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

Enhanced Organic Precursor Removals by Gravel Roughing Filters

Objectives

This research study focused on enhancing slow sand filter (SSF) performance and, in particular, organic precursor removals using gravel roughing filters (GRF) with the addition of ozone or a coagulant. A series of pilot SSF and GRF columns were assembled at a highly colored water source in selected configurations to compare performance. Overall removal of organic precursor material; and filter run times for the selected pretreatment options were evaluated and compared. In addition, for comparison purposes, the performance of a SSF with an embedded layer of granular activated carbon (SSF with GAC) was also evaluated.

The objectives of the study were to:

1. Characterize the selected treatment processes (coagulation, ozonation and biological filtration, and GAC adsorption) and compare their ability to remove organic precursor materials.
2. Investigate headloss development in GRFs as a function of the selected pretreatment operation.
3. Evaluate the selected GRFs pretreatment options on enhancing slow sand filter operational performance.

Methodology

This study investigated four different pilot process configurations, arranged so that side-by-side treatment and operational comparisons could be made. Each of the GRFs and SSFs were identical to one another. The investigation included the following processes:

Table 1: Summary of Treatment Processes

Description	Process Enhancement	Pre-Treatment	Filtration
Process Train #1	Ozone [see Note 1]	Roughing Filter 1 (RF1)	Slow Sand Filter 1 (SSF1)
Process Train #2	Coagulant – Poly Aluminum Chloride (PACl) [see Note 2]	Roughing Filter 2 (RF2)	Slow Sand Filter 2 (SSF2)
Process Train #3 (Control)	None	Roughing Filter 3 (RF3)	Slow Sand Filter 3 (SSF3)
Process Train #4	None	None [see Note 3]	Slow Sand Filter with Granular Activated Carbon (GAC)
		Roughing Filter 3	

Notes:
Ozone dose varied from 0.15 – 1.5 mg/L.
Poly Aluminum Chloride (PACl) replaced Alum because of poor performance of Alum with the raw water. The seasonal dosage range for the PACl was expected to be 20 – 50 mg/L
Initially Process Train #4 was operated without a roughing filter. On July 18, 2004, water supply from RF3 was directed to the SSF with GAC to improve poor filter run times.

A summary of the key design parameters for the pilot plant is provided below in Table 2, and a process schematic outlining the pilot plant configuration is appended to this summary.

Table 2: Summary of Design Parameters

Item	Column Height (mm)	Column Diameter (mm)	Filtration Rate (m/hr)	Design Flow (ml/min)	Filter Area (m^2)	Filter Media Thickness (mm)		Notes
Roughing Filters	1900	200	0.45	235	0.032	Gravel 3	450	1
			0.91	500		Gravel 2	450	1
						Gravel 1	450	1
Slow Sand Filters	2500	300	0.20	235	0.072	Sand	900	2
						Gravel 3	100	1
						Gravel 1	100	1
						Gravel Support	200	3
Slow Sand Filter With GAC	1600	300	0.20	235	0.072	Sand	500	2
						GAC	150	4
						Sand	250	2
						Gravel 3	100	1
						Gravel 1	100	1
						Gravel Support	200	3

Notes:
1. Gravel 1 d10 = 6-8 mm (UC < 1.41), Gravel 2 d10 = 4-6 mm (UC < 1.45), Gravel 3 d10 = 2-4 mm (UC < 1.6)
2. Filter Sand d10 = 0.3-0.35 mm, UC < 2
3. SSF Gravel Support d10 = 14-16 mm, UC < 1.8
4. Granular Activated Carbon, Calgon Carbon F400, d10 = 0.55-0.75 mm (UC < 1.9)

Results

The data collection period extended from August 2003 to August 2004. The average organic precursor removal over the study period is summarized for each process train in Table 3.

Process Trains #1 (Ozone + RF1 + SSF1) and #2 (PACl + RF2 + SSF2) provided similar overall results with the exception that Process Train #2 performed slightly better than Process Train #1, for TOC and DOC but not as well for UV absorbance, SUVA and color. As expected, the organic precursor removal through Process Train #3 was minimal (<8%). Process Train #4 (SSF with GAC) provided the highest percentage reduction of organic precursors (48-55%).

Table 3: Process Train Average Organic Precursor Removal over Study Period

	Raw Water	Process Train #1		Process Train #2		Process Train #3		Process Train #4	
		Effluent	% Reduction	Effluent	% Reduction	Effluent	% Reduction	Effluent	% Reduction
Total Organic Carbon (mg/L)	10.17	8.92	12%	8.38	18%	10.14	0%	5.20	49%
Dissolved Organic Carbon (mg/L)	10.27	8.95	13%	8.21	20%	10.13	1%	5.33	48%
Biodegradable Dissolved Organic Carbon (mg/L)	0.8	1.7	-	1.3	-	1.2	-	2.6	-
UV Absorbance (cm-1)	0.34	0.20	40%	0.22	33%	0.33	2%	0.17	50%
Specific UV Absorbance (L/mg-M)	2.99	1.86	38%	2.59	13%	2.98	0%	2.97	-
Color (TCU)	74	30	60%	47	37%	68	8%	33	55%

Notes:
1. Data cells shown with "-" indicate that the reduction was less than relative percent difference of lab results or inconsistent results.

The removal of organic precursors for Process Train #4 was in the SSF with GAC as there was no significant removal of organic precursor material in RF3 except as noted for Process Train #3. The data for the SSF with GAC indicates that the initial organic carbon removal was 90% and gradually tapered to 20% removal (exhaustion level) of the GAC. This exhaustion level was reached after approximately 6,700 GAC bed volumes. The SSF with GAC removed organic precursors through a combination of adsorption and biological activity. This affected organic precursor material by reducing the organic carbon content, UV absorbance and color

Based on the average flow rate for each filter and the number of days in production, the cumulative flow was calculated for each process train. Each process train was in operation for different periods because there were various times throughout the pilot study period when a particular process train was experiencing operational problems. The flow data was then normalized based on filter column area. The production data for the total of all runs for each process train is summarized below in Table 4.

Table 4: Summary of Total Production Data (All filter runs)

Process Train	Volume Filtered (m^3)	Normalized Filtered Volume (m^3/m^2)	Approximate Duration (days)	Normalized Average Day Production (m^3/m^2)
#1	110	1,535	321	4.78
#2	92.8	1,294	379	3.42
#3	119	1,660	386	4.30
#4	72.2	1,008	367	2.75

Note:
1. Normalized data based on 1 sq.m of filter area.

In addition to significantly reducing organic precursors, Process Train #1 (Ozone + RFI + SSF1) provided similar, but slightly better overall performance in terms of water production when compared to Process Train #3 (Control). Process Train #2 (PACl + RF2 + SSF2) also reduced organic precursors, but ineffective operation of the coagulation process resulted in a lower normalized average production rate than Process Trains #1 and #3. Although the average normalized production of water from the SSF with GAC filter was the lowest, this process train was able to remove a significant quantity of organic precursor material (48-50%), until exhaustion of the GAC media.

Conclusions

Based on the results of this investigation as described above, it is concluded that:

1. Process Train #4 (SSF with GAC) performed best in removing an average of 48-50% of organic precursor material for the operational conditions during this study (6700 bed volumes).
2. Process Trains #1 (Ozone + RF1 + SSF1) and #2 (PACl + RF2 + SSF2) provided similar overall reduction of organic precursor material.
3. There was minimal removal of organic precursor material through Process Train #3 (Control RF3 + SSF3) was less than 3%.

4. Roughing filter RF1 with the preozonation enhanced the performance of SSF1 to provide Process Train #1 with the highest normalized daily production rate of 4.78 m3/m2 of filter area.
5. Roughing filter RF3 enhanced the performance of SSF3 to provide Process Train #3 (Control RF3 + SSF3) with the second best normalized daily production rate of 4.30 m3/m2 of filter area.
6. The production rate for Process Train #2 (PACl + RF2 + SSF2) and #4 (SSF with GAC) were, respectively, 29% and 42% lower than Process Train #1.
7. There was no significant build-up of headloss through any of the gravel roughing filters.

Based on the results and ease of operation, Process Train #1 (Ozone + RF1 + SSF1) seemed to consistently provide the best results for removing organic precursors (12-60% depending on the specific parameter) and facilitating effective slow sand filter operation and performance with the highest filter normalized daily production rate of 4.78 m3/m2 of filter area.

Presentations

Organic Precursor Removals for Small Water Systems Using Gravel Roughing Filters and Slow Sand Filtration (Presentation) AWWA 124th annual Conference and Exposition, June 12-16, 2005, San Francisco, CA.

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Disclaimer

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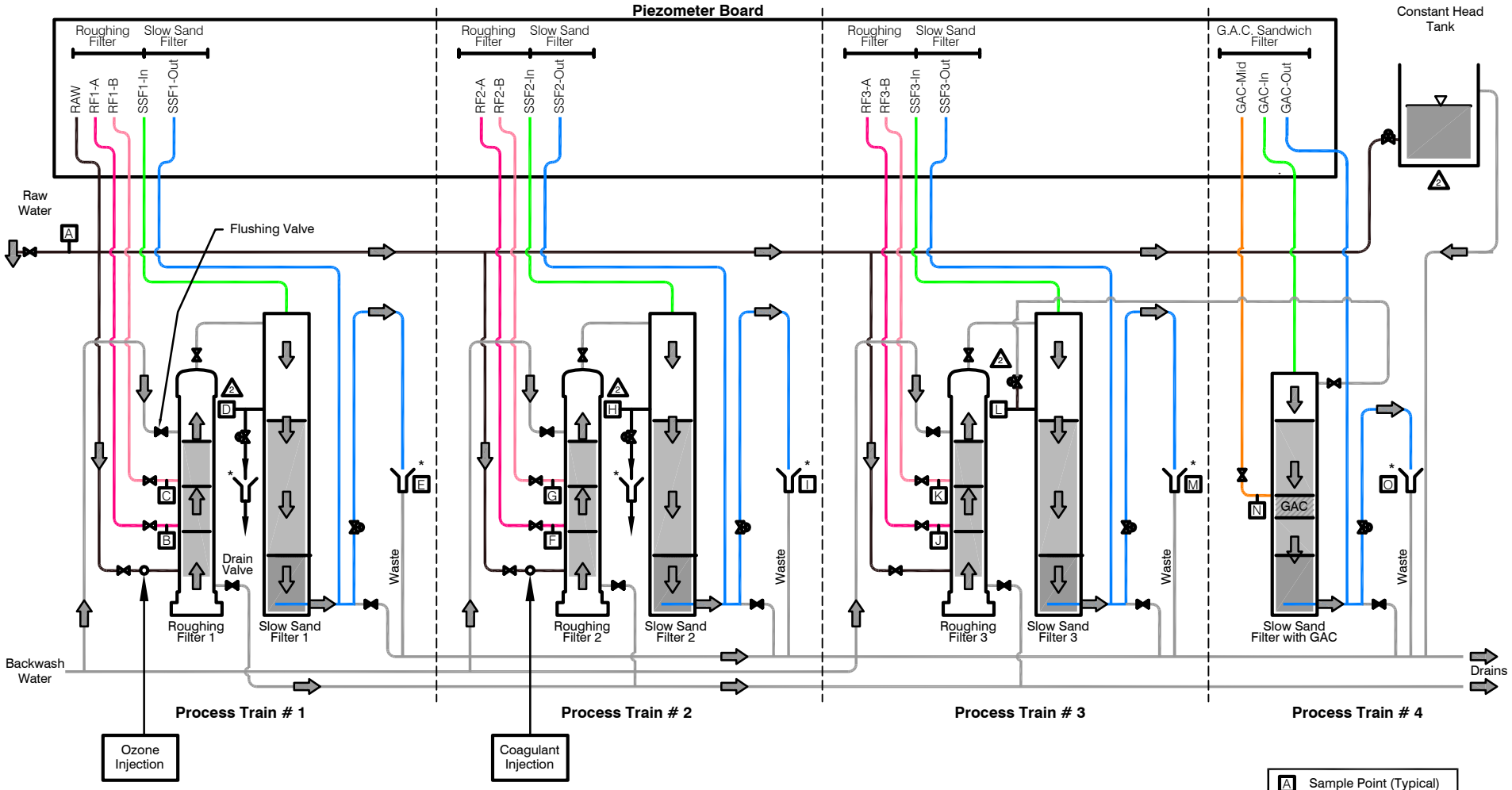

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Enhanced Organic Removals by Gravel Roughing Filter

Process Schematic

* Flow Rates Determined By Volumetric Measurement

Figure E1