Maintaining Distribution System Residuals Through Booster Chlorination [Project #261]

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OBJECTIVES: The goal of this project was to discuss the potential advantages associated with booster disinfection, the kinetics of chlorine decay and trihalomethane (THM) formation under rechlorination conditions, and the use of network hydraulic and water quality models to locate booster disinfection stations and determine their dose characteristics.

BACKGROUND: The practice of using disinfectants to safeguard against the acute effects of waterborne disease are well established and regulated in the United States. New regulations designed to minimize the risks associated with chronic exposure to disinfection by-products (DBPs), however, are changing the current regulatory framework. Changes in disinfection practices meant to comply with these new regulations may inadvertently increase risks associated with microbial contamination. These factors are pushing utilities to consider methods to deliver disinfectants wisely to safeguard against pathogens and minimize DBP formation. Booster disinfection provides significant new flexibility in how doses are distributed throughout the network, and thus can be an important part of a comprehensive residual maintenance strategy.

HIGHLIGHTS: The following are highlights from the research:

- A laboratory procedure was proposed for analyzing chlorine decay under simulated booster conditions.
- An initial set of experiments evaluated disinfectant decay under booster conditions, and found it to be dependent on both the magnitude and time of the boost dose.
- THM formation under booster conditions showed no long-term reduction for any set of results, indicating THM formation is not solely dependent on disinfectant concentration.
- In booster chloramination, boosting with chlorine appeared to be very successful at producing and maintaining a low ammonia concentration by recombining with the ammonia formed from chloramine decay.
- A second-order model, including a reaction component that represents natural organic matter, was developed to describe chlorine decay and THM formation under booster conditions.
- A method was developed to determine good locations and schedules for multiple booster doses by a systematic evaluation of alternative designs using network models.

APPROACH: The experimental approach to investigate rechlorination kinetics involved bench scale rechlorination experiments for chlorine and chloramine systems using various natural waters. The systems design approach involved joining network hydraulic and water quality models with mathematical optimization methods.

RESULTS/FINDINGS: A laboratory procedure was proposed for analyzing chlorine decay under simulated booster conditions. An initial set of experiments evaluated disinfectant decay under booster conditions and found it to be dependent on both the magnitude and time of the boost dose. THM formation under booster conditions showed no long-term reduction for
any set of results, indicating THM formation is not solely dependent on disinfectant concentration. When a single chlorine dose is split between an initial and a booster dose, the THM concentration tended to be reduced prior to application of the boost dose because of the smaller amount of disinfectant applied. In booster chloramination, boosting with chlorine appeared to be very successful at producing and maintaining a low ammonia concentration by recombining with the ammonia formed from chloramine decay.

A second-order model, including a reaction component that represents natural organic matter, was developed to describe chlorine decay and THM formation under booster conditions. A method was developed to determine good locations and schedules for multiple booster doses by a systematic evaluation of alternative designs using network models. Significant disinfectant mass savings, compared to a conventional disinfection scenario (application only at the treatment plant), may be possible through use of coordinated booster stations.

**IMPACT:** Under the proposed regulatory framework, the operation of disinfection processes is over-constrained. Chlorine doses made within the water treatment plant (WTP) must simultaneously provide adequate microbial inactivation, provide residual maintenance at all points in the distribution system, and comply with DBP and taste and odor thresholds. If chlorine is only applied within the WTP, there is only one opportunity to simultaneously meet all treatment objectives. A booster chlorination strategy involves multiple coordinated doses applied throughout the distribution system. Such a strategy physically separates the doses meant for disinfection efficiency (microbial inactivation) requirements at the treatment plant from those meant for residual maintenance in the distribution system. This physical separation improves a utility’s operating flexibility for meeting disinfection efficiency, residual maintenance, and DBP requirements simultaneously. By exploring the disinfection decay kinetics under rechlorination, and developing methods for booster chlorination systems design, the project results will assist utilities and consultants in making better use of booster disinfection as a residual maintenance approach.

**MULTIMEDIA:** The report includes a CD-ROM.

**PARTICIPANTS:** Six utilities participated in this project.