Water Main Flushing and Disinfection

Lincoln Water System

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Background

Because it is necessary to disinfect all water mains that do not meet bacteriological criterion, the American Water Works of America (AWWA) has developed a standard for the disinfection processes. The standard describes methods of disinfecting newly constructed potable-water mains; mains that have been removed from service for planned repairs or for maintenance that exposes them to contamination; mains that have undergone emergency repairs because of physical failure; and mains that, under normal operation, continue to show the presence of coliform organisms. This report presents a proposed automated computerized method of flushing and disinfecting newly constructed potable-water mains.

There are numerous variables involving calculations for proper flushing and disinfection. As a result, the task of performing calculations for flushing and disinfecting newly constructed water mains can be very time consuming. In the past, the Lincoln Water System has calculated various flushing and disinfection parameters by hand, and if a variable needed to be changed, the calculations would be carried out again. It was suggested by Steve Owen, Superintendent of Water Distribution, and fellow coworkers that a spreadsheet would be useful to obtain quicker and more dependable results.

Spreadsheet

Flushing

The spreadsheet created contains several tabs that analyze the processes of flushing and disinfecting a new water main. A water main is flushed with water to clean the pipe of surface dirt and other debris in the pipe. AWWA recommends flushing at a velocity of 2.5 ft/s. It is often difficult for contractors and others to determine the velocity at which the water is flowing through the main pipe. One way to estimate this velocity is to apply a formula based on a specific discharge apparatus. Figure 1 below is a diagram from the AWWA disinfection manual that displays this concept.

![Figure 1. AWWA figure for estimating discharge.](image)
Rearranging the equation and substituting main pipe velocity times area (V*A) in for discharge, the discharge distance (Sₓ) can be solved in terms of the main pipe diameter, the discharge pipe diameter (d), the height of the discharge pipe above the ground (Sᵧ), and the velocity of the water in the main pipe (see equation 1 below).

\[ Sₓ = \frac{V \times A \times Sᵧ^{\frac{1}{2}}}{2.83 \times d^2} \]  

(1)

The spreadsheet applies equation 1, and a contractor can adjust the control valve so that the water discharges the required distance, an easy field measurement, to obtain the desired velocity. Figure 2 displays the flushing spreadsheet.

**Disinfection**

Once a water main is flushed, it must be disinfected to rid the system of potentially harmful pathogens. Chlorine gas, sodium hypochlorite (NaOCl), and calcium hypochlorite (Ca(OCl)₂) are the primary disinfecting chemicals. The spreadsheet also assists with two different disinfection methods: continuous feed method and the slug method.

**Continuous Feed Method**

With the continuous feed method, water entering the new main receives a dose of chlorine fed at a constant rate such that the water will have a concentration not less than 25 mg/L free chlorine. Chlorine application continues until the entire main is filled with
heavily chlorinated water. In the now static system, the chlorinated water is retained in the main for at least 24 hours before final flushing.

The spreadsheet assists with the calculations to successfully use the slug method of disinfection. When the pipe length to be disinfected, the concentration of chlorine, and the flow are entered into the spreadsheet, several parameters including total chlorine needed, chlorine feed rate, and time to fill the pipe are calculated. Also if sodium hypochlorite (NaOCl) is used as a disinfecting agent, given the percent chlorine, the total amount of sodium hypochlorite and the feed rate are determined.

**Slug Method**

With the slug method, water entering the new main receives a single dose of chlorine fed at a constant rate until the water will have a concentration not less than 100 mg/L free chlorine. The chlorine is applied continuously and for a sufficient period to develop a solid column, or slug, of chlorinated water that will expose all interior surfaces to a concentration of about 100 mg/L for at least 3 hours as it moves through the water main.

Given water main length to be disinfected, the desired slug length, concentration of chlorine desired, and contact time (usually three hours), the spreadsheet calculates the maximum discharge to ensure three (3) hours of contact time. The volume of the slug and the time to complete the disinfection are also calculated. If the percent chlorine of NaOCl or available chlorine per tablet of Ca(OCl)₂ is given, the gallons of NaOCl or pounds of Ca(OCl)₂ needed to produce a slug of proper concentration will also be calculated.

Figure 3 below displays how the spreadsheet facilitates calculations.

<table>
<thead>
<tr>
<th>Measured Quantities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Length (ft)</td>
<td>4150</td>
</tr>
<tr>
<td>Slug Length (ft)</td>
<td>400</td>
</tr>
<tr>
<td>Desired Concentration ppm</td>
<td>100</td>
</tr>
<tr>
<td>Contact Time (min)</td>
<td>180</td>
</tr>
<tr>
<td>Percent Chlorine of NaOCl</td>
<td>12.5%</td>
</tr>
<tr>
<td>Available Cl per tablet Ca(OCl)₂</td>
<td>65%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main Pipe Diameter (in)</th>
<th>Maximum Blowoff Discharge (gpm)</th>
<th>Maximum Blowoff Discharge (gpm)</th>
<th>Velocity of Slug (ft/s)</th>
<th>Volume of Tank/Slug (gallons)</th>
<th>Time to Complete Disinfection (hrs)</th>
<th>Total Chlorine Needed for Desired Concentration (lb)</th>
<th>NaOCl at % Chlorine (gallons)</th>
<th>Ca(OCl)₂ (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>82</td>
<td>0.97</td>
<td>0.037</td>
<td>0.400</td>
<td>31.1</td>
<td>7.64</td>
<td>6.27</td>
<td>12.07</td>
</tr>
</tbody>
</table>

*Figure 3. Example exert from the spreadsheet for the slug method.*
The length of the slug can be altered to change the slug volume and the time required to complete disinfection. Lengthening the slug will shorten completion time but will increase the slug volume. Contractors or others doing the disinfection may want to experiment with different slug lengths to obtain completion times and slug volumes that are most desired.

**Pollution Prevention**

Using the spreadsheet will result in more consistent results because calculations can be reproduced and variables easily changed as conditions warrant. Besides being more reliable and saving time, the spreadsheet for flushing and disinfecting water mains provides some pollution prevention benefits. Because calculations can be arduous, often it is unclear exactly how much chlorine is required to thoroughly disinfect a water main. In an effort to ensure passing of bacteriological tests, much more chlorine is often used. Greater chlorine use results in higher expenses and an increased chance of highly chlorinated water reaching natural streams and ponds causing fish kills and other undesired phenomena. Using the spreadsheet to determine chlorine amounts should reduce cost and the risks associated with high concentrations of chlorine.

NOTE: An electronic version of the spreadsheet accompanies this report.