By Richard W. Elliott, P.E.

Evaluation of the Use of Crushed Recycled Glass as a Filter Medium: Part 2

Part 1 of this article, which introduced crushed glass as an alternative and compared capital and annual costs versus sand filtration, appeared in the July issue.

Performance

The performance of the Sleepy Hollow Wastewater Treatment Facility was extensively monitored for a sixteen week period. The influent and effluent were tested weekly for BOD, TSS, COD, temperature, pH, ammonia, nitrate, total Kjeldahl nitrogen and DO. Table 4 is a tabulation of the laboratory data generated during the sixteen-week period. In addition, monthly reports were prepared by the Treatment Operator for submission to the New York State Department of Environmental Conservation for compliance with the SPDES permit. Table 5 is a summary of the data from those reports.

During the entire test period, the facility was operated at a 2:1 recirculation rate. The average daily flow entering the facility varied from 5,140 gal/day to 10,100 gal/day. This indicates an application rate of 1.24 gallons per square foot per day to 2.47 gallons per square foot per day, respectively.

The average daily flow for the entire period was 7,520 gal/day or 1.86 gallons per square foot per day. Average rainfall in Central New York State is approximately 38″ per year, which when collected by the three open filters totals 144,000 gallons per year or 395 gallons per day of additional flow through the wastewater treatment facility. On an annualized basis this rainfall adds approximately 5 percent to the plant flow. However, the rainfall does not occur uniformly. If a ½″ rainfall occurs during a given day, an additional 1,900 gallons would flow through the plant during that day. It is unlikely that the rainfall addition ever exceeds 10 to 15 percent of the flow since the higher flows no doubt coincide with periods of heavy rainfall or snow melt.

The variations in plant flow (as much as 300 percent) are the result of inflow and infiltration in the sewage collection system. The Engineer's Report[1] documented instantaneous wastewater flows at the original treatment facility during snow melt and excessive rainfall events such as 25,000 to 30,000 gallons per day. In March of 1999 the monthly reports to NYSDEC reported a maximum flow of 34,000 gallons per day.

During the course of the monitoring period some operating problems

Table 4: Operating Data

	Date	T C	pH-F	pH-O	BOD-S	BOD-F	BOD-O	TSS-S	TSS-F	TSS-O	DO	Am-F	Am-O	TKN-F	TKN-O	NO-F	NO-O	COD-F	COD-O	Flow
1	5/21	16	7.2	6.7	116	144	11	82	21	1	6.4	27	0.73	45	2.8	0.02	20	170	20	8,220
2	5/28	19	7.4	6.5	106	135	6	56	17	0.02	4.5	28	0.62	52	2.3	0.02	18	190	25	8,480
3	6/2	19	7.3	6.4	185	143	7	66	30	0.7	5	4.7	2.2	10	5.2	0.025	17	120	22	8,830
4	6/9	17	6.9	6.6	234	162	4	127	52	2	5.4	31	1.8	51	5.5	0.1	18	170	3.6	7,820
5	6/16	17	7.3	6.3	164	165	8	194	86	3	4.4	27	1	47	4.4	0.1	16	200	25	6.880
6	6/23	18	7.2	6.2	182	185	5	100	60	2	4.6	35	2.2	57	4.4	0.1	14	73	28	7,560
7	6/30	17	6.4	6.4	109	290	7	112	46	3	4.5	33	2.9	58	6.5	0.18	17	200	46	9,440
8	7/7	18	7.3	6.4	248	220	5	154	50	1	5.2	26	1.3	51	4.2	0.11	17	210	29	10,100
9	7/21	18	7.2	7	152	215	32	239	41	10	4	29	12	45	19	0.1	3.9	400	99	8,580
10	7/28	20	7.2	6.6	99	184	20	194	78	3	3.7	29	10	47	14	0.1	9.2	400	61	5,260
11	8/4	20	7.7	7	120	220	14	64	46	8	4	34	14	44	19	0.13	7.6	340	98	5,420
12	8/11	20	7.8	7	86	175	13	38	8	0.3	3.4	31	7.2	35	8.3	<0.1	4.3	350	60	5,140
13	8/25	21	7.1	6.9	58	56	9	38	83	2	5	7.1	5.2	8.9	6.3	3	0.97	50	56	6,460
14	9/29	19	7.4	6.9	117	199	5	63	38	0.3	4.6	25	0.69	56	2.6	0.23	14	360	23	6,690
15	10/6	18	7.6	6.6	138	178	18	46	33	2	8.6	33	2.4	48	3.8	<0.1	18	370	32	7,860
16	12/15	12	7	6.9	169	170	7	84	74	2	6.7	19	1.5	37	4.1	<0.1	7.5	200	8	—
Ave.			7.3	6.7	143	178	10.7	104	48	2.5	5	26.2	4.1	43.2	7	0.3	12.7	238	39.7	

occurred that resulted in interruptions in the weekly tests and some anomalies in the data. The pump dedicated to Filter No. 2 failed during Week No. 9 and the operator started dosing Filter No. 3, alternating with Filter No. 1. The operator immediately observed a substantial reduction in filter effluent quality. Since Filter No. 3 had not been dosed with Septic Tank effluent it did not have an opportunity to develop any biological activity and as a result provided reduced treatment. The operator chose to skip that week's testing and also made a dosing pump switch that permitted the operation to return to alternate dosing of Filters No. 1 and 2. The filters did not return to their earlier performance for approximately three weeks.

During Week No. 15 additional dosing pump failures occurred. During this period the entire plant flow was applied by only one filter. This also resulted in filter effluent quality reduction. All of the pumps were replaced in early December and following two weeks of operation the sixteenth and final week of testing was conducted.

Over the entire sixteen weeks of testing the average BOD, TSS, Ammonia and DO was 10.7 mg/L, 2.5 mg/L, 4.1 mg/L and 5.0 mg/L. Based on the first eight weeks of operation, the average effluent BOD, TSS, Ammonia and DO of 6.6 mg/L, 1.6 mg/L, 1.6 mg/L and 5 mg/L respectively, indicate that the Sleepy Hollow Wastewater Facility is substantially achieving the degree of treatment required by its SPDES Permit. While the average for thirteen weeks is somewhat higher as a result of the operating problems, Weeks Nos. 13, 14 and 16 appear consistent with the first weeks of operation.

The BOD and TSS reduction by this facility during the eleven weeks of trouble-free operation was 96 and 99 percent, respectively. The increase of nitrate nitrogen and lowering of pH together with ammonia reduction of 94 percent indicates effective nitrification in the filter beds. The lower temperatures experienced during the October and December samples appear to impact the dissolved oxygen in the effluent the most significantly. It can be anticipated that nitrification may be suppressed somewhat by lower temperatures; however, that does not become evident from the data for Week No. 16.

Physical Characteristics

The state and federal standards for intermittent sand filter media[4,5] specify only effective size (ES) and uniformity coefficient (UC) with some general descriptions of organic content, solubility, durability, composition and particle shape. Organic content sometimes is specified to be less than one percent and acid solubility sometimes is specified to be less than three percent. Some standards suggest that shale and other soft rock-based sands experience a reduction in particle size distribution that can increase the potential for clogging of the filter bed. While it often is reported that filter media porosity or permeability can be an indicator of the potential for clogging of the filter, no reference could be found that related any measure of permeability to long-term filter performance.

As part of the evaluation of the use of crushed recycled glass filter media, a series of physical tests was performed on samples of the crushed glass used in Sleepy Hollow and the natural sand in use for intermittent sand filters locally. The physical tests include determining and comparing the grain size distribution, acid solubility, magnesium sulfate soundness and permeability of each material.

Grain Size Distribution: A Sieve Analysis was prepared by Atlantic Testing Laboratories, Ltd., in accordance with ASTM C-136 and C-117. The following is the calculated ES and UC for each material.

	ES	UC
Crushed Recycled Glass	**0.7**	**5.6**
Natural Sand	**0.53**	**1.7**

The Clean Washington Center study reported comparable sieve analyses for

Table 5: Monthly NYSDEC Permit Operating Data

	Flow		Temp		pH		BOD		TSS		Ammonia	
Month	*Min*	*Max*	*Infl*	*Effl*	*Infl*	*Effl*	*Infl*	*Effl*	*Infl*	*Effl*	*Infl*	*Effl*
April 1998			12	10	7.1	7	47	3	40	3	12	1.8
May 1998	8,000	8,800	14	15	7.2	6.8	100	3	58	0.7	19	0.2
June 1998	5,000	12,000	17	20	7.1	6.7	107	8	88	2	4.1	1.5
July 1998	4,400	13,000	20	22	7.1	6.7	220	5	50	1	26	1.1
August 1998	3,100	9,200	20	22	7.5	7	56	9	83	2	25	7.1
September 1998	6,000	9,000	20	22	7	6.9	123	6	88	2		
October 1998	4,000	8,200	19	20	7.1	6.9	161	5	160	1.2	32	2.7
November 1998			13.5	12	7	6.9	103	3	77	2	19	1.2
December 1998	6,800	13,000	13	12	7.1	6.9	103	3	77	2	19	1.2
January 1999	8,700	20,000	11	7	7	6.9	67	3	42	0.8	2.9	1.1
February 1999	6,600	16,000	12	7.5	7.1	6.9	43	2	40	1.4	8.3	7.4
March 1999	7,100	34,000	11	7.5	7	6.9	70	3	56	1.4	5.6	1.4

crushed glass and natural sand filter media. It is noted that both filter media materials tested in the Clean Washington Center study were generally a finer grained material as represented by ES and UC. The standard specification for intermittent sand filter media in Washington State is ASTM C33, which is actually a standard for concrete aggregate. New York State does not recommend ASTM C33 and has developed a standard specification referenced earlier in this report. The following is a tabulation of the ES and UC of the crushed glass and tested as part of the Clean Washington Study.

CWC Study	ES	UC
Crushed Glass	**0.24**	**7.8**
Natural Sand	**0.27**	**6.0**

Acid Solubility: The acid solubility test was performed in accordance with NYSDOT 225 which is intended to test the durability of various aggregates used in the manufacture of Portland cement concrete and blacktop. The test results that follow are reported in percent total weight loss.

	Crushed Glass	Natural Sand
Acid Solubility (NYSDOT 255)	**0.075%**	**2.2%**

The weight loss of the glass was significantly less than the sand during this test. However, it should be noted that the weight loss of the sand was within the recommended standard of 3 percent maximum. Since change in the particle size distribution is a factor as well as total weight loss, a grain size analysis was performed on both the crushed glass and sand samples as received from the sources and after treatment in the acid solubility tests. The acid solubility and magnesium sulfate soundness test report indicates very minor changes in grain size distribution that do not yield a significant change in ES or UC.

Magnesium Sulfate Soundness: The Magnesium Sulfate Soundness test was performed in accordance with ASTM C88. This test also determines the durability of aggregates. The test results are reported in percent total weight loss.

	Crushed Glass	Natural Sand
Mag. Sulfate Sound. (ASTM C88)	**0.45%**	**7.51%**

The crushed glass had substantially less weight loss than the natural sand in this test. One informal source indicated that a weight loss of less than 10 percent was acceptable for filter media. A grain size analysis before and after treatment again revealed no significant change in ES or UC.

Permeability: A test to compare the permeability of the two filter media materials was devised and conducted for this study. Figure 4 shows the apparatus that was fabricated. It essentially consisted of a 4″ diameter column that contains 30″ of filter media with 12″ for water above the top of the media. The time needed for the water to fall 12″ was measured and recorded. This was repeated at intervals that permitted the media to drain such that the media column was not in a saturated condition.

Permeability	
Crushed Glass Filter Media	**10 sec/in**
Natural Sand Filter Media	**36 sec/in**

The permeability rate of both the crushed glass and the locally available natural sand is substantially less than reported by the Clean Washington Center.

Observations

The following observations were made throughout the study period.

- During the dosing of the filters there was never a time when the entire surface was flooded. At the beginning of operation (February 1998) approximately one-third of the surface was actually flooded. After several weeks of operation a growth of algae was observed on the flooded portion of each filter and it was noted that the size

Table 6a: Maximum Allowable Loss

	Crushed Glass		Filter Sand	
U.S. Standard Sieve Size	Fraction % Loss	Weighted % Loss	Fraction % Loss	Weighted % Loss
4	0.10	0.03	0.39	0
8	0.39	0.13	4.77	0
16	0.80	0.13	9.15	1.29
30	1.29	0.09	7.57	4.57
50	1.45	0.06	7.40	1.65
Total Loss	**0.45**		**7.51**	

Table 6b: Acid Solubility, NYSDOT 255

	Crushed Glass		Sand	
	Sample Split % Loss	Sample Split % Loss	Sample Split % Loss	Sample Split % Loss
Acid Soluble	0.06%	0.09 %	1.9%	2.5%
Acid Insoluble	99.94%	99.91%	98.1%	97.5%
Average Acid Soluble Residue	**0.075%**		**2.2%**	

of the flooded portion was growing. The flooded area had grown to approximately one-half of the filter by the first week of December.

- The application rate (excluding recycle) varied from 1.24 to 2.47 gallons per square foot per day during the comprehensive testing period. During the very high flows of March 1999 the application rate with all three filters in service reach 5.67 gallons per square foot per day.

- Total suspended solids (TSS) removal in the septic tanks averaged approximately 60 percent. Further removal in the filters resulted in an overall removal of approximately 98 percent.

- Biochemical oxygen demand (BOD) reduction in the septic tanks is limited, and in some cases an increase occurred. However, reduction in the filters resulted in an overall removal of approximately 96 percent.

- Nitrification occurred throughout the period of this study as evidenced by ammonia reduction of 94 percent and an increase in nitrate nitrogen from an average of 0.1 mg/L to 17 mg/L.

- The dissolved oxygen (DO) in the filter effluent was 5.0 mg/L. It appears that the effluent's dissolved oxygen may be increased at lower temperatures.

- The pH was reduced across the plant from an average of 7.2 to 6.6. Reduction of pH is a typical result of effective nitrification.

- The weight loss of the crushed glass filter media in an acid solubility and magnesium sulfate soundness test was significantly less than that of the natural sand in identical tests.

- The permeability rate of the crushed glass was significantly lower (faster) than that of the natural sand tested.

Conclusions

The Sleepy Hollow Wastewater Treatment Facility, when utilizing crushed glass filter media, substantially met the NYSDEC discharge permit requirements for BOD, TSS and ammonia from May 21, 1998 to December 15, 1998 with occasional anomalies caused by failures of the dosing and recycle pumps.

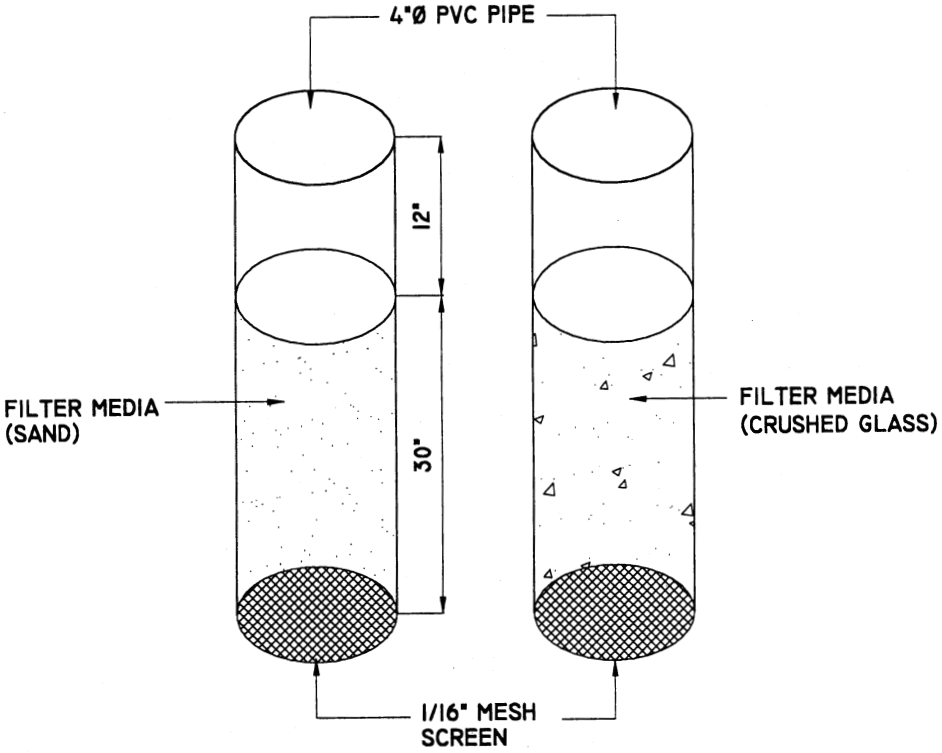
The crushed glass filter medium cost approximately $12.50 per ton less than a natural sand available and commonly used for this purpose in Central New York State. The price of the crushed recycled glass filter media used in this project was not driven by the market price of recycled glass since this product was made from a waste stream that would have had to be landfilled. Some cost is added to the product due to the required additional processing to meet the specified uniformity coefficient and effective size. It is likely that when sufficient demand for this material exists, the price will be directed by competition from natural sand and other processors. It should be noted that of the total delivered price nearly 50 percent is transportation cost.

The crushed glass filter media used in this project is higher in ES and UC as well as permeability than the natural sand available in Central New York State.

Based on magnesium sulfate soundness and acid solubility tests it appears that the crushed glass filter medium is more durable than the natural sand tested.

It also appears that the crushed glass filter medium is more economical and mechanically superior to the natural sand commonly used for recirculating intermittent sand filters. It remains to be demonstrated that the crushed glass filter medium will perform adequately in a once-through intermittent sand filter.

Figure 4: Permeability Apparatus



REFERENCES

1. *Report on Study of Proposed Upgrade of Sleepy Hollow Sewage Treatment Facilities,* Prepared for Town of Oswego, N.Y. by Richard W. Elliott, P.E., civil engineer, January 1997.

4. *Design Standards for Wastewater Treatment Works, Intermediate Sized Sewerage Facilities.* New York State Department of Environmental Conservation, 1988.

5. *Design Manual—Onsite Wastewater Treatment and Disposal Systems,* U.S. Environmental Protection Agency, October 1980, EPA 625/1-80-012.

About the Author:
Richard W. Elliott, P.E., is a civil engineer located in Cazenovia, N.Y.

For more information on this subject, circle 866 on the reader service card.