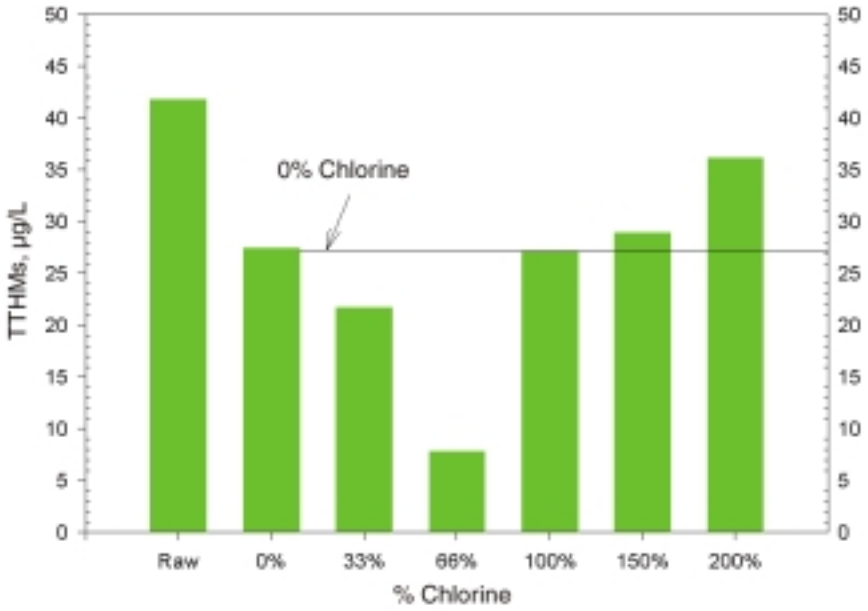
Figure 5: 2 mg/L Chlorine Dioxide Dose and Percent of Chlorine Doses



Impact of Mixing Chlorine and Chlorine Dioxide on Total Trihalomethane Formation: Part 2

Part 1 described the search for more potent disinfection technologies and began the discussion of the laboratory studies.

Comparison of the Effect of 2 mg/L of ClO_2 and Chlorine Doses on TTHMs

Figure 5 shows the effect on TTHM formation of 2 mg/L of chlorine dioxide dosages with chlorine doses ranging from 0 percent chlorine to 200 percent. The 0 percent chlorine sample shows a 15 ppb reduction of TTHMs from the raw TTHM level of 42 ppb. The 2 mg/L chlorine dioxide dose apparently is sufficient to exceed the immediate chlorine dioxide demand than the 1 mg/L dose. At the 33 percent and 66 percent chlorine doses, the TTHMs are reduced significantly more than the 1 mg/L chlorine dioxide dose with comparable chlorine levels, indicating that more chlorine dioxide is being formed from the reaction between the chlorite byproduct and free chlorine. As before, the 100 percent, 150 percent and 200 percent chlorine dosages are showing increasing TTHM levels but lower than comparable chlorine levels with 1 mg/L chlorine dioxide doses.

Chlorine Effect on Chlorite and Chlorate at 2 mg/L Chlorine Dioxide Dose

Figure 6 shows the chlorite and chlorate levels plotted for chlorine levels from 0 percent to 200 percent for the same samples depicted in Figure 5. As before, the chlorite levels are decreasing while the chlorate level increases at a lower rate. The chlorite levels range from 0.90 to 0.69 or 0.21 mg/L difference as compared to the chlorate difference of 0.11 mg/L. The difference in the chlorite range of values is twice the amount compared to the 1 mg/L chlorine dioxide dose indicating that more chlorine dioxide reformation is possible with the greater amount available from the higher chlorine dioxide dose. Therefore, the 2 mg/L chlorine dioxide doses with chlorine reactions seem to have a similar consistent pattern as the 1 mg/L chlorine dioxide doses.

Comparison of the Effect of 3 mg/L of ClO_2 and Excess Chlorine Doses on TTHMs

Figure 7 shows the average effect on TTHM formation from two sets of data depicting 3 mg/L of chlorine dioxide dosages with chlorine doses ranging from 0 percent chlorine to 200 percent chlorine level. The 25 ppb TTHM reduc-

Figure 6: Effect of Chlorine on Chlorite and Chlorate at 2 mg/L Chlorine Dioxide

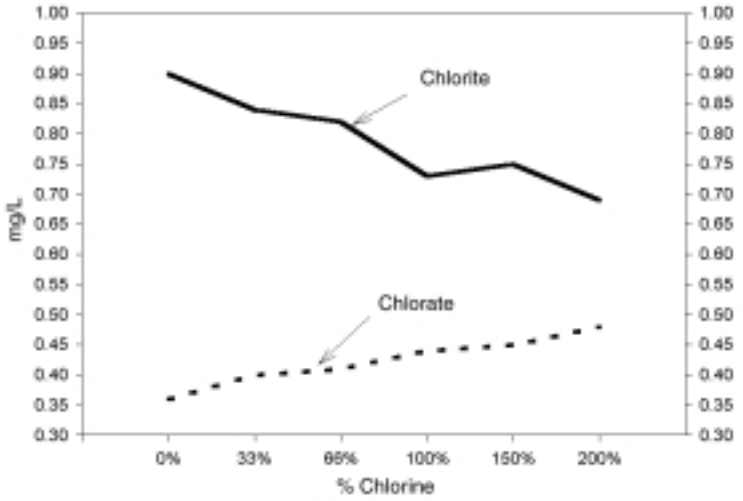


Figure 7: 3 mg/L Chlorine Dioxide vs. Percent of Chlorine Doses

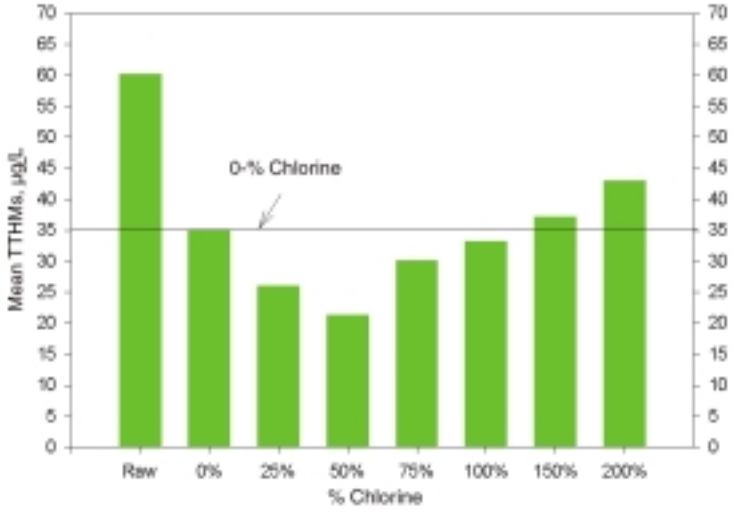
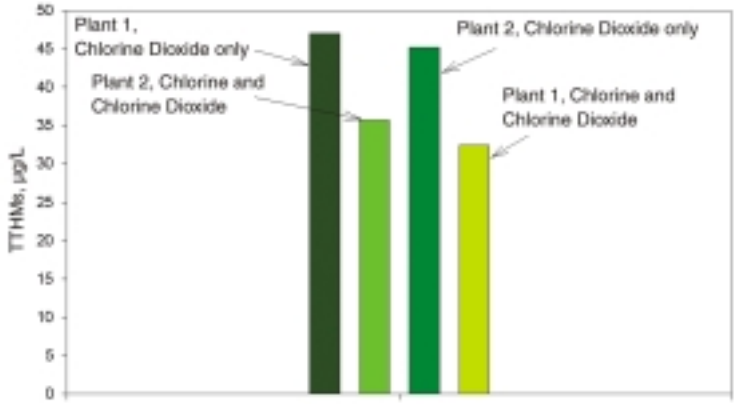


Figure 8: Plant 1 and 2 Studies of Chlorine Dioxide and with Chlorine



tion from the raw to the 0 percent chlorine dose is greater than the 15 ppb reduction obtained at the previous 2 mg/L chlorine dioxide dose. Again, the 25 percent and 50 percent chlorine doses show decreasing TTHMs while the 75 percent, 100 percent, 150 percent and 200 percent chlorine doses have increasingly higher TTHM values. It seems apparent that 66 percent chlorine is the most beneficial for TTHM reduction for all three chlorine dioxide dosages.

Full Plant Studies

Since the previous laboratory studies indicated that mixing chlorine with chlorine dioxide is beneficial in reducing TTHM formation, it was important to verify the results on a plant scale. Because El Paso's Canal Plant has two 20-mgd treatment trains, it was ideal for comparison testing. Figure 8 depicts TTHM results for samples taken from Plant 1 and Plant 2 secondary effluents. The samples were spiked, like previous laboratory samples, with 7-mg/L chlorine and held for a 1-hour contact time in order to form TTHMs.

In the first round of plant testing, the Plant 1 raw water was dosed with about 2.5 mg/L chlorine dioxide only. At the same time, Plant 2 also was dosed with 2.5 mg/L of chlorine dioxide, but with about 50 percent chlorine. The results showed that plant 2 with the chlorine had a greater reduction by about 12 ppb TTHMs as compared to Plant 1 with chlorine dioxide alone.

Next, it was decided to repeat the experiment by reversing the treatments for each plant. If there were other factors affecting the results in the plant processes, then the results would not repeat. In the second round of plant testing, Plant 1 received the chlorine with chlorine dioxide while Plant 2 received only chlorine dioxide. The TTHM results were almost the same, showing a significantly greater reduction in Plant 1, which was receiving the chlorine dioxide with chlorine.

Conclusions

Based on the laboratory and plant studies conducted in this investigation, the following conclusions can be made with reasonable certainty.

- A 1 mg/L chlorine dioxide dose alone did not reduce TTHMs significantly. However, at 1 mg/L chlorine dioxide dose with 66 percent chlorine, TTHMs were reduced by 7 ppb or 15 percent.
- The 2 mg/L and 3 mg/L chlorine dioxide doses with 0 percent chlorine were able to reduce the TTHMs. However, the 66 percent chlorine dose in combination with these higher chlorine dioxide doses was able to reduce TTHM formation considerably more.
- Increasing chlorine dioxide doses with 66 percent chlorine showed a higher rate of TTHM reduction, perhaps because higher chlorite byproduct levels are available for reaction with higher chlorine levels to reform chlorine dioxide.
- The laboratory and plant data suggest that about 66 percent chlorine mixed with chlorine dioxide reduces TTHMs better than chlorine dioxide alone at all three chlorine dioxide dosages studied in this investigation.
- Chlorite reduction occurs at a greater rate than chlorate formation with increasing chlorine doses added to chlorine dioxide.
- The chlorine dioxide generator was able to obtain additional TTHM reduction when chlorine was added.

Recommendations for Future Studies

On the basis of the results presented in this paper, additional investigations are warranted to

- Determine if synergistic disinfection benefits are possible with 66 percent chlorine mixed with chlorine dioxide,
- Determine if CT disinfection credit can be determined for both the chlorine and chlorine dioxide in the same disinfection zone, and
- Determine if the oxidation of iron and manganese occurs with the 66 percent chlorine mixed with chlorine dioxide and if TTHM reduction is adversely impacted when these elements are present.

Acknowledgments
Thanks are extended to the El Paso Water Utilities/Public Service Board for funding and making their facilities available to complete this study. Special thanks go to Richard Wilcox for his invaluable contributions and outstanding laboratory work in analyzing our samples.

For a list of references, please go to www.waterinfocenter.com.

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