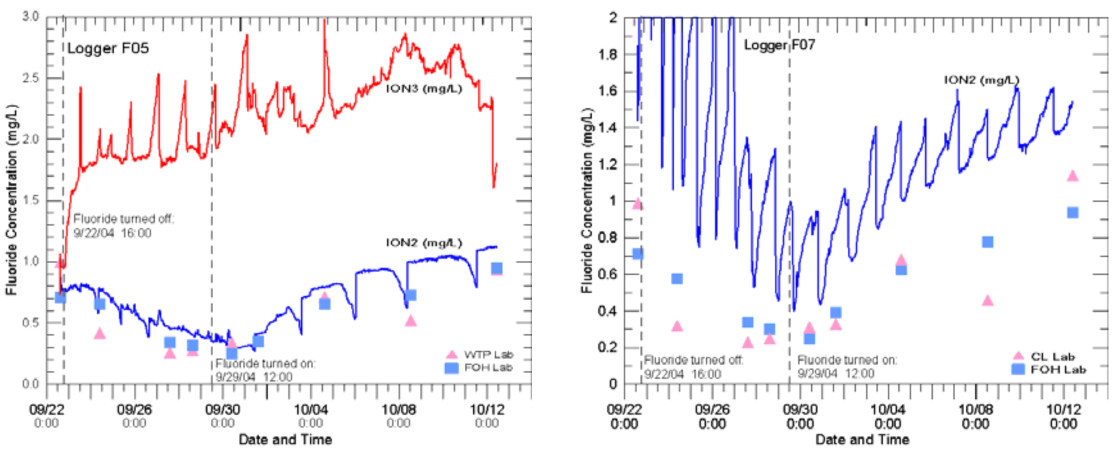

Figure 8. Graphs of fluoride concentration for loggers F05 and F07 showing marked departure of continuously recorded data (solid lines) from grab sample data (symbols).

Summary

An emerging and innovative technology that is a possible alternative to manual sampling is the use of CR-WQME at sampling locations for collecting multiple ion-specific tracer data. Advantages of using CR-WQME include the ability to record continuously water-quality events during a tracer test at short time intervals of 15 minutes and a significant reduction in labor needed to conduct the test. Disadvantages could include the cost of multiple ion-specific sensors and units for large or complex systems, the effort required to calibrate the equipment by setting up a test-site water-quality laboratory, and the reliability of the equipment for long-term monitoring events. Based on results obtained from the tracer test described herein, the use of CR-WQME is an emerging and innovative technology that still requires refinement and the use of some grab samples to properly provide QA/QC during the tracer test. However, using CR-WQME should be considered as a monitoring option when designing and conducting multiple parameter tracer tests for water-distribution system model calibration activities.

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