New England Water Treatment Technology Assistance Center
University of New Hampshire • Durham, New Hampshire
NE-WTTAC
PROJECT SUMMARY REPORT

Evaluation of a New Method for Ozone Addition Using Super-Saturated Solutions of Ozonated Water

Objectives

This project has been a collaboration between the New England Water Treatment Technology Assistance Center at the University of New Hampshire, Dufresne & Associates, PC (Windsor, VT), and the Town of Newmarket, NH. An ozone pilot treatment system was installed at the Packer Falls Water Treatment Facility in Newmarket, NH and evaluated and compared to the current drinking water treatment methods utilized by the facility. Available space within the existing facility was a limiting factor in determining alternative treatment methods. The facility faces multiple treatment objectives including the removal of taste and odor compounds, the removal of iron and manganese, and the removal of organic precursor materials which contribute to the formation of disinfection byproducts. This project focused on the evaluation of a new drinking water treatment method for ozone addition using a super-saturated solution of ozonated water that could be more amenable for small water systems than previous techniques that rely on the addition of an ozone gas in a controlled reactor.

Methodology

Two separate pilot treatment trains were constructed and operated side-by-side. One treatment train initially mimicked the existing treatment plant consisting of coagulation, upflow clarifier, and mix-media filtration (conventional pilot). After approximately one month of running the pilot system the conventional pilot treatment train was altered to allow for the addition of ozone prior to the filter. The second train included pre-ozonation addition by the sidestream ozone feed system followed by an upflow clarifier and mix-media filtration. A schematic of the pilot system layout is included as Figure 1.

During the operation of the pilot treatment systems various conditions were tested in an effort to determine the most effective treatment configuration. Condition changes included varying the chemical doses including the ozone dose, varying the location of ozone addition, adjusting pH, varying coagulants, and adding carbon filter media.

The water quality parameters monitored on a daily basis were color, temperature, turbidity, and manganese. In addition, the following process parameters were monitored on a regular basis: total organic carbon, dissolved organic carbon, UV absorbance, flow to each treatment unit, all chemical feeds, clarifier headloss rates and flush times, filter headloss rates, and filter run times. Continuous sampling monitoring boards were set up at the raw water feed, conventional pilot filter effluent and ozone pilot filter effluent to monitor turbidity, particle counts, and pH. Other parameters evaluated include biodegradable organic matter (BOM), total trihalomethane forming potential and haloacetic acid formation potentials under uniform formation conditions, and ozone demand.

Results

The organic carbon content and manganese level of the source water varied throughout the pilot study. The organic carbon ranged from roughly 7 to 13 mg/L with the highest observed near the end of the study. Manganese varied from 0.20 mg/L near the beginning of the pilot study and generally decreased to 0.05 mg/L at the end of the study. Apparently the organic carbon levels increased with decreasing temperatures for this raw water source.

Manganese removals during the last week of pilot plant operation were greater than 80 percent and were the highest achieved during the study (Figure 2). Manganese removal was not apparent during the early operation of the pilot, and in fact manganese levels sometimes increased through the system due to the use of potassium permanganate and lower pH levels.

Removal of apparent color was generally greater than 90 percent throughout the duration of the pilot study. The conventional pilot train during the first month of the pilot was operated under conditions mimicking the existing Newmarket Treatment Plant, which was most effective at removing color.

A good correlation exists between the UV254 absorbance and the DOC concentration as noted in Figure 3. This curve was generated using data from raw water and filter effluents from the conventional pilot and ozone pilot. A good correlation also exists between apparent color and UV254 absorbance. These correlations indicate that DOC and apparent color can be approximated based on the UV254 absorbance of the water.

There were occasions when both the pilot conventional and ozone filters produced DOC levels below 3 mg/L. In general, conventional treatment was more consistent in producing lower DOC and organic precursor levels. The ozone pilot system never achieved optimum biological removals due to the relative low ozone dosages, the intermittent filter operation and minimal evidence of biological ripening on the filter media.

The DOC removals using ozone were highest during the last two weeks of the pilot study, removals ranged from 62% to 85% as noted in Figure 4. Some of the higher removals may be due to the use of GAC filter media. The GAC adsorption greatly decreased over a relative short period of time (8 days) suggesting that GAC will become quickly exhausted if adequate pretreatment is not provided. Although a large percentage of the DOC was removed, the effluent concentrations were still high resulting in a high concentration of DBPs as shown in Table 1. The DBP concentrations observed were above the impending EPA MCLs.

Conclusions and Recommendations

The use of ozone was effective in reducing particle counts, color, and manganese levels. The pilot operator also observed a reduction in taste and odor through the use of ozone; however, there was no data to quantify taste and odor removals. The ozone also reduced DOC levels, however not to a level sufficient enough to reduce the DBP below the upcoming EPA MCLs. The use of ozone was effective in enhancing coagulation by reducing the number and amount of chemical coagulants used to achieve similar removals as the conventional treatment.
In conclusion the use of ozone was effective for improving coagulation and the aesthetic qualities of the water including removing color and manganese; however, the ozone application as tested during this pilot study was not effective in reducing the organic precursors to a level sufficient to reduce the DBPs.

Future studies should explore higher coagulant doses with higher alkalinity levels but the short detention times available at the existing treatment facility may hinder consistent performance for all three treatment goals. Nevertheless, elevated coagulant dosages and corresponding alkalinity levels can enhance coagulation removals of TOC (EPA, 1999). Suggested aluminum doses vary with pH but the following have been cited by Edzwald:

pH 5.5	:	0.5 mg as Al/mg DOC
pH 6-6.5	:	0.7 mg as Al/mg DOC
pH 7-7.5	:	1.0 mg as Al/mg DOC

These aluminum levels imply for Newmarket with DOCs greater than 12 mg/L that alum doses be increased to roughly 60-70mg/L to 120 mg/L. The alkalinity will have to be increased accordingly as 0.5mg/L as $CaCO_3$ alkalinity will be consumed for every 1 mg/L alum addition. This increase in sludge production and chemical costs will need to be compared with alternative solutions.

Further innovative treatment options should be considered for future studies. Alternative treatment options to explore may include:

- Nanofiltration
- Pretreatment with much higher ozone dosages
- Adsorptive filter media such as Fe/Al oxides, GAC, and MIEX resin
- Working with the Town of Durham to share a new treatment facility

The two most likely candidates include nanofiltration and the use of more adsorptive media. Preozonation may still be utilized for taste and odor concerns and manganese oxidation.

References

Edzwald, J.K. Coagulation in Drinking Water Treatment: Particles, Organics, and Coagulants. Water Science and Technology, 27:11:21-35, 1993.

EPA. Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual. USEPA Office of Water, EPA 815-R-99012, Washington, D.C., May 1999.

Disclaimer

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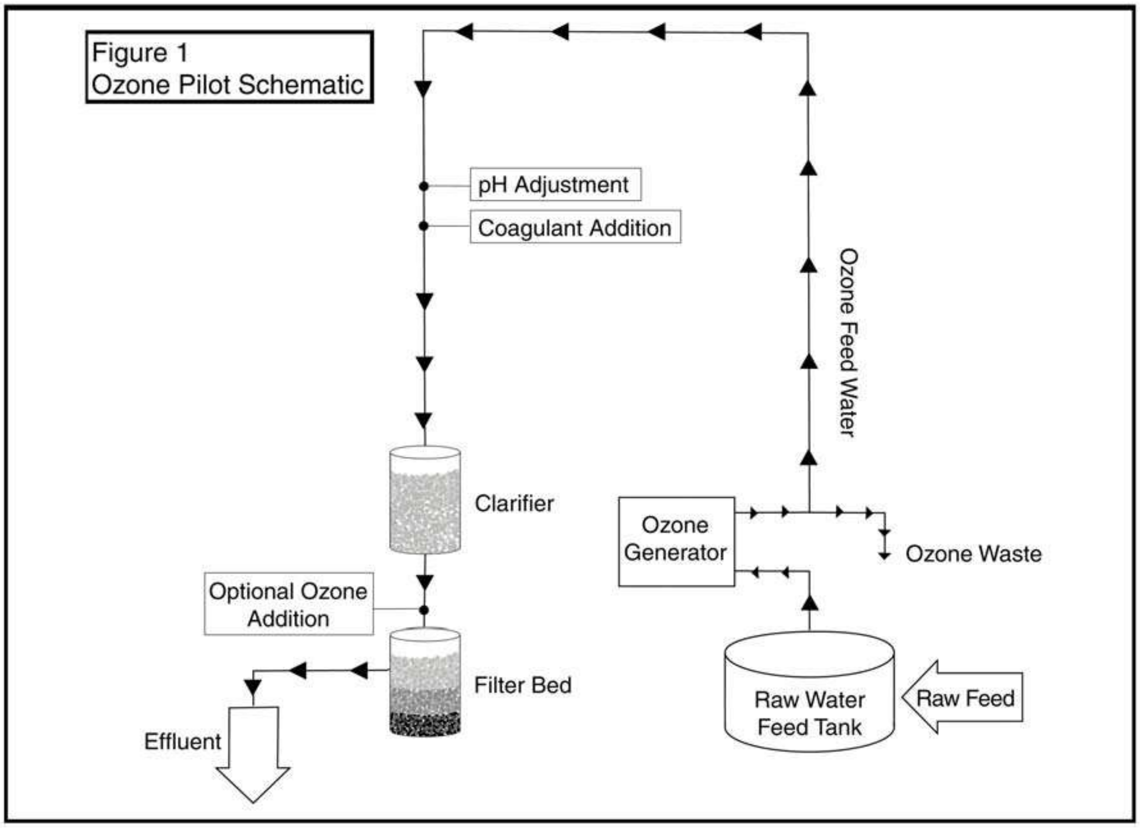
Figure 1
Ozone Pilot Schematic
pH Adjustment
Coagulant Addition
Ozone Feed Water
Clarifier
Ozone Generator
Ozone Waste
Optional Ozone Addition
Filter Bed
Effluent
Raw Water Feed Tank
Raw Feed

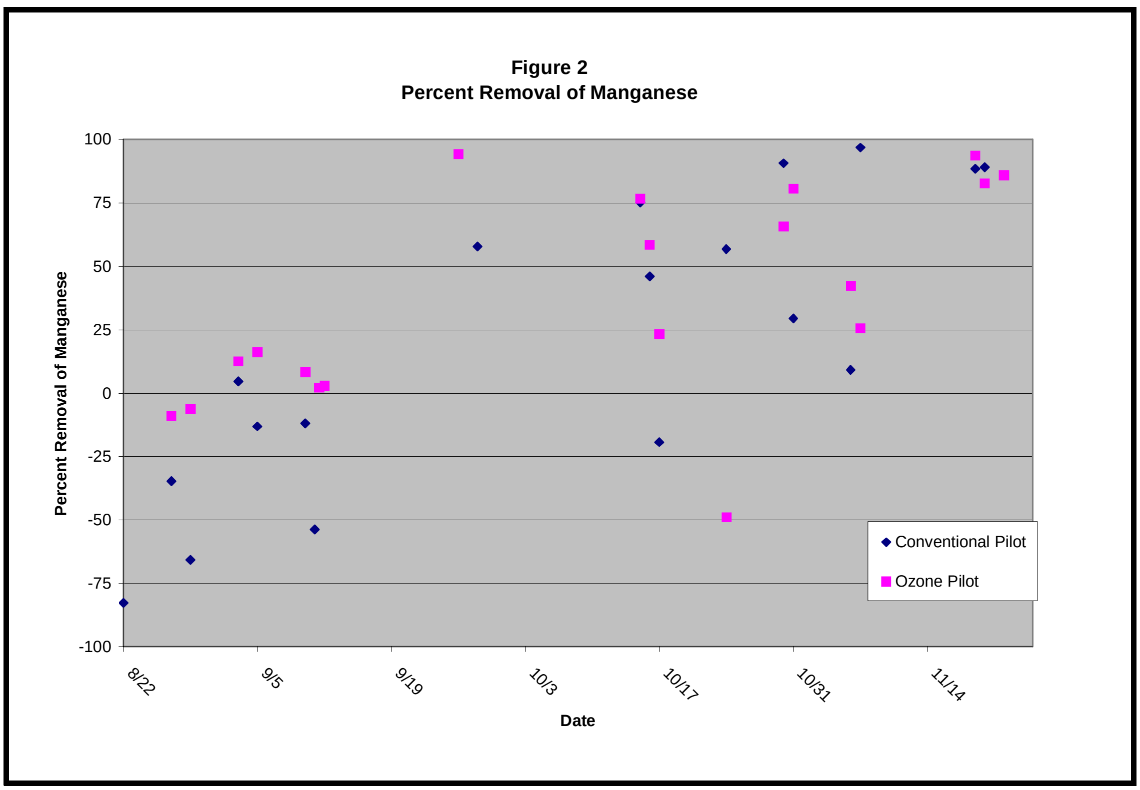
Figure 2
Percent Removal of Manganese
Percent Removal of Manganese
100
75
50
25
0
-25
-50
-75
-100
8/22
9/5
9/19
10/3
10/17
10/31
11/14
Date
Conventional Pilot
Ozone Pilot

Figure 3
DOC vs. UV_{254} Absorbance for All Data Points

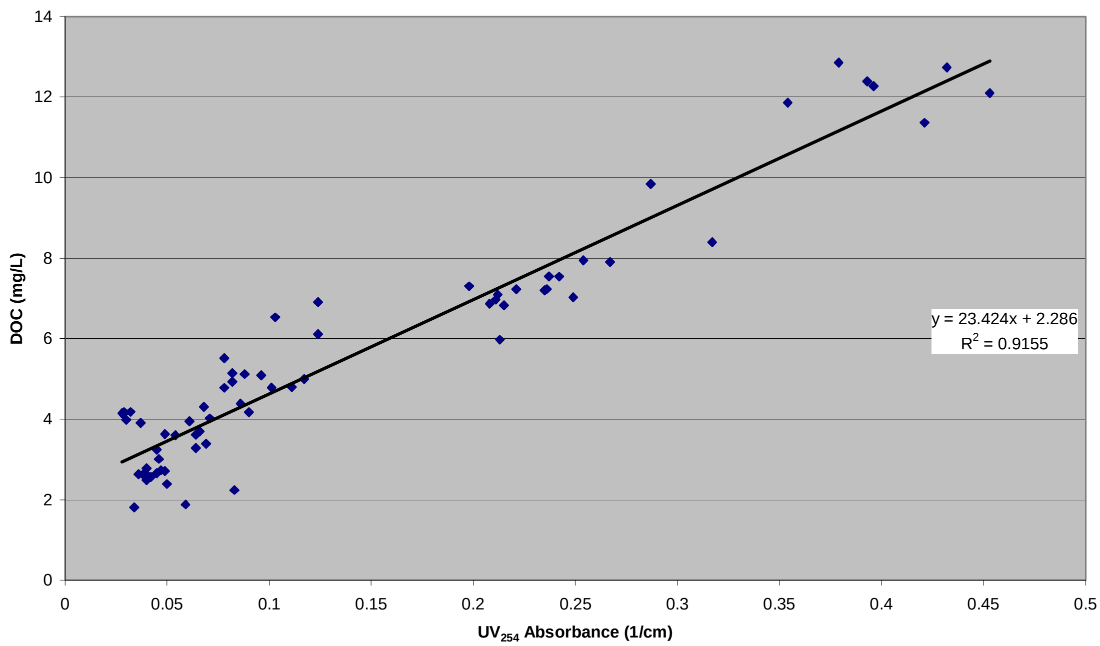

Figure 4
Percent Removal of DOC

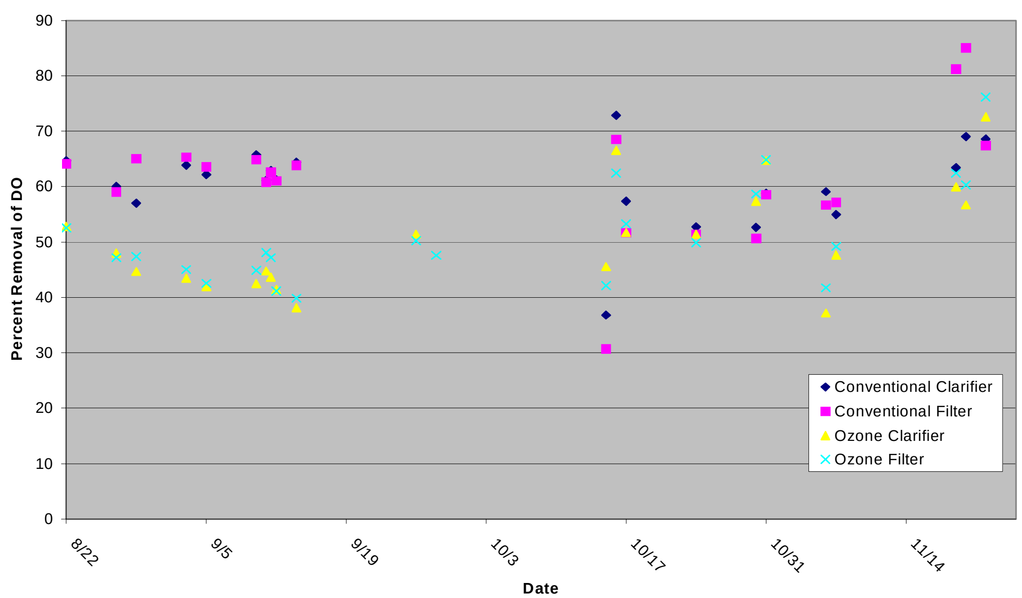

Table 1. Disinfection By-Products

Sample Date	Sample Location	Parameter	Result (ppb)
11/19/2002	Raw	TTHM	319
11/19/2002	Pilot Conventional Filter	TTHM	71
11/19/2002	Pilot Ozone Filter	TTHM	195
11/19/2002	Raw	THAA	628
11/19/2002	Pilot Ozone Filter	THAA	40
11/21/2002	Raw	TTHM	360
11/21/2002	Pilot Conventional Filter	TTHM	159
11/21/2002	Pilot Ozone Filter	TTHM	319
11/21/2002	Raw	THAA	488
11/21/2002	Pilot Conventional Filter	THAA	39
11/21/2002	Pilot Ozone Filter	THAA	99