APPLICATION OF BIOTRICKLING FILTER FOR ODOR CONTROL AT THE MORRIS FORMAN WASTEWATER TREATMENT PLANT

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ABSTRACT

Pilot-scale study of a biotrickling filter using synthetic, high surface area media was undertaken by MSD Louisville, with the intention of saving the high cost of operating thermal oxidizers. Currently, two recuperative thermal oxidizers are used to treat odorous emissions from various sources. The pilot study showed that it is possible to treat hydrogen sulfide and organic sulfur compounds at high removal rates to achieve exit odor concentrations below the levels currently attained by the thermal oxidizers. Specifically, removal rates attained in the biotrickling filter were 99.99% for hydrogen sulfide, 98.92% for methyl mercaptan, 97.4% for dimethyl sulfide, 99.73% for carbon disulfide and 99.05% for dimethyl disulfide. The organic sulfur compounds were removed at an overall 99.33% with an odor reduction of 96.38%. The annual operating costs for the biotrickling filter are estimated to be about 5% of the thermal oxidizers to achieve comparable odor reductions.

INTRODUCTION

Metropolitan Sewer District (MSD) in Louisville, KY currently treats air drawn from the thickened waste activated sludge (TWAS) holding tanks, sludge dewatering facilities and sludge blending tank in two recuperative thermal oxidizers. Figure 1 shows a schematic diagram of the air flows with each thermal oxidizer designed to treat 9,200 cubic feet per minute (cfm) of air. Currently the oxidizer treats 5,300 cfm with the second unit serving as backup. For effective treatment of the odors, the oxidizer has to operate at a temperature of 1,425°F, with annual fuel costs exceeding $320,000. A solids receiving tank (SRT) is currently under construction which will receive liquid biosolids from MSD's four satellite treatment plants. Initially, odors from this tank will be controlled by drawing 3,000 cfm of air from the tank and treating it in the oxidizer, which will increase natural gas costs to approximately $500,000 per year. In view of these high yearly operating costs, MSD decided to investigate the use of biotrickling filters for treating the contaminants.

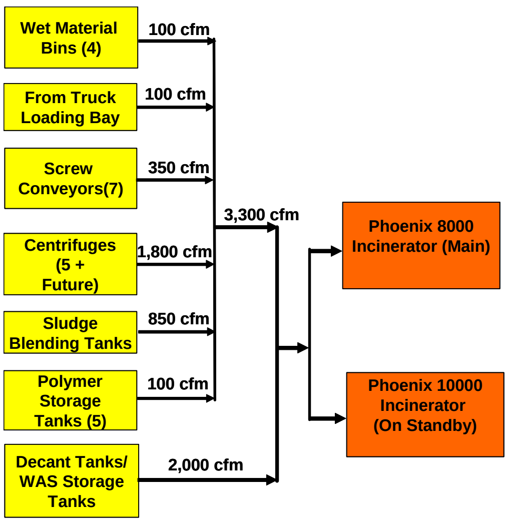


Figure 1. Schematic of the Fume Incinerator Air Collection System

Application of biofilters for treating emissions of hydrogen sulfide have been commercialized for some time. A wide variety of bacterial species can utilize sulfide under aerobic conditions. *Thiobacillus denitrificans* and *Paracoccus pantotrophus* (formerly *Paracoccus denitrificans* and *Thiomicrospira pantotrophus*) can function aerobically or anaerobically using nitrate as a source of oxygen. The obligately aerobic sulfide and mercaptan oxidizer, *Starkeya novella* (formerly *Thiobacillus novellas*), does not produce acid during oxidation and is facultatively able to degrade general BOD and a wide assortment of fatty acids. Figure 2 summarizes some of the species and pH conditions that are involved in

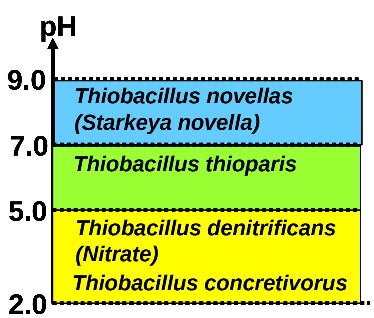


Figure 2. Dependence of species on pH for sulfide oxidation

sulfide oxidation. Hydrogen sulfide oxidation can occur aerobically under neutral and/or alkaline conditions. The main advantage of operating at neutral or slightly alkaline conditions is the ability to simultaneously biodegrade reduced sulfur compounds, such as mercaptans, sulfides and disulfides, which are present with hydrogen sulfide in emissions from lift stations, wastewater treatment plant headworks, etc.

DESCRIPTION OF PILOT-SCALE SYSTEM

Pilot-scale studies were begun in July 2003 to test a biotrickling filter for treating the odors. The pilot system was designed to receive a gas flow rate in the range of 100 – 600 cfm drawn from the air duct currently supplying the #2 Phoenix Thermal Oxidizer (PTO). The biotrickling filter consisted of a 4 feet diameter vessel, about 17 ft height, with two beds (4 ft height of lower bed or1st stage; 2 ft height of upper bed or 2nd stage) of synthetic, high surface area biomedia. Figure 3 shows a schematic of the biotrickling filter system. A temporary 8 inch diameter PVC duct was installed from the existing duct immediately prior to the PTO fan. A new centrifugal fan with a variable speed drive was installed to draw the air from the existing duct and force it through the biotrickling filter.

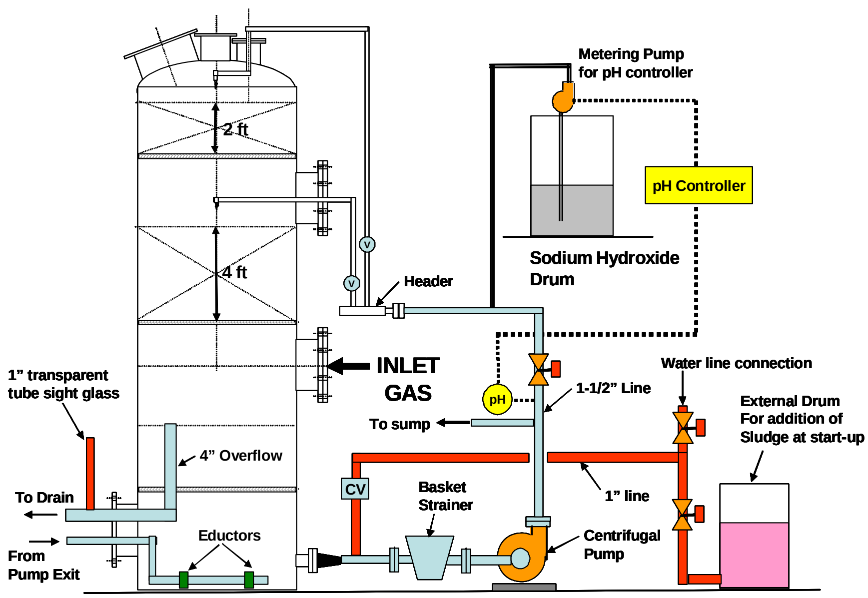


Figure 3. Pilot-Scale Biotrickling Filter

Liquid from the sump was recycled to the spray heads, located above each of the two media beds, at a maximum flow rate of 65 gallons per minute (gpm). The media was seeded using activated sludge liquor from the plant's aeration basin. Sodium hydroxide was used to maintain pH in the biofilter sump using a pH controller and the pH was maintained in the range of 7.7 – 9.0. Proprietary nutrients were added to the biofilter sump periodically to maintain the activity of the organisms. The only water loss from the sump was due to entrainment through the mist eliminator. Later, a continuous flow of water was added to the top spray head, which resulted in a constant overflow blowdown from the sump.

A total of ten (10) air samples were collected on five (5) different days at different operating conditions. The samples were shipped via overnight delivery to St. Croix Sensory for odor panel analyses in accordance with ASTM E679-91 and to Mayfly Environmental for analysis of Reduced Sulfur Compounds (RSC) using a GC/FPD. Odor thresholds were determined using an ASCENT ® Dynamic Dilution Traiangle Olfactometer that has a sample presentation flow rate of 20 liters per minute (lpm). The samples were collected and tested as shown in Table 1.

Table 1. Type of Analyses conducted in this study.

Sample #	Location	Analysis Conducted
1 and 2	System Inlet Gas	Odor and RSC
3 and 4	Biofilter 2nd Stage Outlet	Odor and RSC
5 and 6	System Outlet	Odor and RSC
7	Fume Incinerator Outlet	Odor
8	System Inlet	RSC
9	Biofilter 2nd Stage Outlet	RSC
10	System Outlet	RSC

The air samples were collected in chemically inert tedlar bags. Hydrogen sulfide measurements were also made simultaneously with the Interscan handheld monitor (Interscan Corporation, CA), which uses an electrochemical sensor.. A vacuum chamber was used to draw the air out of the system and into the bag through tygon tubing. An impinger was used to capture any condensate water. Air flow rates were established using a pitot tube and micro-manometer to measure gas velocity in the duct.

EXPERIMENTAL DATA

Experimental data collected is summarized in Table 2. Concentrations of hydrogen sulfide, methyl mercaptan, dimethyl sulfide, carbon disulfide and dimethyl disulfide were measured at the inlet, 1st stage outlet and biofilter exit. The odor measurements (dilutions to threshold) were also measured for some samples (unshaded values in table). The % removals were calculated for the 1st stage and overall biofilter, and are also given in the table. Experimental values that violated mass balance were discarded from further analysis.

Table 2. Summary of Experimental Data collected during the Pilot-Scale Study. (The shaded regions show calculated values.)

Sample #		1	2	3	4	5	6	7	8	9	10
Air Flow Rate (cfm)		255	255	185	185	112	138	138	146	200	340
Detention Time (sec)		17.7	17.7	24.5	24.5	40.4	32.8	32.8	31.0	22.6	13.3
Inlet Concentrations (ppb)											
	Hydrogen Sulfide	19,200	44,400	55,300	1500	13,200	7,000	5400	4600	42,800	12,400
	Methyl Mercaptan	2,300	2,600	1,940	1240	1,150	1,100	880	540	2,200	1,200
	Dimethyl Sulfide	440	472	257	247	291	269	250	131	385	287
	Carbon Disulfide	2,197	5,240	4,472	240	3,277	1,846	2,225	2,248	4,765	1,780
	Dimethyl Disulfide	469	402	132	162	211	63	304	144	389	317
	Total OSCs	5,406	8,714	6,801	1,889	4,929	3,278	3,659	3,063	7,739	3,584
	Odor (D/T)	12,000	18956	18,000	6873	3,000	4,400	12,000	6,700	17521	10513
Biofilter 1st Stage Outlet	Hydrogen Sulfide	470	520	5	5	5	420	622	210		
	Methyl Mercaptan	1,600	1,720	810	820	310	140	930	490		
	Dimethyl Sulfide	418	381	213	233	213	135	145	94		
	Carbon Disulfide	891	2,509	2,260	59	42	506	58	57		
	Dimethyl Disulfide	317	245	199	207	352	9	31	22		
	Total OSCs	3,226	4,855	3,482	1,319	917	790	1,164	663		
	Odor (D/T)	11,000	12858	9,100	5415	3,500	2400	4984	3431		
1st Stage % Removal	Hydrogen Sulfide	97.55	98.83	99.99	99.67	99.96	94.00	88.48	95.43		
	Methyl Mercaptan	30.43	33.85	58.25	33.87	73.04	87.27	-5.68	9.26		
	Dimethyl Sulfide	5.00	19.28	17.12	5.67	26.80	49.81	42.00	28.24		
	Carbon Disulfide	59.44	52.12	49.46	75.42	98.72	72.59	97.39	97.46		
	Dimethyl Disulfide	32.41	39.05	-50.76	-27.78	-66.82	85.71	89.80	84.72		
	Total OSCs	40.33	44.29	48.80	30.17	81.40	75.90	68.19	78.35		
	Odor (D/T)	8.33	32.17	49.44	21.21	-16.67	45.45	58.46	48.80		
Biotrickling Filter Outlet (ppb)	Hydrogen Sulfide	5	5	5	5	5	5	172	88	3	1
	Methyl Mercaptan	1,160	1,000	620	610	140	90	420	280	22	13
	Dimethyl Sulfide	360	335	184	153	184	96	127	69	10	8
	Carbon Disulfide	372	1,292	1,241	107	3	79	35	25	13	6
	Dimethyl Disulfide	197	142	201	305	399	3	9	8	7	3
	Total OSCs	2,089	2,769	2,246	1,175	726	268	591	382	52	30
	Odor (D/T)	9,100	8858	6,400	5015	2,300	1,600	4,800	4,800	634	440
Biotrickling Filter % Removal	Hydrogen Sulfide	99.97	99.99	99.99	99.67	99.96	99.93	96.81	98.09	99.99	99.99
	Methyl Mercaptan	49.57	61.54	68.04	50.81	87.83	91.82	52.27	48.15	99.00	98.92
	Dimethyl Sulfide	18.18	29.03	28.40	38.06	36.77	64.31	49.20	47.33	97.40	97.21
	Carbon Disulfide	83.07	75.34	72.25	55.42	99.91	95.72	98.43	98.89	99.73	99.66
	Dimethyl Disulfide	58.00	64.68	-52.27	-88.27	-89.10	95.24	97.04	94.44	98.20	99.05
	Total OSCs	61.36	68.22	66.98	37.80	85.27	91.82	83.85	87.53	99.33	99.16
	Odor (D/T)	24.17	53.27	64.44	27.03	23.33	63.64	60.00	28.36	96.38	95.82

After the first eight (8) samples had been collected and analyzed, it was found that the % removals for the organic sulfur compounds (OSC), which includes methyl mercaptan, methyl disulfide, carbon disulfide and dimethyl disulfide compounds, were not increasing in spite of higher detention times. This was mainly due to higher aqueous solubility of these compounds and accumulation of these soluble compounds in the biofilter sump liquid. Since the sump liquid was recycled to the spray heads, the soluble compounds were continuously stripped into the exit gas, decreasing the % removals and increasing the exit odor values. Values for the total OSC concentrations are also given in the above table. For the last two samples (Sample # 9 and 10), the biofilter system was modified to introduce a continuous make-up water in the upper bed spray, which resulted in continuous overflow from the drain. The make-up water flow rate was 7 gpm with a continuous drain overflow at the same flow rate. This continuous blowdown reduced the soluble concentration of the organic sulfur compounds in the biofilter sump, which increased their removal efficiency. For samples 9 and 10 no samples from the 1st stage were taken, but the exit odor values were calculated to be below 800 odor units.

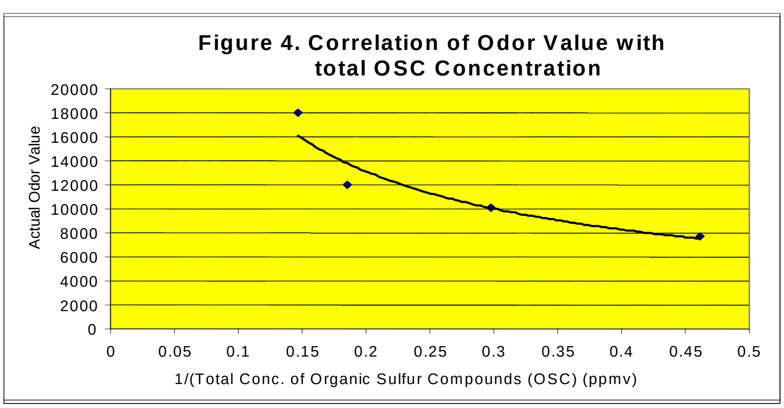
ANALYSIS OF EXPERIMENTAL DATA

The gas Detention time in the biotrickling filter beds (1st stage and 2nd stage) was calculated as follows:

$$Detention\ \ Time\ \ (\sec onds) = \frac{60*(\pi D^2/4)(H_1+H_2)}{F}$$

where D is Diameter of the Biotrickling Filter (4 feet), H_1 is height of 1st stage (4 feet), H_2 is height of 2nd stage (2 ft) and F is gas flow rate (cfm). The gas Detention time varied between 13 and 40 seconds.

The odor measurements were correlated with the inverse of the total concentration of organic sulfur compounds (OSC), and this correlation is shown in Figure 4. As the organic sulfur compound concentration increases, the Odor value also increases. The following correlation for this data was obtained:



$$\text{Odor Value} = 4506.4(1/Ca)^{-0.6636}$$

where Ca is the total Concentration of the Organic Sulfur Compounds (OSC) in ppmv. This equation was used to calculate the unmeasured odor values (shown in shaded areas in Table 2). Odor values less than 800 units were obtained when the biotrickling filter was operated with continuous blowdown. This shows that in many biotrickling filter systems, where a high water flow rate is used without recycle, many organic sulfur compounds (OSC) are removed mainly due to their aqueous solubility rather than by biodegradation.

The loading and Elimination Capacity for a Biotrickling Filter are defined as follows:

$$\text{Inlet Loading} = KFC_{in}MW_i$$

$$\text{Elimination Capacity} = \text{Inlet Loading x Fractional Removal}$$

where K = conversion constant = 5.367×10^{-7}, F is gas flow rate (cfm), C_{in} is inlet contaminant concentration (ppb), MW_i is molecular weight of contaminant i, and V is total volume of media in the biotrickling filter (ft^3). Table 3 summarizes the results of the loading and elimination capacity for each contaminant.

Table 3. Summary of Inlet Loading and Elimination Capacity for each contaminant.

	Sample #									
	1	2	3	4	5	6	7	8	9	10
Gas Flow Rate (cfm)	255	255	185	185	112	138	138	146	200	340
Average Gas Temperature (F)	82	82	82	82	82	82	82	82	82	82
Gas Detention Time (sec.)	17.7	17.7	24.5	24.5	40.4	32.8	32.8	31.0	22.6	13.3
Cotaminant Loading (mg/min.m3)										
Hydrogen Sulfide	89.557	207.102	187.136	5.076	27.043	17.670	13.631	12.285	156.579	77.119
Methyl Mercaptan	15.145	17.120	9.268	5.924	3.326	3.920	3.136	2.036	11.362	10.536
Dimethyl Sulfide	3.742	4.014	1.586	1.524	1.087	1.238	1.150	0.638	2.568	3.254
Carbon Disulfide	22.895	54.607	33.810	1.814	14.999	10.411	12.548	13.413	38.946	24.733
Dimethyl Disulfide	6.046	5.182	1.235	1.515	1.195	0.440	2.121	1.063	3.933	5.449
Total OSCs	47.828	80.923	45.898	10.777	20.607	16.008	18.955	17.149	56.809	43.971
Inlet D/T	12,000	18956	18,000	6873	3,000	4,400	12,000	6,700	17521	10513
Elimination Capacity (mg/min.m3)										
for 1st Biofilter Stage										
Hydrogen Sulfide	87.365	204.676	187.119	5.059	27.033	16.610	12.061	11.724		
Methyl Mercaptan	4.609	5.795	5.398	2.006	2.429	3.421	-0.178	0.189		
Dimethyl Sulfide	0.187	0.774	0.271	0.086	0.291	0.617	0.483	0.180		
Carbon Disulfide	13.610	28.460	16.724	1.368	14.807	7.557	12.221	13.073		
Dimethyl Disulfide	1.960	2.024	-0.627	-0.421	-0.798	0.377	1.905	0.900		
Total OSCs	20.366	37.052	21.767	3.040	16.729	11.971	14.431	14.342		
D/T Value	11,000	12858	9,100	5415	3,500	2400	4984	3431		
Elimination Capacity (mg/min.m3)										
Total in 1st and 2nd Stages										
Hydrogen Sulfide	89.534	207.078	187.119	5.059	27.033	17.657	13.197	12.050	156.568	77.113
Methyl Mercaptan	7.507	10.536	6.306	3.010	2.921	3.599	1.639	0.980	11.248	10.421
Dimethyl Sulfide	0.680	1.165	0.450	0.580	0.400	0.796	0.566	0.302	2.501	3.163
Carbon Disulfide	19.019	41.143	24.428	1.006	14.985	9.965	12.351	13.264	38.840	24.649
Dimethyl Disulfide	3.507	3.352	-0.645	-1.337	-1.064	0.419	2.058	1.004	3.862	5.397
Total OSCs	30.712	56.195	30.539	3.258	17.242	14.779	16.614	15.550	56.452	43.631
Outlet D/T Value	9100	8858	6400	5015	2300	1600	4800	4800	634	440

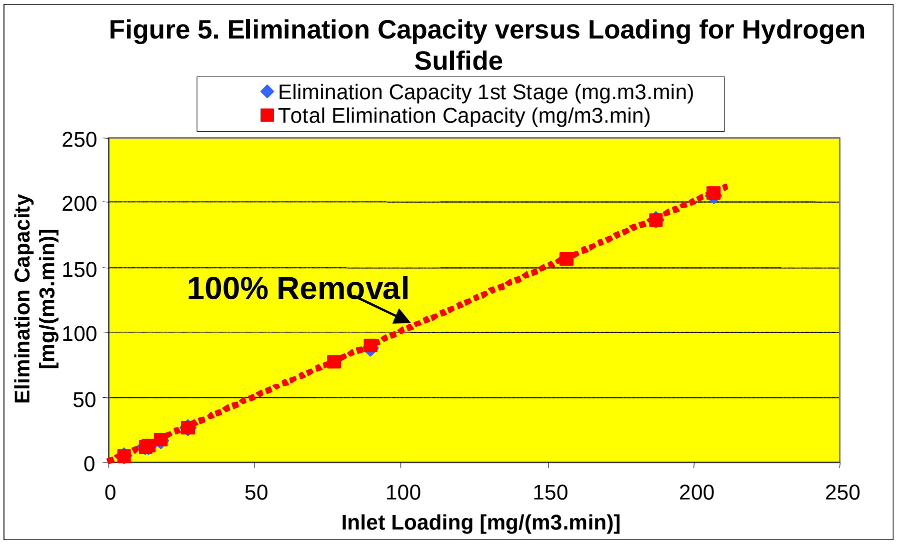


Figure 5. Elimination Capacity versus Loading for Hydrogen Sulfide

If complete removal of a contaminant is achieved in the biotrickling filter, a plot of Elimination Capacity versus Loading for that contaminant will be a straight line with a slope of 45°. This was the case for hydrogen sulfide, with removals exceeding 95%. Further, as seen in Figure 5, most of the hydrogen sulfide is removed in the 1st stage of the biotrickling filter.

It should be noted that this removal was achieved at neutral pH, whereas most autotrophic biotrickling filters have reported hydrogen sulfide removals at low pH. This is significant since at neutral pH, organic sulfur compounds can also be biodegraded simultaneously, whereas at low pH, bioegradation of carbon compounds is strongly inhibited. Hence, for biotrickling filters operating at low pH, successive stages are required to achieve high removals for organic sulfur compounds, which are usually present with hydrogen sulfide in lift station applications. Further, as shown in Figure 5, the elimination capacity for hydrogen sulfide did not achieve a plateau value, indicating that the biotrickling filter has the capacity to remove hydrogen sulfide at higher inlet loadings.

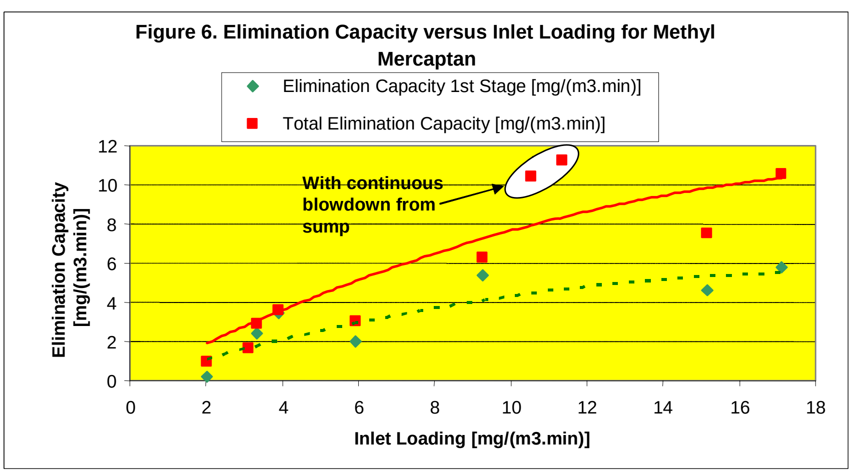
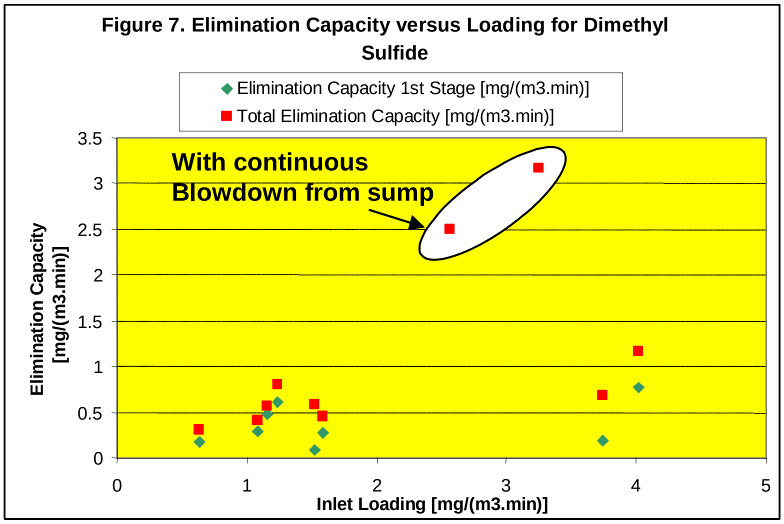


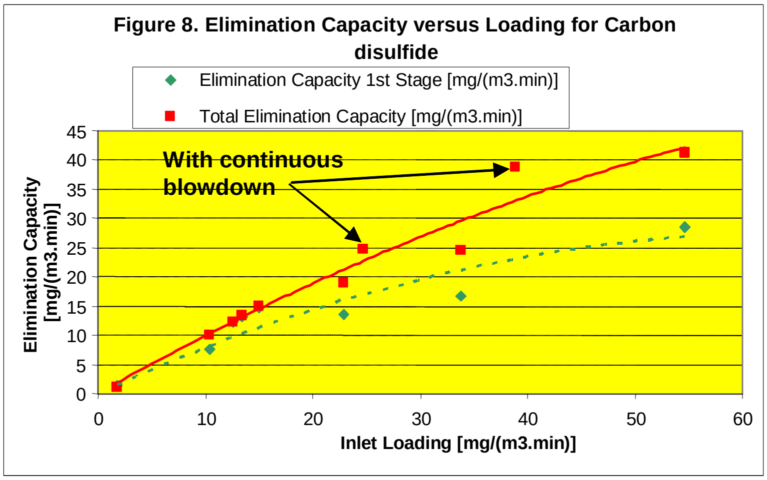
Figure 6. Elimination Capacity versus Inlet Loading for Methyl Mercaptan

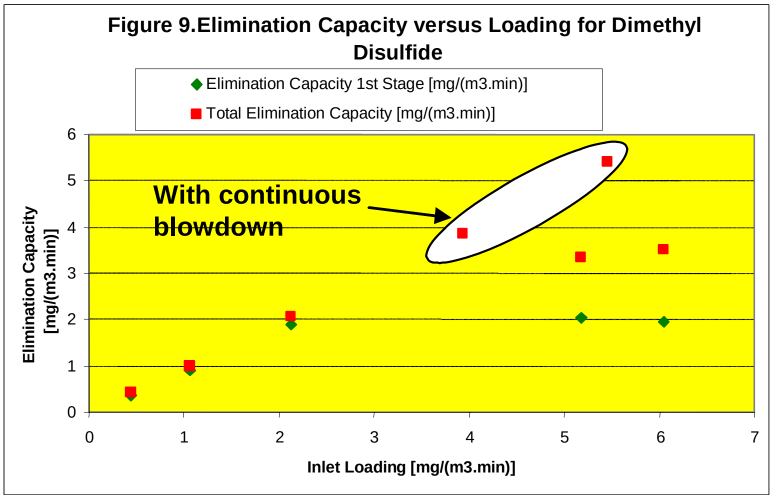
The elimination capacity for methyl mercaptan is shown in Figure 6. About 30% of the inlet loading is removed in the 1st stage, with the remaining being removed in the second stage. The two points corresponding to continuous blowdown operation have been circled, and these points show higher elimination capacity than when the biotrickling filter was operated with no blowdown. The elimination capacity curve seems to achieve a plateau value at about 10.5 mg/(m3.min). The lines have been drawn to show the data trend rather than obtain a good fit.

The results for dimethyl sulfide are shown in Figure 7. With continuous blowdown from the biofilter sump, the elimination capacity for dimethyl sulfide increased significantly, as shown by the circled points. However, without continuous blowdown, the elimination capacity for this compound was about 1 mg/m3.min. Also, the removals in the 1st stage were comparable to the total removals in the biotrickling filter. The aqueous solubility for dimethyl sulfide has been reported as 6,300 mg/L, which can explain the higher elimination capacity when continuous blowdown was used.



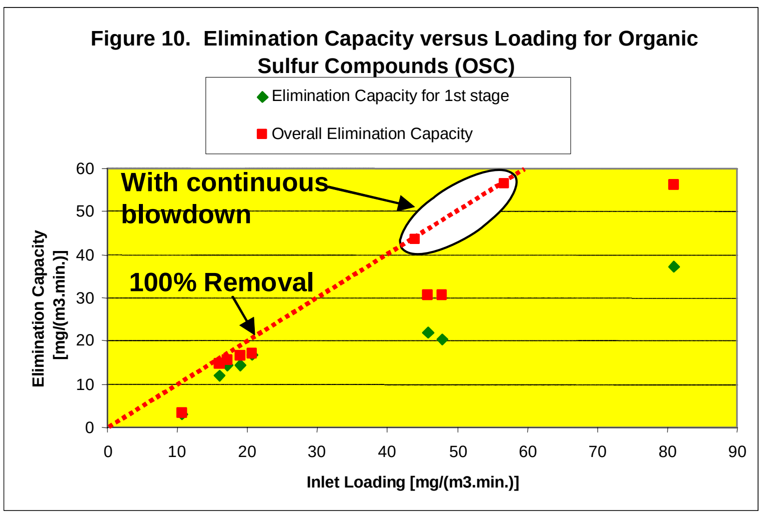
The elimination capacity for carbon disulfide is shown in Figure 8. As with other organic sulfur compounds, the removals with continuous blowdown are higher than when there was no blowdown from the biotrickling filter sump. The removals in the 1st stage were about 60% of the total removals. The highest elimination capacity was about 41 mg/m3.min, and the curve did not seem to have achieved a plateau, indicating that possibly higher removals could be obtained in this filter.





The elimination capacity for dimethyl disulfide is shown in Figure 9. The elimination seemed to achieve a plateau value at about 3.5 mg/m3.min. and the removals with continuous blowdown were higher than without blowdown. At lower loadings the removal in the 1st stage was about the same as the total removal; however at higher loadings the removals in the 1st stage were about 50% of the total removals in the biotrickling filter.

Figure 10 shows the elimination capacity versus loading for all the organic sulfur compounds (OSC). With continuous blowdown from the sump of the biotrickling filter,



the elimination capacity corresponds to 100% removal of the compounds. Significant removals are achieved in the 1st stage of the biotrickling filter, and this is mainly due to the neutral pH in the sump, which is maintained by the pH controller, using controlled addition of concentrated sodium hydroxide. Under the operating conditions attained during this pilot-scale test, the maximum elimination capacity of the organic sulfur compounds is about 56 mg/(m3.min.).

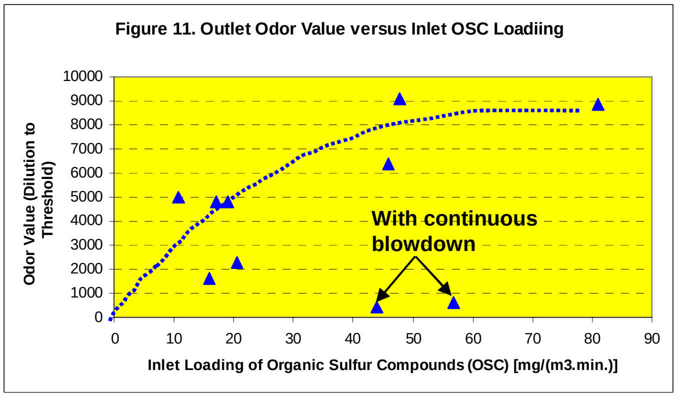


Figure 11. Outlet Odor Value versus Inlet OSC Loadiing

Figure 11 shows the measured exit odor value as a function of the inlet loading of organic sulfur compounds (OSC). As the inlet loading increases, the exit odor value increases, except for the case when continuous blowdown of liquid from the sump of the biotrickling filter is used. In this case, the exit odor value (calculated) is less than 800 units. The limit of 800 odor units is the value that is currently attained by the PTO (Phoenix Thermal Oxidizer).

The % removals and the elimination capacities attained in the biotrickling filter, with and without continuous blowdown, are summarized in Table 4. Clearly, continuous blowdown improves the performance of the biotrickling filter, mainly due to aqueous solubilization of the organic sulfur compounds and minimal stripping of these compounds into the exit gas from the recycled liquid spray on the top bed.

Table 4. Summary of Performance Data for Biotrickling Filter

	Without Blowdown		With Continuous Blowdown	
Contaminant	**Max. % Removal**	**Max. Elimination Capacity**	**Max. % Removal**	**Max. Elimination Capacity**
Hydrogen Sulfide	99.99	207 mg/(m3.min) at 207 mg/(m3.min) loading	99.99	207 mg/(m3.min) at 207 mg/(m3.min) loading
Methyl Mercaptan	91.82	10.5 mg/(m3.min) at 17.12 mg/(m3.min) loading	98.92	11.3 mg/(m3.min) at 11.4 mg/(m3.min) loading
Dimethyl Sulfide	64.31	1.17 mg/(m3.min) at 4.0 mg/(m3.min) loading	97.4	3.16 mg/(m3.min) at 3.25 mg/(m3.min) loading
Carbon Disulfide	99.91	41.14 mg/(m3.min) at 54.6 mg/(m3.min) loading	99.73	38.84 mg/(m3.min) at 38.95 mg/(m3.min) loading
Dimethyl Disulfide	97.04	3.51 mg/(m3.min) at 6.1 mg/(m3.min) loading	99.05	5.4 mg/(m3.min) at 5.45 mg/(m3.min) loading
Total OSCs	91.82	56.2 mg/(m3.min) at 80.9 mg/(m3.min)	99.33	56.45 mg/(m3.min) at 56.81 mg/(m3.min) loading
Odor	63.64		96.38	

Also, a gas detention time of 13 seconds with continuous blowdown results in high removal efficiencies for hydrogen sulfide and all organic sulfur compounds, and 96% reduction in the inlet odor values, which exceeds the current performance of the thermal oxidizer with an exit odor value of 800 units.

SCALE-UP CONSIDERATIONS

Based on the inlet gas measurements, the average characteristics for the inlet gas were established as follows:

	Average	**Max. Value**
Gas flow rate	9,200 cfm	10,000 cfm
Hydrogen sulfide	23 ppmv	200 ppmv
Methyl mercaptan	1,500 ppb	2,600 ppb
Dimethyl sulfide	300 ppb	500 ppb
Dimethyl disulfide	200 ppb	500 ppb
Odor	10,000 DT	18,000 DT

The volume of media required in the biotrickling filter can be calculated using the following equation:

$$V\,(ft^3) = \frac{4.04742x10^{-5}\, G(cfm) * C_{i,max}\,(ppb) * MW_i}{EC_{i,max}}$$

where V is the volume of media in the Biotrickling Filter (ft^3), G is the gas flow rate (cfm), $C_{i,max}$ is the maximum expected concentration of contaminant i (ppb), MW_i is the molecular weight of contaminant i and $EC_{i,max}$ is the maximum elimination capacity of contaminant i. For each contaminant, the volume of media can be calculated, and the volume of media needed will be the maximum volume. Using the values for each contaminant, results given in Table 5 are obtained.

Table 5. Volume of Media needed in Biotrickling Filter based on each contaminant.

Contaminant	Max. C (ppb)	EC (max) [mg/(m3.min.)]	Mol. Wt	Media Volume (ft3)
Hydrogen Sulfide	200,000	207	34.08	13327
Methyl Mercaptan	2600	11.3	48.11	4480
Dimethyl Sulfide	500	3.16	62.13	3979
Carbon Disulfide	500	38.84	76.14	397
Dimethyl Disulfide	500	5.4	94.19	3530
Total OSCs	4100	56.45	58.86	1730

Since the maximum inlet concentration of hydrogen sulfide is high, the volume of media in the biotrickling filter is based on hydrogen sulfide requirements. Hence, about 13,300 ft^3 of media will be needed to meet the elimination capacity requirements for hydrogen sulfide. However, as noted earlier, since the biotrickling filter is capable of achieving higher elimination capacities for hydrogen sulfide, the actual media volume required may be significantly less.

Another issue is the cost of sodium hydroxide needed to maintain pH in the biotrickling filter sump. It was estimated that for a gas flow of 10,000 cfm with an average inlet hydrogen sulfide concentration of 100 ppmv, the annual sodium hydroxide consumption will be $15,000. This is not a significant cost especially since at neutral pH operation, no acidic water blowdown occurs, and simultaneous biodegradation of the organic sulfur compounds can be achieved.

CONCLUSION

The pilot study demonstrated that it is possible to treat hydrogen sulfide and organic sulfur compounds in a biotrickling filter, operating at neutral pH. The removal of some organic sulfur compounds is mainly by dissolution in the water rather than due to biodegradation. Due to water solubility of some organic sulfur compounds, if there is no blowdown of water, the compounds can be stripped back into the exit gases, thereby decreasing the overall treatment efficiency. However, with blowdown of water from the sump, high treatment efficiencies can be attained for all the organic sulfur compounds. It was shown that significant odor reductions were obtained with an exit odor value of less than 800 units with 13 seconds of detention time. Since biotrickling filters operate at ambient conditions, significant cost savings can result from using this technology compared to thermal oxidizers.