



New England Water Treatment Technology Assistance Center

University of New Hampshire • Durham, New Hampshire

PROJECT SUMMARY REPORT

Assessment of Various Pretreatments and “Packaged” Construction of a Slow Sand Filtration Facility

Objectives

The Town of North Haven, ME is an island community located approximately 12 miles off the coast of Maine. The island maintains a year round population of approximately 350 residents, most of who are employed in the fishing and lobstering industries. The summer population increases to over 2,000 residents. The peak design flow of the drinking water supply facility is 0.25 million gallons per day (MGD).

The remote location of the highly colored drinking water source surface water presented a variety of challenges to the design engineer. These issues included: chemical delivery difficulties, local generation and high cost of electricity, high cost of concrete delivery, limited skill level of available operator, and multiple regulatory treatment requirements. The regulatory concerns included the surface water treatment rules (SWTRs), disinfection by-product rule (DBP), and the lead and copper rule.

After various pilot studies were evaluated, a multi-stage prefabricated treatment system including pre-oxidation and roughing filtration pretreatments followed by slow sand filtration (SSF) and limestone bed contactor was selected. The initial goal of this study was to conduct a side-by-side comparison between ozonation and hydrogen peroxide (H_2O_2)/UV as a pretreatment for the slow sand filtration process to determine which pre-oxidative process would be most effective for enhancing color and organic precursor removals by the subsequent biological filters. Another major objective was to provide design and construction details on the first multi-stage packaged SSF installation in the United States.

Methodology

The preoxidation comparisons were made by two side-by-side pilot systems. Each pilot train utilized 30-cm diameter slow sand filters (SSF) operating near a hydraulic loading rate of 0.16-0.18 m/hr. One train utilized H_2O_2 addition (roughly 1 mg/L dose) followed by low pressure UV irradiation with less than 10 seconds exposure before the SSFs. The second pilot train used an ozone generator, ozone contact chamber, and an upflow roughing filter before the SSFs.

The results from the pilot study were used to design the full-scale treatment facility. The proposed treatment train included numerous treatment processes that were conducive for incorporation into a “packaged” multi-stage filtration unit to reduce costs and to facilitate treatment system construction and installation.

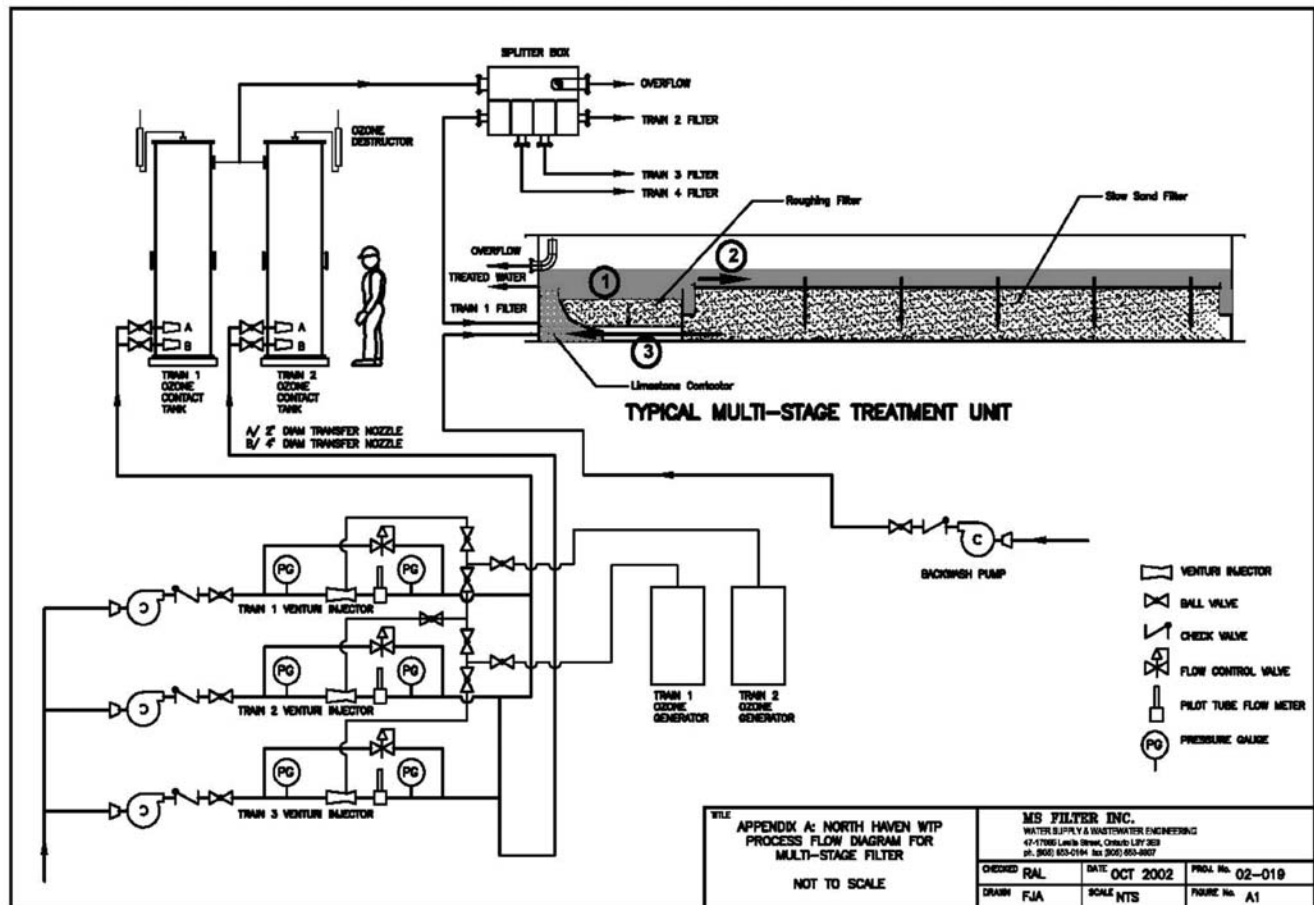
The design and costing data for the treatment system were obtained from Wright-Pierce Engineers and MS Filter, Inc. A schematic of the packaged multi-stage filtration system is shown in Figure 1. The overall design of the water treatment facility had to take into account the extreme variation in seasonal flows. A summary of the design variables for the various flow conditions are shown in Table 1.

Four multi-stage filtration units were installed, each capable of treating a maximum flow of approximately 68,000 gallons per day. Each multi-stage filter is a 3-chamber, marine grade aluminum box with a total surface area of roughly 51 m². The first chamber is a back-washable roughing filter which removes small debris and excessive



biological growth potential from preozonated water before entering the slow sand filter. The last chamber is used as a limestone contactor and is filled with crushed limestone that slowly dissolves as water passes over it to provide corrosion control by raising pH and adding alkalinity to the water. All four filters are kept in operation year-round, except when one is off-line for maintenance. During the winter, flows through the filters will be approximately one third of the design loading rate, and this will help to maintain biological treatment as the raw water temperature decreases.

Figure 1



**Table 1. Design Parameters for the Prefabricated, Multi-Staged Filtration System - North Haven, ME**

	Peak Day	Average Summer Day	Average Winter Day
Flow Rate, gallons per day	250,000	125,000	80,000
Flow Rate, gallons per minute	175	90	55
Design ozonator contact time, minutes	5	10	16
Ozone demand, mg/L	2.6	10	16
Ozone residual after the contactor, mg/L	0.25	0.25	0.25
Total effective ozone dosage, mg/L	2.9	3.0	1.4
Assumed transfer efficiency	67%	67%	67%
Design ozone dosage, mg/L	4.3	4.5	2.1
Ozone production, lb/d	9.0	4.7	1.4
Roughing filter filtration rate, gpm/ft ²	0.74	0.37	0.24
Roughing filter empty bed contact time, minutes	53	106	165
Slow sand filtration rate, gpm/ft ²	0.12	0.06	0.04
Slow sand filter empty bed contact time, minutes	324	648	1,010
Limestone contactor flow rate, gpm/ft ²	1.1	0.55	0.35
Limestone contactor filter empty bed contact time, minutes	20	40	62

Significant Findings

The H₂O₂/UV pretreatment did not enhance organic precursor removals by the following gravel roughing and slow sand filters pilot. There may not have been enough H₂O₂ for the highly colored source to have an impact but the most likely problematic concern was the fouling of the UV lamps. The isolation of the pilot study site prevented routine maintenance of the lamps thereby minimizing the ability of the UV light to convert H₂O₂ by-products to ozone radicals. The pre-oxidation focus then shifted to ozone.

The pilot ozone system had some mass transfer issues primarily due to inefficient gas transfer in the contactor. The pilot treatment data confirmed the ability of preozonation to reduce color (roughly 80%) but TOC reduction rarely exceeded 28% through the SSF. The expected steady-state removal of TOC was closer to 40-60%. There was evidence to suggest the ozone consumed was not always high enough to significantly increase the biodegradable organic material (BOM) available for removal in the biologically active pilot SSFs. There was overlap in removals between the pilot and full size biological filtration systems. A brief summary of the operation data from the full-scale multi-stage filtration system is summarized in Table 2.



Table 2. Operational Treatment Summary of North Haven's Multi-Stage Prefabricated Filtration System 5/28/03 to 6/12/03

<pre> graph LR RawWater[Raw Water] --> Preozonation[Preozonation] Preozonation --> URFilter[Upflow Roughing Filter] URFilter --> SSFilter[Slow Sand Filter] SSFilter --> Limestone[Limestone Bed Contactor] </pre> Plant Start Date: Feb. 25, 2003 Preozonation Start Date: May 28, 2003				
Turbidity (NTU)	0.8	0.3	0.2	----
Color (CU)	25	----	5	----
UV Abs. (cm-1)	0.489	0.202	0.187	0.185
TOC (mg/L)	9.89	7.10	6.36	6.27

The total costs for this 0.25 MGD multi-stage water treatment facility were \$2,441,680 (Summer 2002 costs). The cost breakdown is depicted in Table 3. The pre-fabricated treatment units of the construction costs were \$398,000 which included an ozonation system and four modules each with a roughing filter, slow sand filter, and limestone bed contactor.

Table 3. Summary of Construction Costs for Multi-Staged Slow Sand Filtration System - North Haven, ME

Item	Budget
Contractor's Bid	\$2,216,747
(Filtration & Ozone Equipment)	(\$398,000)
Legal and Administrative	\$5,000
Engineer Administrative/Inspection	\$148,000
Operation & Maintenance Manual	\$10,500
Interest & Refinance	\$15,000
Contingency	\$24,320
Town Contribution	\$73,680
Balance Return	-\$51,567
Total	\$2,441,680



The total slow sand filter area is 127.7 m² which converts to roughly \$19,123/m² or \$9.80/gpd. This unit cost is as much as 2-3 times what has been observed elsewhere. These elevated costs should not be surprising for two reasons: (i) the slow sand filters were 'enhanced' by preozonation, roughing filters and limestone beds which can add significant increases to total costs, and (ii) overall construction costs on an island have been estimated to add 30-40% additional expenses to any construction when compared to mainland costs.

Conclusions

Several conclusions were made from this study including:

- Construction site constraints can be overcome by "packaged" treatment technology.
- Construction costs for small slow sand filters can be reduced via package manufacturing.
- Packaged slow sand filtration is conducive for modification additions, e.g., preozonation, roughing filtration, limestone bed contactors.

Recommendations

Additional costing breakdowns for prefabricated/packaged slow sand filtration plants should be developed to verify the amount of savings over more conventional in-situ constructed SSF facilities. Moreover, treatment comparisons between H₂O₂/UV and ozonation were not resolved by this study and warrant additional study.

Publication

"Design and Construction of Packaged Slow Sand Filtration with Preozonation and Roughing Filtration - A Case Study", by M.R. Collins, A.N. Begin, J.P. Musich and R.A. LeCraw. Proceedings of AWWA Annual Conference, Anaheim, 2003.

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