

# The *E. coli* Killing Ability of Chlorinated Finished Water at pH 9.7

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Drinking water utilities that use sodium hypochlorite or chlorine gas in the final step of treatment, must consider the water pH effect on the inactivation of microorganisms. As the water pH rises, chlorine tends more toward the hypochlorite ion form ( $\text{ClO}^-$ ) and away from the hypochlorous acid ( $\text{HOCl}$ ) form. Once the pH exceeds 9.5, there is very little hypochlorous acid remaining in the solution. Both hypochlorite ion and hypochlorous acid are reactive against microorganisms; however, the neutrally-charged hypochlorous acid is thought to be much more toxic to gram-negative bacteria.

Des Moines Water Works performs a total coliform and an *E. coli* treatment assessment daily, using river, post-lime softening, filter effluent, and finished water samples. In the history of the utility, coliforms have never been detected in the finished water at the plant. Despite this, the disinfecting ability of the Des Moines Water Works finished water was studied experimentally using *E. coli* (ATCC 25922) as the target bacterium.

## Study I

An unusual episode of high ammonia in the Des Moines River required large doses of chlorine more than three times normal in order to achieve free chlorine levels in the clearwell sufficient to obtain adequate CT. Total chlorine levels leaving the plant approached 3 mg/l. The first study was performed during this time. The finished water pH was 9.7, which theoretically contained very little hypochlorous acid.

### Method:

Three tubes with 40ml finished water were assembled. An inoculum of approximately 25 cells of *E. coli* was added to each tube. Total chlorine, free chlorine, and *E. coli* levels were tested at one-minute, ten-minutes, and sixty-minutes. A control tube of distilled water was used to determine the experimental *E. coli* count. All bacterial counts were determined using IDEXX's most probable number (MPN) Quanti-tray 2000 with Colilert medium system. Each 40ml tube of water was poured into a 200ml IDEXX vessel with sodium thiosulfate to quench the disinfecting action of the sodium hypochlorite. A medium packet and an additional 60ml of water were added to bring the sample to proper volume for Quanti-tray 2000 inoculation. The test was conducted at 20°C.

### Results:

At one-minute, the total chlorine was 3.3 mg/L, the free chlorine was 3.1 mg/L, and the *E. coli* count was a MPN of 5. At ten-minutes, the total chlorine was 3.3 mg/L, the free chlorine was 3.1 mg/L, and the *E. coli* count was a MPN

of 0 (<1). At sixty-minutes the total chlorine was 3.3 mg/L, the free chlorine was 3.0 mg/L, and the *E. coli* count was a MPN of 0 (<1). The control had a MPN *E. coli* count of 25.

**Study I** beginning with an initial *E. coli* count of **25** per tube.

Minutes of Chlorine Contact	Total Chlorine mg/L	Free chlorine mg/L	<i>E. coli</i> count
1	3.3	3.1	5
10	3.3	3.1	0
60	3.3	3.0	0

## Study II

Within two days of study I, the river ammonia level decreased enough to reduce the chlorine feed rate by 50%. The second study was performed at this time. The finished water remained at pH 9.7. The test was conducted at 20°C.

### Method:

Three tubes with 40ml finished water were assembled. An inoculation of approximately 276,000 *E. coli* cells was added to each tube. The total chlorine, free chlorine, and *E. coli* levels were tested at one-minute, ten-minutes, and sixty-minutes. A control tube of distilled water was used to determine the experimental *E. coli* count. All bacterial counts were determined using IDEXX's most probable number (MPN) Quanti-tray 2000 with Colilert medium system. Each 40ml tube of water was poured into a 200ml IDEXX vessel with sodium thiosulfate, to quench the disinfecting action of the sodium hypochlorite after the experimental time period had elapsed for the individual tube. A medium packet and an additional 60ml of water were added to bring the sample to proper volume for Quanti-tray 2000 inoculation. The test was conducted at 20°C.

### Results:

At one-minute, the total chlorine was 1.8 mg/L, the free-chlorine was 1.6 mg/L, and the *E. coli* count was a MPN of 2. At ten-minutes, the total chlorine was 1.8 mg/L, the free chlorine was 1.6 mg/L, and the *E. coli* count was a MPN of 0 (<1). At sixty-minutes the total chlorine was 1.7 mg/L, the free chlorine was 1.5 mg/L, and the *E. coli* count was a MPN of 0 (<1). The distilled control had a MPN *E. coli* count of 276,000.

**Study II** beginning with an initial *E. coli* count of **276,000** per tube.

Minutes of Chlorine Contact	Total Chlorine mg/L	Free chlorine mg/L	<i>E. coli</i> count
1	1.8	1.6	2
10	1.8	1.6	0
60	1.7	1.5	0

**Discussion:**

In both studies, the finished water expressed a rapid and thorough ability to kill the target *E. coli*, taking less than ten-minutes for completion despite the 9.7 pH.

These studies confirm DMWW's ability to adequately disinfect its water with chlorine despite its high pH finished water.

