Performance Validation of a Shell Media Biological Odor Control System

Gayle Van Durme, Sock-Hoon Kohis, and Alan K. Gay

Orange County Utilities (OCU) conducted pilot testing of a new biofilter technology at the Stillwater Crossing Pump Station No. 3961 in Windermere. As shown in Figure 1, the site is across the street from a large subdivision. The new technology is produced by Bord na Mona and uses a seashell media referred to as MÓNASHELL ™. The seashell media has the desirable qualities of availability, low cost, long life, and high sustainability. The purpose of the pilot testing was to verify that the system could provide acceptable hydrogen sulfide (H_2S) and odor removal. The testing also allowed collection system staff to gain familiarity with the operational requirements of the system. Effective treatment and operator satisfaction with the pilot unit would allow the technology to be considered for full scale applications on future OCU projects.

Shell-Media Technology

Bord na Mona, which is headquartered in Dublin, Ireland, identified seashells as a potential media because of the built-in buffering from the calcium carbonate ($CaCO_3$) makeup of shells. Other desirable qualities of the shell media include: high porosity; ability to sustain high irrigation rates; capacity to retain large quantities of water; size and shape in the correct range for good mass transfer; good support for biological activity; and high affinity for sulfur compounds. Laboratory and field trials demonstrated treatment effectiveness, and there are currently more than 600 systems installed worldwide for applications with H_2S exceeding 500 parts per million (ppm).

Shell-media technology can be viewed as a combination of biofilter and biotrickling filter technologies. High irrigation rates are required in conventional biotrickling filters to control pH, but the seashells slowly release calcareous compounds, which neutralize the acid, so water use is lower. The shell media is eventually consumed, but life spans are longer than with conventional biofilter media. A more neutral pH in the system also improves the removal of other odorous compounds.

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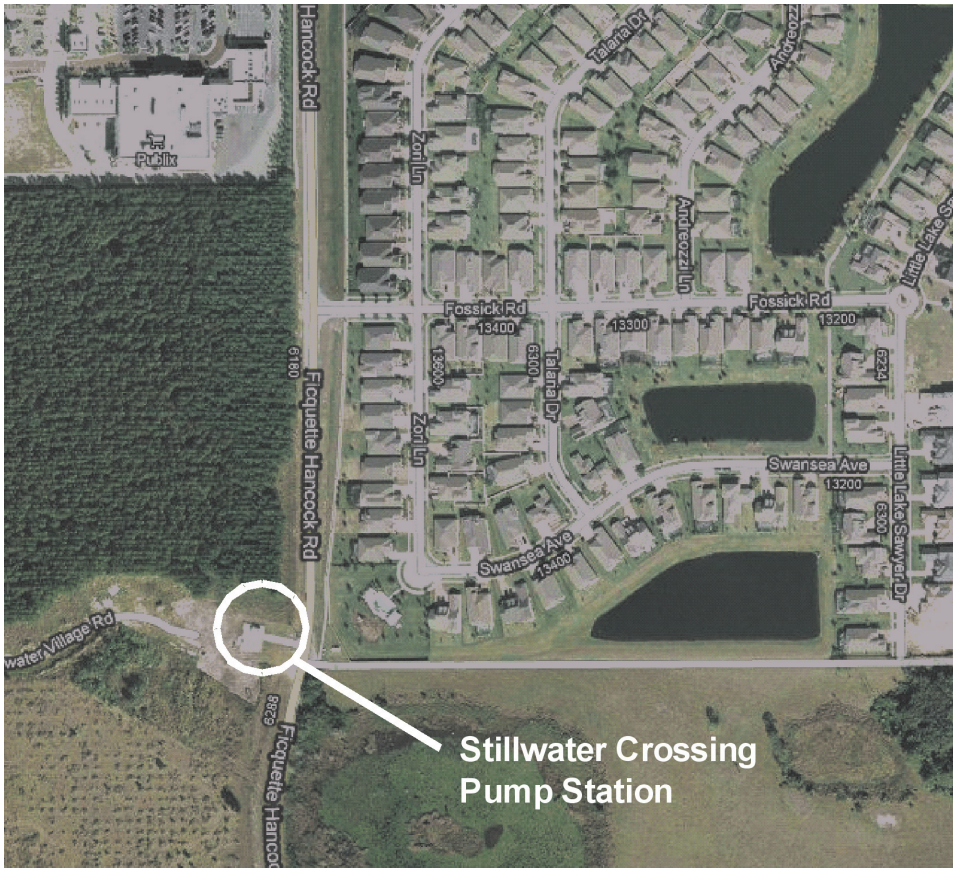

Figure 1. Site Map of Stillwater Crossing Pump Station No. 3961

The first U.S. system was installed in March 2009 at the T.Z. Osborne Water Reclamation Facility in Greensboro, N.C. That system is treating 500 cubic feet per minute (cfm) of air containing high concentrations of H_2S and reduced sulfur compounds (RSCs) with reported removal efficiencies of over 99 percent for H_2S and RSCs, and about 96 percent for odor as detection threshold (Naples, 2010).

The OCU pilot unit at the Stillwater Crossing Pump Station, installed in September 2009, was the second installation in the U.S. In March 2010, a full-scale shell media system was installed by the Town of Cary, N.C., for treatment of odor emissions from a flow distribution box at its North Cary Wastewater Treatment Plant. The system treats 500 cfm of air containing an average of 25 ppm H_2S.

Stillwater Crossing Pilot Unit

The skid-mounted, modular shell-media system installed at the OCU Stillwater Crossing Pump Station consists of a bolted fiberglass reinforced panel (FRP) housing and seashell media contained within, control panel, two FRP sumps, two water recirculation pumps, a fan with unit-to-fan ductwork, and a vertical exhaust stack. Six galvanized steel legs elevate the skid-mounted unit above the

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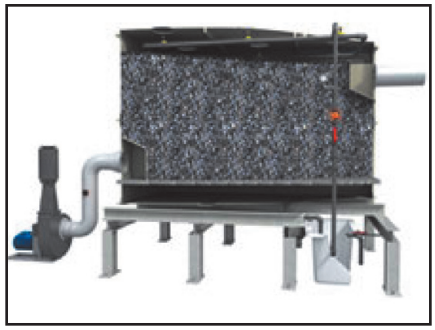
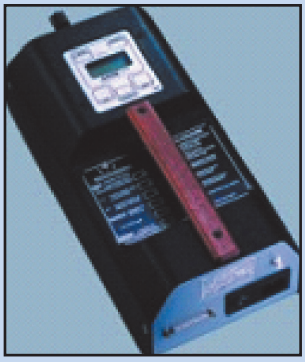
Shell-media system.

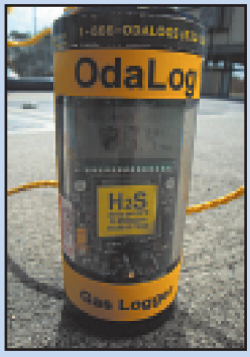


Cutaway view showing media.

Figure 2. Stillwater Crossing Installation



Jerome Model 631-X H2S meter



OdaLog H2S meter

Vacuum Chamber for Tedlar Bag Samples

Figure 3. Sampling Equipment

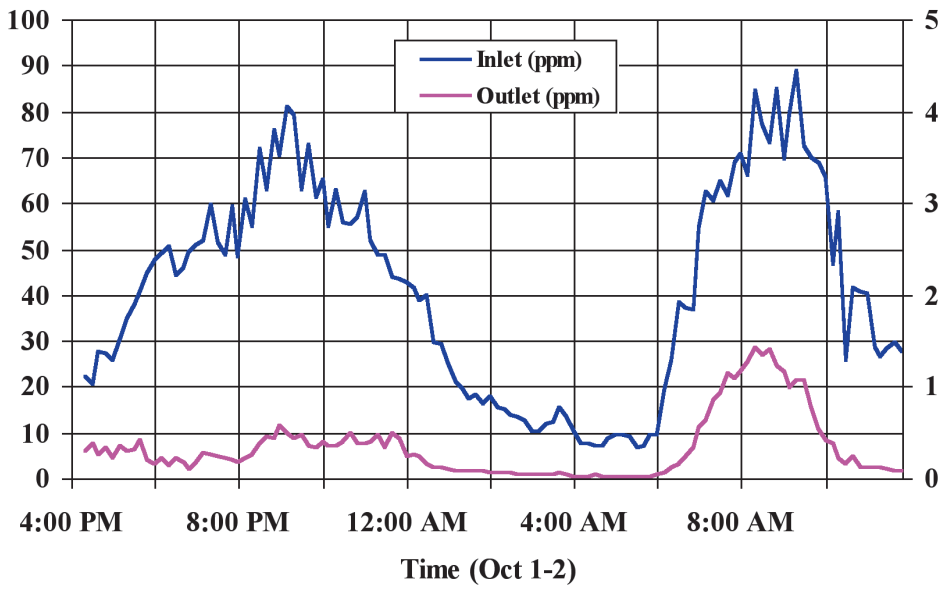


Figure 4. Shell-Media Startup Performance

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sumps to decrease the civil works requirements. The unit dimensions are 12.5 ft x 4.6 ft x 8.2 ft high. The system weighs 7,100 pounds and has support requirements of 410 lb/ft3. Figure 2 shows the skid mounted pilot system installed at the Stillwater Crossing Pump Station, with a cutaway view showing the shell-media and internal configuration.

Two two-inch diameter drains empty the return liquor into the sumps, which are located above ground and beneath the biofilter. To ensure that the sumps do not overflow, an overflow drain is piped to the wet well. The OCU staff installed the pipework from the sump to the drain, connected the potable water supply, and made the electrical connections to the unit.

Sampling Methods and Equipment

The H_2S grab sampling was performed during the bag sampling using a Jerome Model 631 X H_2S meter with a sensitivity of 1 part per billion (ppb). During startup, the vendor used OdaLog H_2S meters at the inlet and outlet for one day; all subsequent sampling was performed by Orange County Utilities staff, assisted by Black &Veatch. A full week of inlet and outlet H_2S data was collected near the end of the trial. In addition to H_2S sampling, transparent bags were used to collect bag samples for odor and compound analyses. Figure 3 shows some of the field sampling equipment.

A comprehensive sampling program was performed to verify the H_2S removal and odor reduction capabilities of the shell-media unit. In addition to H_2S samples, four rounds of bag sampling were performed for odor panel analysis. The odor bag samples were analyzed for detection threshold (DT) and recognition threshold (RT) using test method EN13725/ASTM E679-04.

Parallel bag samples were analyzed for a wide range of compounds, including reduced sulfur compounds (RSCs) using test method ASTM 5504-01, and volatile organic compounds (VOCs) with test method EPA TO-15 Modified. The compound analysis was not performed for the fourth sampling round.

Additional operational measurements included airflow with an anemometer, outlet pressure with a manometer, and sump pH.

Sampling Data

The system commenced operation on Sept. 30, 2009, with a starting airflow of 100 cfm. After the first round of odor and com-

pound testing in November, the air flow was adjusted upwards to about 250 cfm prior to the second round of sampling. The airflow remained at that rate through the third round of sampling. In May 2010, the airflow was increased to 500 cfm prior to the fourth and final round of sampling.

Following installation of the pilot unit, the vendor performed initial H_2S testing to confirm system startup. As shown in Figure 4, the pilot provided good H_2S removal right after installation. With peak H_2S of 88.8 ppm, the pilot unit reduced H_2S by 98.8 percent, and the average H_2S removal over the time period was 99.3 percent.

Additional data was collected during the first week of February 2010. As shown in Figure 5, the inlet H_2S concentration was much lower than in October 2009, with an average of only 1.3 ppm and the highest peak value at 5.4 ppm.

The outlet data for the first week in February, presented in Figure 6, show that good removal was maintained throughout the week-long period. The 0-50 ppm meter employed was not sensitive enough for this low outlet, and a low range (0.01 2 ppm) instrument would have yielded more precise outlet readings. It was noted that the meter read 0.1 ppm, instead of zero, when it was turned on in fresh air. It was thought that it might eventually zero out during operation, but the extensive flat regions at 0.1 ppm indicate that the meter did not go to zero. If the 0.1 ppm concentration is assumed to be zero, then the outlet concentration was at zero most of the time, with frequent spikes to 0.2 ppm and just two spikes of 0.3 ppm.

As indicated in Figure 6, the average reading over the week-long period was 0.1 ppm, but that would become near zero with the appropriate correction. At the highest inlet spike of 5.4 ppm, the corrected outlet would have been 0.1 ppm, so the removal efficiency would be 98 percent. It should be noted that removal efficiency typically starts to decrease as the inlet concentration decreases below 10 ppm.

The initial testing demonstrated the effectiveness of the pilot unit, but operators noted some fugitive odors from the wet well, even at the increased airflow of 250 cfm. For a permanent system, it was recognized that a greater airflow was needed to maintain a negative pressure at the wet well and completely contain the odors. The OCU staff decided to extend the lease on the pilot unit to continue odor mitigation at the Stillwater site to allow time to publicly bid the purchase of a permanent system.

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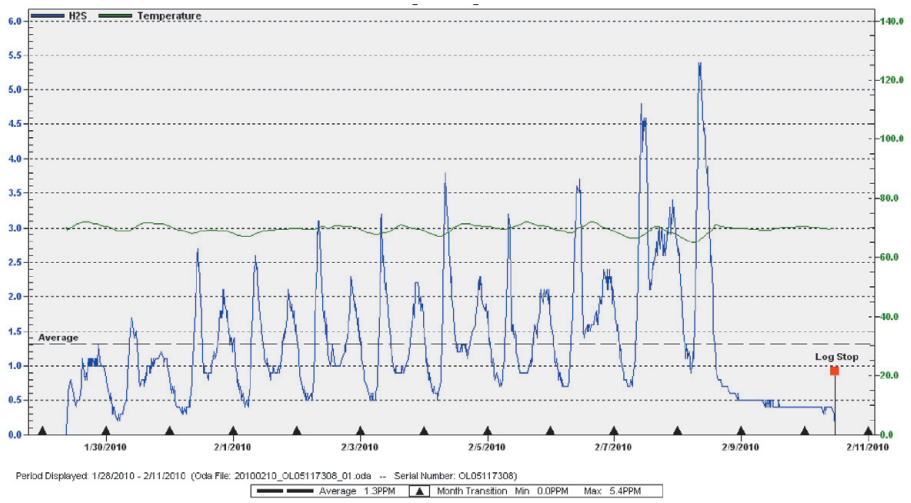

Figure 5. Inlet H_2S Data 1/30 to 2/8/2010

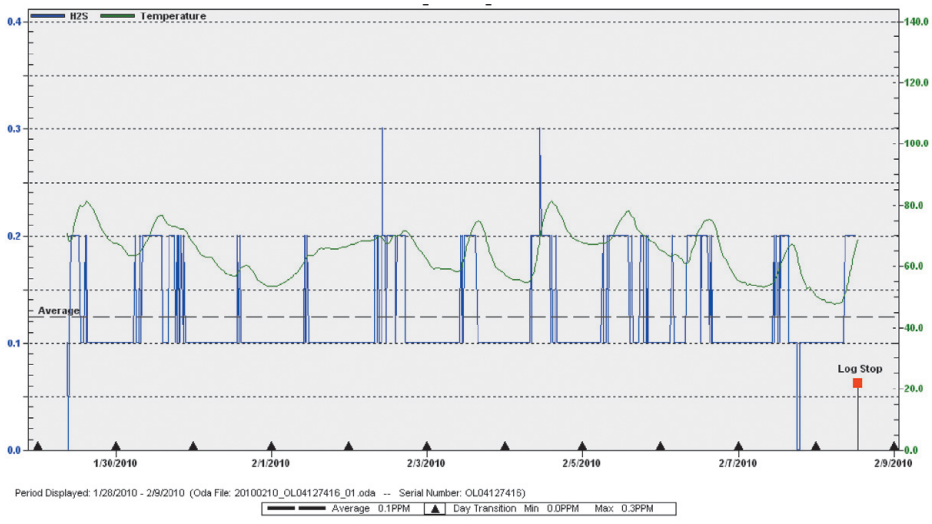

Figure 6. Outlet H_2S Data 1/30 to 2/8/2010

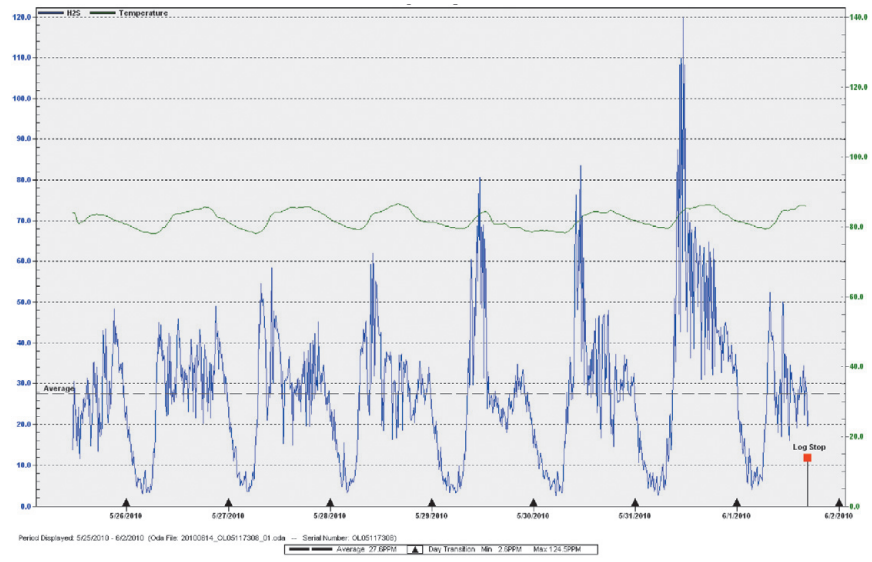

Figure 7. Inlet H_2S Data 5/25 to 6/2/2010

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The pilot system continued to operate effectively with minimal attention through the early months of 2010. In May 2010, the vendor elected to increase the airflow in the pilot unit to the maximum capacity of the blower, which was 500 cfm. The air flow was adjusted upwards on May 19, 2010, and additional H_2S data and odor panel data were collected after a short period of acclimation.

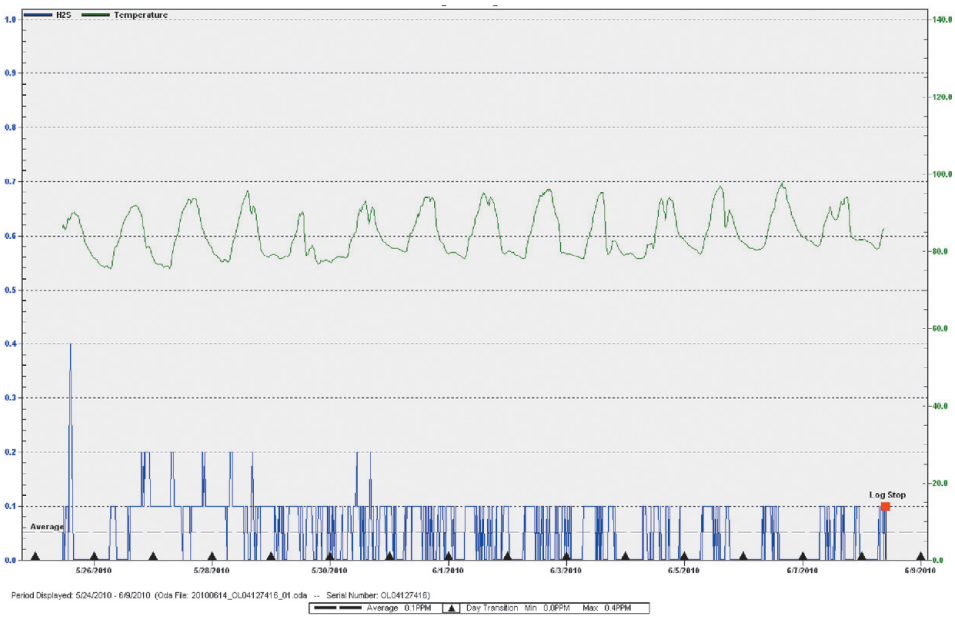

Figure 8. Inlet H_2S Data 5/25 to 6/8/2010

The inlet H_2S data was collected for eight days from May 25 to June 2, with outlet H_2S collected for 14 days from May 25 to June 8. As shown in Figure 7, the inlet H_2S concentration was much higher in May and June, with an average of 27.6 ppm and a peak value of 124.5 ppm. The typical diurnal variation shows declining H_2S after midnight, with the daily low value occurring in early morning. The H_2S values then increased gradually to a peak about noon.

The outlet data, presented in Figure 8, show that good removal was maintained throughout the 15-day sampling period. The 0-50 ppm meter was zeroed out before installation in the outlet stack, so these readings are more indicative of performance than the February readings. The average outlet H2S was 0.1 ppm, with a single spike of 0.4 ppm and several brief spikes of 0.2 ppm.

At the higher inlet H_2S values the removal efficiency was very good. At the average inlet H_2S of 27.6 ppm and average outlet of 0.1 ppm the removal efficiency is 99.64 percent. An examination of the tabulated data showed that at the highest H_2S value of 124.5 ppm, the corresponding outlet H_2S was 0.1

ppm, so the removal efficiency was very high at 99.92 percent. At the next two highest peaks of around 80 ppm, the outlet was also 0.1 ppm, so the removal efficiency was about 99.9 percent.

In addition to the H_2S meter data, the bag samples were collected four times during the pilot testing for odor panel analysis and compound testing. The first round of bag sampling was performed on Nov. 11, 2009, the second round on Dec. 22, 2009, the third round on Feb. 8, 2010, and the fourth and last round on June 8, 2010.

Parallel bag samples were collected for RSC and VOC compound analyses for the first three rounds of sampling, but these analyses were not done for the fourth round of sampling. In the last round of bag sampling, two outlet samples were collected as a precaution to improve the validity of the results at the lower odor values.

In the initial round of odor and compound sampling, the bag samples were collected in the inlet duct and at the outlet stack, as shown in Figure 9. In subsequent sampling, outlet samples were collected at the unit outlet to ensure no dilution was occurring in the stack sample.

The grab sample Jerome H_2S meter data and odor bag analyses are summarized in Table 1, along with the detection threshold (DT) and recognition threshold (RT) results.

The RSC and VOC test results are summarized in Tables 2 and 3. Although 75 VOCs were evaluated, the list shown in Table 3 represents only those that were detected.

Discussion of Results

The initial H_2S data collected in October show the unit had already started to provide excellent removal soon after startup. The H_2S sampling data show that the unit continued to provide excellent H_2S removal throughout the trial period. The H_2S and odor removal efficiencies were calculated and are summarized in Table 4.

As shown in Table 4, the H_2S removal efficiency was typically 99.9 percent after the initial testing in October during acclimation. In pilot testing conducted at the reclamation facility in Greensboro, similar performance was obtained with much higher inlet H_2S. At the average inlet H_2S of 34.5 ppm, the average outlet H_2S was 0.05 ppm. Inlet H_2S varied widely, and at the highest peak of 376.6 ppm, the outlet was 1.08 ppm, for a removal efficiency of 99.7 percent (Naples, 2010).

Odor removal efficiency was also excellent. In the first round of sampling, the effi-

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Figure 9. Stillwater Crossing Bag Sampling

Bag sample collection at inlet duct

Bag sample collection at outlet stack

Table 1. H_2S and Odor Panel Results

Location	Time	H_2S (ppm)	Odor (DT)	Odor (RT)	Remarks
11/10/2009					
Unit inlet	0930	42	-	-	
Wet Well	0940	39.9	-	-	Peak in wet well
Unit outlet	0945	0.007	-	-	
Stack outlet	0950	0.005	-	-	
11/11/2009					
Unit inlet	1130	31 (34[1])	83,000	51,000	
Stack outlet	1145	0.018 (0.013[1])	920	570	
12/22/2009					
Unit inlet	1600	14[1]	26,000	15,000	
Unit outlet	1645	0.005[1]	620	410	
2/8/2010					
Unit inlet	1230	11[1]	82,000	47,000	
Unit outlet	1245	ND[1]	350	230	
6/8/2010					
Unit inlet	0950	25	6,800	4,800	
Unit outlet	0920/0935[2]	-	460/690[2]	270/430[2]	Unit outlet

Notes: [1] Values taken from RSC analyses, [2] Two bag samples collected

Table 2. CAS Reduced Sulfur Compound Results (ASTM D 5504-01)

		11/11/09		12/22/2009		2/8/2010	
CAS #	Compound	Inlet ppbV	Outlet ppbV	Inlet ppbV	Outlet ppbV	Inlet ppbV	Outlet ppbV
7783-06-4	Hydrogen Sulfide	34,000	13	14,000	5.3	11,000	ND
463-58-1	Carbonyl Sulfide	45	6.4	7.2	9.8	6.1	6.1
74-93-1	Methyl Mercaptan	3,300	ND	690	49	1,100	ND
75-08-1	Ethyl Mercaptan						
75-18-3	Dimethyl Sulfide	140	8.4	23	25	33	17
75-15-0	Carbon Disulfide	7.2	ND				
75-33-2	Isopropyl Mercaptan						
75-66-1	tert-Butyl Mercaptan	23	ND				
107-03-9	n-Propyl Mercaptan	19	ND				
624-89-5	Ethyl Methyl Sulfide						
110-02-1	Thiophene						
513-44-0	Isobutyl Mercaptan						
352-93-2	Diethyl Sulfide						
109-79-5	n-Butyl Mercaptan						
624-92-0	Dimethyl Disulfide	26	ND	3.1	2.5	3.1	ND
616-44-4	3-Methylthiophene						
110-01-0	Tetrahydrothiophene						
110-81-6	Diethyl Disulfide						

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ciency was about 98.9 percent. The efficiency was lower in the next round of sampling with the lower inlet odor, which would be expected. In the third round of sampling, the outlet odor was the lowest, with a relatively high inlet odor. In the final round, outlet odor was also very good, with a relatively high inlet H_2S. The inlet odor results were significantly lower than would be expected from the measured wet well H_2S of 25 ppm. It is good practice to measure H_2S directly from the bag to obtain a reading for direct comparison with the odor results, and also confirm that there were no problems in sampling. However, an appropriate H_2S meter was not available for reading from the bag, so the problem was not recognized until the lab results were received.

Based on the outlet odor and assuming an H_2S odor threshold of 0.5 ppb, the 6,800 odor units is equal to only 3.4 ppm. The source variability would not have been that great, so a sampling error must have occurred. At the measured wet well H_2S value of 25 ppm, the theoretical odor value would be 50,000 DT. As shown in Table 4, the odor removal efficiency is 91.54 percent, based on the measured inlet odor, but would be 98.85 percent based on the more realistic calculated inlet odor value.

It should be noted that the highest final outlet odor of 920 DT is an acceptable outlet odor for a biological treatment technology at these contaminant loadings. Previous odor sampling conducted in the OCU collection system at an organic media biofilter showed 5,500 DT in the outlet due to residual H_2S. Biofilters typically provide between 500 and 1,000 DT at lower H_2S loadings. A biotrickling filter had outlet odor of 2,600 DT, which was not due to residual H_2S and is typical for that technology. In comparison, the shell media unit provided as much odor removal as a typical biofilter, but it did so at relatively high H_2S loadings.

The RSC testing indicates that the highest compound measured, methyl mercaptan, is effectively removed by the system. The remaining RSCs detected were in very low concentrations. The few VOCs that were detected were also present in very low concentrations.

It is interesting to note that d-Limonene was detected in the inlet and outlet. This compound is often used as an odor masking agent and the source was thought to be a deodorant block suspended in the wet well. The highest outlet level of 96 ppb would not account for much odor as the detection threshold is 10 ppb, so 96 ppb would only result in about 9.6 DT. No other specific compounds, including the outlet H_2S, account for the outlet odor, so as is often the case, the compounds causing the outlet odor were not identified.

The OCU considers package biofilters as an appropriate technology for annual H_2S concentrations, ranging from 15 to 30 ppm. Package biotrickling filters are the preferred technology for average annual H_2S concentrations above 30 ppm. It is recognized that, with biotrickling filters, activated carbon polishing may be required to reduce the outlet odor to an acceptable level.

Based on the pilot test results at Stillwater Crossing, the shell-media system effectively treated H_2S as high as 124.5 ppm, with acceptable outlet H_2S and odor. This means the technology might be used in place of biotrickling filters without requiring carbon polishing.

The pilot unit provided good odor control at the Stillwater Crossing site, but operators noted some residual odor, which was thought to be due to fugitive emissions. The airflow rate of 250 cfm was not sufficient to prevent fugitive emissions escaping from the wet well, but the fugitive emissions were better contained at 500 cfm. A full scale system should be sized for at least that air flow to ensure that emissions are completely captured and no odor nuisance occurs in the nearby residential neighborhood.

Table 3 – CAS VOC Results (EPA TO-15 Modified)

		11/11/09		12/22/2009		2/8/2010	
CAS #	Compound	Inlet ppbV	Outlet ppbV	Inlet ppbV	Outlet ppbV	Inlet ppbV	Outlet ppbV
64-17-5	Ethanol			38	ND	53	29
67-64-1	Acetone			60	29	96	60
67-63-0	2-Propanol			13	5.7	13	ND
75-09-2	Methylene Chloride			7.5	7.7	2.8	2
75-15-0	Carbon Disulfide	100	ND				
78-93-3	2-Butanone (MEK)	ND	5.4				
110-54-3	n-Hexane			1.5	1.9		
67-66-3	Chloroform	29	18	29	32	23	22
75-27-4	Bromodichloromethane	ND	1.5	3.3	3.4	2.7	2.6
80-62-6	Methyl Methacrylate	ND	5.8				
108-88-3	Toluene	120	110	15	6.9	13	4.7
124-48-1	Dibromochloromethane			0.67	0.72		
127-18-4	Tetrachloroethene			2.8	3.0		
111-84-2	n-Nonane			1.2	ND		
80-56-8	alpha-Pinene	59	5.8	5.4	ND	1.9	ND
5989-27-5	d-Limonene	340	96	65	8.8	33	4.8
95-63-6	1,2,4 Trimethylbenzene					2.3	2.1
109-99-9	Tetrahydrofuran					4.1	2.9
141-78-6	Ethylacetate					2.9	ND

Table 4. Summary of Performance of Shell-Media System at Stillwater Crossing

Sample Date	H_2S			Odor		
	Inlet (ppm)	Out (ppm)	Rem (%)	Inlet (DT)	Out (DT)	Rem (%)
10/1-2/2009 (Avg)	41.3	0.33	99.34	-	-	-
10/1-2/2009 (Peak Inlet)	88.8	1.06	98.80	-	-	-
11/10/2009 (Grab)	42	0.007	99.98	-	-	-
11/11/2009 (Grab)	31	0.018	99.94	83,000	920	98.89
12/23/2009 (Grab)	14[1]	0.005[1]	99.96	26,000	620	97.62
1/30-2/8/2010 (Peak Inlet)	5.4	0.1[2]	98.15	-	-	-
2/8/2010 (Grab)	11[1]	0.005[3]	99.95	82,350	350	99.57
5/26-6/2/2010 (Avg)	27.6	0.1	99.64	-	-	-
5/26-6/2/2010 (Peak Inlet)	124.5	0.1	99.92	-	-	-
6/8/2010 (Grab)	25	-	-	6,800	575	91.54
6/8/2010 (Adjusted Grab)	25	-	-	50,000[2]	575	98.85

Notes: [1]Values taken from RSC analyses, [2]Adjusted value, [3]Method detection limit used

Summary of Findings and Conclusions

The findings and conclusions of the shell-media system pilot testing at the Stillwater Crossing Pump Station are summarized as follows:

- During the eight month trial, the shell media pilot unit provided reliable H_2S treatment. At inlet H_2S concentrations as high as 124.5 ppm, over 99 percent removal was maintained.
- The shell-media system also provided very good odor removal efficiencies of 98.9, 97.6, 99.6, and 99.9 percent, with corresponding final outlet odor of 920, 620, 350, and 575 DT.
- Based on previous odor sampling in the OCU collection system, the shell media system provided better odor reduction than a biotrickling filter, and as good as a well operated biofilter.
- The RSCs and VOCs detected were all in the low ppb range and the specific compounds causing the residual outlet odor were not identified.
- The OCU considers biofilters as acceptable for average annual H_2S loadings of 15 to 30 ppm and biotrickling filters for applications above 30 ppm. The shell media system effectively treated H_2S as high as 124.5 ppm, which puts it in the categories of both biofilters and biotrickling filters.
- The pilot testing indicated that the shell media provided lower outlet odor, compared to biotrickling filters, and the technology may be able to maintain acceptable outlet odor without activated carbon polishing.
- The pilot unit provided good odor reduction at the Stillwater Crossing site, but the airflow rate of 250 cfm was not sufficient to contain fugitive emissions from the wet well. At the increased airflow of 500 cfm, containment was improved, and a permanent system should be sized for that airflow or greater to maintain a negative pressure at the wet well to ensure effective odor control at this sensitive location next to a residential neighborhood.

Acknowledgements

Thanks to Ian Phillips, the original inventor of the MÓNASHELL ™ Biofiltration System, and Mike Kearney of Bord na Mona Environmental Products U.S.,Inc., now Anua, for their assistance during the pilot testing and for the detailed information on the technology.

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