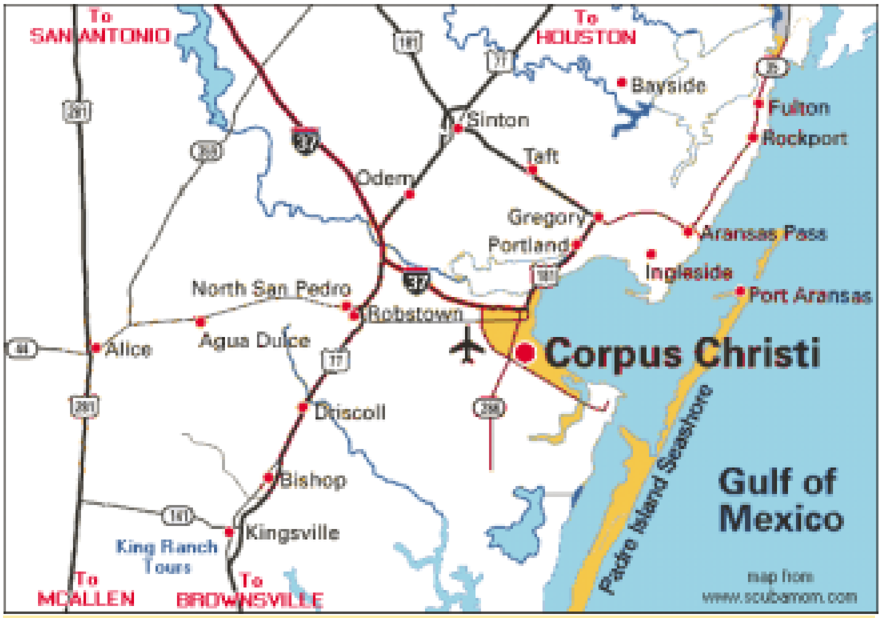


Chlorine residual boosting has been used to better disinfect the water supply from Corpus Christi to some surrounding towns.

Chlorine Residual Boosting in Distribution Water:

Problems with Chlorine Application and Disinfection Byproducts – Part 2

Part one of this article covered breakpoint chlorination and discussed the stability of chlorine, chloramine and Cl:NH$_3$ after chlorination.

Low Chloramine

The town of Driscoll (population: 690, 30 miles south of the plant) receives water from the Corpus Christi (C.C.) plant with a total chlorine of 0.3–0.5 mg/L and NH$_3$–N: 0.6 mg/L. (The plant discharge is 3.5–4.0 mg/L total chlorine, total ammonia 1.2–1.5 NH$_3$–N.) The water also has a slight increase of nitrate (0.7 mg/L) (Figure 1). The BP chlorination with Driscoll intake water (4/30/01) occurs with a typical BP curve. However, the curve has a lower maximum level, and reaches the BP at a lower chlorine dose, as expected from water with a low total ammonia to start.

Table 2 (Driscoll) shows that there is a significant dissipation after BP. The boosted chlorine, 0.83 mg/L (checked 60 minutes after BP chlorination) dissipates in 24 hours to an unacceptable 0.19 mg/L.

Table 2 (Driscoll) suggests that an application of a higher concentration (6.0 mg/L) after BP may be appropriate and sufficient to yield a 2.4 mg/L free chlorine residual at 24 hours.

Intake water with practically zero chlorine residual can be neutralized with the free chlorine and, as a result, the residual free chlorine becomes stabilized for several days at room temperature.

Driscoll is injecting chlorine gas with a target for free chlorine of 5.0–6.0 mg/L in the storage tank (170,000 gallon, retention time of 24 hours). This level drops to about 2.5 mg/L free chlorine residual after 24 hours. The water then moves to the elevated tank (150,000 gallon, 8 hour retention time) where it discharges the water (approximate 2.0 mg/L) into the distribution system. The distribution water sampled was found to be stable for several days in the laboratory at 25° C, and in the field, maintaining a 1.5–1.7 mg/L free chlorine residual at the terminal distribution sites.

Case of Depleted Chloramine

Kingsville, the largest user of C.C. water, receives the intake water 40 miles south of the plant. The residual is practically zero (0.05–0.10 mg/L) at the intake with the total ammonia not detected (<0.1 mg/L). Zero chlorine residual also was found at the southeast end of distribution system (40 miles) at Padre Island.

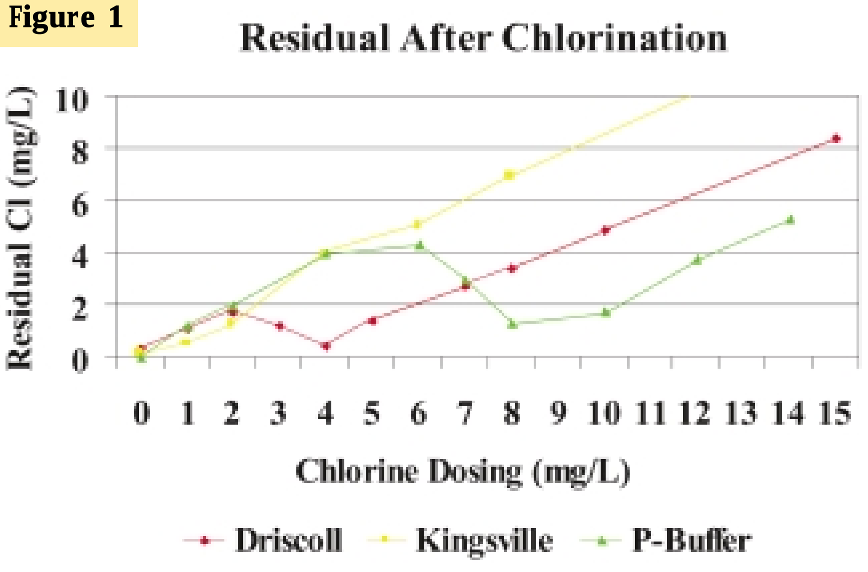
It seems that the additional 10 miles makes a significant reduction in the chlorine residual. This means that the retention time in the last 10 miles plays a critical role in the chlorine dissipation in the pipe. The enhanced level of the nitrate (1.0 mg/L) in both Kingsville and Padre Island may suggest that nitrification is partially responsible for the zero chlorine level in intake waters.

With ammonia depletion in the intake water, chlorination with Kingsville intake water results into a straight line instead of a breakpoint curve (Figure 1). However, supplement this water with ammonia sulfate (1.0 mg/L NH_3–N) and a typical BP curve is formed. This indicates that there is no inhibitor formation to block the breakpoint chlorination in the Kingsville's intake water, instead the depletion of ammonia (free or combined) would be responsible for incomplete formation of the BP curve.

Significant dissipation also was found in the newly formed chlorine after chlorination in Kingsville's intake water. It was not observed with an added preformed monochloramine at the concentration (2.0–7.0 mg/L). This difference in susceptibility to the free and combined chlorine suggests that intake water a long distance from the C.C. plant water still carries the chlorine demand, but is not reactive with the chloramine. Therefore, BP is not a prerequisite for chlorine dissipation. Water in the chemical receiving basin (prior to chlorine and ammonia sulfate injection) in the plant was found to contain such demand in considerable amounts.

This intake water, with practically zero chlorine residual, can be neutralized with the free chlorine and, as a result, the residual free chlorine becomes stabilized for several days at room temperature. However, the addition of straight intake water (50 percent) to the previously stabilized water (50 percent) could result in destabilization, with the stabilized free chlorine residual dissipating again.

Figure 1



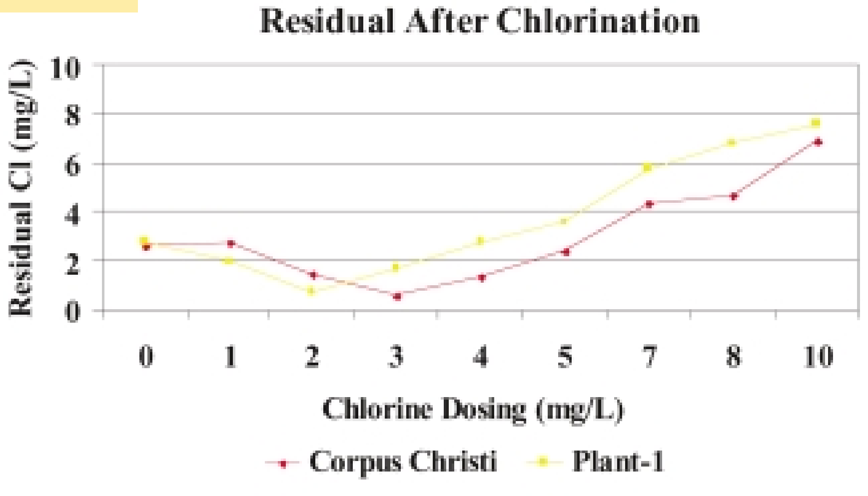
Driscoll. *Breakpoint chlorination of the intake water. Date of sample: 4/26/01(total chlorine 0.5 mg/L). Date of test: 4/30/01. Sample refrigerator at 5° C for 4 days. Total Ammonia: 0.6 mg/L. pH 7.4. The residual chlorine is the total chlorine.*

Kingsville. *Breakpoint chlorination of the intake water. Date of sample: 4/18/01(total chlorine 0.03 mg/L). Date of test: 4/19/01. Sample refrigerator at 5° C for 4 days. Total Ammonia: <0.1 mg/L. pH 7.6.*

P-Buffer. *Breakpoint chlorination of the phosphate buffer supplemented with 1 mg/L (NH_3–N). pH 7.2. Test temperature: 25° C.*

The rapid decline of chlorinated water follows a hyperbolic line with time, regardless of the sampling sites (plant discharge or distributions). Data show that 24 hours of rapid decline is followed by a slow dissipation (Table 2). Therefore, the chlorination dosing at 3.0–4.0 mg/L is sufficient enough to maintain the free chlorine residual level, 1.5–2.0 mg/L after the first 24 hours (50

Figure 2



Corpus Christi. *Breakpoint chlorination of the Corpus Christi Distribution. Sampling site: 2121M. Date of sample: 1/31/01(total chlorine 2.6 mg/L). Date of test:1/31/01. Total Ammonia:1.3 mg/L. pH 7.7.*

Plant. *Breakpoint chlorination of the P1 C.C. plant water. Date of sample:1/28/01(total chlorine 0.5 mg/L). Date of test: 1/28/01. Total Ammonia: 0.9 mg/L. pH 7.7.*

Table 2: Dissipation of Boosted Chlorine Residual After Breakpoint

Table 2a: Driscoll (Intake Sampling. Total Cl: 0.5. Sampling Date: 4/26/01. Testing Date: 4/28/01.)

	Total Chlorine (mg/L) Based on Time (Hours) After BP		
Dose (Cl)	**1**	**24**	**48**
3.8	0.83	0.19	0.11
7.5	6.0	2.4	1.7
10	10.6	5.3	4.0

percent reduction) judging from the laboratory data at 25° C. However, the operator indicated that the free chlorine residual (3.5–4.5 mg/L) dissipated as low as 0.5–1.0 mg/L after 24 hours inside the storage tank. A second boost was necessary to increase the free chlorine to a level of 2.0 mg/L. This double boosted water is stable without dissipation in the free chlorine residual for several days, and it is blended with the chlorinated groundwater (80 percent) for the distribution discharge.

An enhanced decline in the storage tank results not only from the post breakpoint dissipation, but also from the bacterial activity in the biofilmed layer on the wall of the storage tank. The biofilm problem does not exist in laboratory tests using the very clean acid-washed glassware. In addition, much higher temperatures in the storage tank during the summer months in south Texas can lead to dissipation.

Normal Level of Chloramine

BP chlorination cannot be applied to the distribution water of chloramine if it is in a normal range. In this article, the addition of free chlorine to the C.C. water was conducted for the purpose of testing and for a comparison with a low level of chloraminated water. BP chlorination (1/31/02) with distribution water in the city (20 miles from plant) yields the same BP as other samples (2/4/02), showing the breakpoint with increasing dose of chlorine (Figure 2), and followed by instability of the formed free chlorine after BP (Table 2 C.C.). The BP curve has a chlorine residual reaching the maximum point and the breakpoint in lower chlorine dosing because of the preexisting normal level of combined chlorine in the sampled water. Chlorine residual in the BP curve does not start at the zero level, but at the residual level of the distribution water (Figure 2). The plant discharge (P1 sample shown in Figure 2) does not have the maximum peak of BP curve as seen in C.C. water. This suggests that this plant water sample has been treated with a high ratio of chlorine to ammonia (e.g., 5:1 or slightly higher).

Regardless of sampling sites, the C.C. water is potentially reactive to free chlorine after BP chlorination. Its reactive strength may be different depending on the season or weather.

When forming the monochloramine in the plant, the ratio (Cl:NH_3–N) is the most critical factor. A simple formula ranging from 3:1 to 5:1 encourages stability and the formation of combined chlorine. There is no definite formula when boosting low levels of chloramines with free chlorine because of the complexity involved in the boosting process as well as plant and distributional influences. Besides BP dissipation, the monitoring breakpoint chlorine concentration (dosing chlorine concentration to reach BP) would change depending on the total ammonia concentration in the field. However, both utilities have made an empirical application to acquire stable chlorinated water for their distribution systems, without information as to BP and chlorine dissipation.

Boosting Check

Before boosting the chloaminated water with BP chlorination, routine water quality information (e.g., pH, alkalinity, free and total chlorine, etc.,), the total ammonia and, if possible, the ammonia specification (free and combined ammonia) is needed to determine the water's quality. A BP curve at 60 minutes after dosing free chlorine at different concentrations as well as a stability test for the newly formed free chlorine also is necessary. While the results obtained in the laboratory may not represent the reaction in the storage tank, these results still will provide a basic line (dosing and residual chlorine at

Table 2b1: Kingsville (Intake Sampling. Total Cl: 0.06. Sampling Date: 7/16/01. Testing Date: 7/16/01.)

	Total Chlorine (mg/L) Based on Time (Hours) After Chlorination			
Dose	**1**	**24**	**48**	**72**
5.0	5.0	2.3	1.8	1.2
10	10.5	8.3	7.8	6.6
20	19.2	14.6	14.7	13.1

Table 2b2: Kingsville (Intake Sampling. Total Cl: 0.05. Sampling Date: 6/20/01. Testing Date: 7/10/01.)

	Total Chlorine (mg/L) Based on Time (Hours) After Chlorination		
Dose	**1**	**24**	**48**
1.6	1.2	0.21	0.16
4.0	3.5	1.6	1.0
8.0	7.0	4.2	3.5

Kingsville intake waters do not enter breakpoint after chlorination due to lack of ammonia. (See text.) Samples have been kept in the refrigerator prior to chlorination.

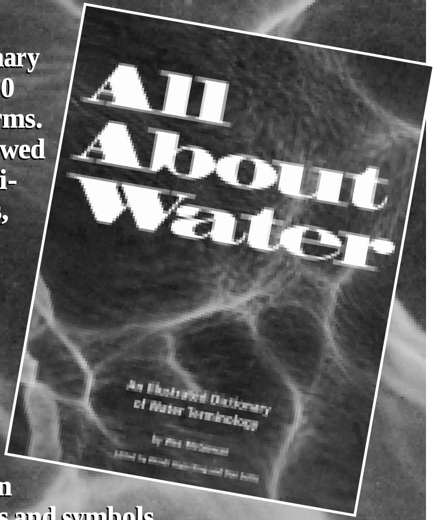


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Table 2: Dissipation of Boosted Chlorine Residual After Breakpoint (continued)

Table 2c: Corpus Christi (2121 MW Sampling.)

			Total Chlorine (mg/L) Based on Time (Hours) After Chlorination			
Total (Cl)	**Sampling/Testing Date**	**Dose**	**1**	**24**	**48**	**72**
3.2	2/4/01	5.0	1.5	0.49	0.16	0.19
3.3	2/10/01	6.0	1.7	0.82	0.36	0.22
2.6	2/11/01	5	2.6	1.4	1.7	0.52
2.6	2/11/01	10	6.2	4.7	4.1	3.4

Table 2d: Corpus Christi Plant (P1 Discharge Sampling.)

			Total Chlorine (mg/L) Based on Time (Hours) After Chlorination			
Total (Cl)	**Sampling/Testing Date**	**Dose**	**1**	**24**	**48**	**72**
3.5	7/30/01	10	4.8	2.6	1.8	1.4
2.5	1/3/02	10	6.2	4.7	4.1	3.4
2.8	1/29/02	7	4.4	3.0	2.6	2.2

BP) in order to prepare for boosting in the field.

Small utilities with limited lab equipment can use a pocket chlorine photometer for the breakpoint test. The free chlorine for dosing can be prepared by diluting an approved commercial bleach (5.25 percent) for water disinfection.

If the BP curve at 60 minutes after chlorination is deviating from a typical BP figure (i.e., without a sharp drop between the maximum and breakpoint), the water to be boosted must be contaminated with intrusions of organic nitrogen or some other chlorine demand.

BP Boosting and THMs

The THM rule has made many utilities switch from chlorination to chloramination as a disinfectant byproduct mitigation strategy. Breakpoint chlorination changes the disinfection mode from monochloramine to free chlorine. This process induces instability in the newly formed free chlorine in C.C. water, and may have formed THMs as well. Breakpoint chlorination can initiate THMs formation as chloramines decline and free chlorine starts to increase.[3]

The Kingsville's intake water, though practically zero in the chlorine residual, still contains 44 mg/L TTHM. This is almost the same level discharged from the C.C. plant. This level increases to 220 mg/L with 2.2 mg/L total chlorine (August 2002) after the first boosting. While the data on DBPs is too scarce to draw any conclusions, it does suggest that the THMs are formed during retention in the storage tank. It may be that THMs are formed more efficiently in the treated water after BP chlorination than in raw water sources by chlorination.

Kingsville maintains a low level of THMs in the distribution system (annual average less than 15 mg/L) through dilution. The distribution water is blended with 20 percent boosted water and 80 percent chlorinated groundwater. If utilities can obtain a high level of chloramine in the distribution, problems such as dissipation and THMs can be reduced.

Safety

The city of Corpus Christi is in the coastal bend of Texas, where hurricanes and tropical storms occur. Hurricane Bret[2] which caused $20 million in damage to south Texas, touched down just 70 miles south of Corpus Christi. The west side of Driscoll was flooded with three feet of water for a few days. Therefore, all types of boosting methods must be prepared for such an emergency in order to avoid intrusion by pathogens into the distribution system.

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3. AWWARF. *Optimizing Chloramines Treatment.* Denver, Colo., AWWA. (1993).

About the Author:
Shin-ichi Tokuno retired as a microbiologist in December 2002 from the Water Utilities Laboratory at the City of Corpus Christi, Texas.