Broomfield Water Reclamation Plant Engineered Media Biofilter A Decade of Operation

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ABSTRACT

This paper presents the case study of one of the longest operating Biosorbens® engineered media biofilters in North America, located at Broomfield Water Reclamation Facility in the City of Broomfield, Colorado. The biofilter was installed in 2004 and treats a total of 14 sources throughout the plant from headwork, primary and secondary treatment and sludge management areas. During more than a decade of continuous operation, the biofilter has exceeded design performance consistently. For example, in July 2015, removal efficiency for H_2S and total odor was 99% and 97% respectively, exceeding the design performance handily. Out of the 20 organic sulfur compounds, only two compounds exceeded Method Detection Limit by approximately 5 ppbv. Recent examination showed that the original Biosorbens® media remains in an excellent condition, and Biorem anticipates another decade of trouble free operation. This long media life proves the cost advantage of engineered media biofilters over organic media systems.

KEYWORDS: Biofilters; Biofiltration; Engineered Media; Odor control; Sewage Plant Odor

INTRODUCTION

Engineered biofiltration media was introduced to North America in 1999. Although a large number of systems using this media have been built, published data is lacking on operating experience beyond the 10-year media life claimed by suppliers such as Biorem.

Broomfield Water Reclamation Facility in Broomfield Co offers an excellent case study in the use of engineered media biofilter as it is an advanced wastewater treatment plant with a full range of processes. The biofilter receives exhausts from most of these processes, and is an "open air design" operating in cold winter environment.

This paper describes the plant, the odor sources, and the biofilter system. Biofilter test results from four monitoring campaigns are discussed. Media samples were taken and analyzed, and results are discussed in the context of future performance.

ENGINEERED MEDIA FOR BIOFILTRATION

Key benefits of engineered media include:

- Shorter Empty Bed Residence Time (EBRT) and smaller biofilter footprint than organic media
- Dimensional stability with negligible settling and channeling even after long operation
- Low, stable pressure drop
- Long life
- High performance coating that promotes microbial growth and contaminant retention
- Porous media core for high moisture retention
- High resistance to sulfuric acid and other by-products

Biosorbens®, the engineered media used at Broomfield was brought to market 15 years ago by Biorem in North America. Since that time, about 600 full scale systems have been built throughout the world. While a large majority of installations are in wastewater treatment, Biosorbens® has been used in organics processing, rendering, pet food production, petrochemical, and other industrial applications. Reliability of the media has been demonstrated in very large systems with capacities exceeding 236 m^3/s. In a biosolids application in Toronto, where Biosorbens® was used to replace organic media in two of the four biofilters, superiority of engineered media was demonstrated by side by side test results presented in Figure 1.

After success with Biosorbens®, Biorem commercialized an advanced engineered media, XLD™, in 2008. Key objective was to reduce empty bed residence time (EBRT) by 50% over Biosorbens. Key features of XLD are uniform, spherical particle size, and proprietary base and coating to enhance performance. Figure 2 shows a picture of XLD.

XLD was developed specifically for sewage plant application. It has been highly successful, and almost 100 systems have been built world-wide. Odor removal efficiency of 95% or higher is typical in XLD installations for biosolids exhausts and other sewage applications.

SELECTION OF ENGINEERED MEDIA BY BROOMFIELD

Broomfield installed a compost biofilter in 1998. While the biofilter worked well for about a year, channeling resulted in air bypass and poor odor removal. At that time, housing developing was underway close to the plant, and a wastewater treatment capacity expansion was also being considered. The management decided to proactively address a potential odor problem by building an engineered media biofilter. Key rationale for selection of an engineered media was to avoid the problems experienced with the organic media biofilter, including poor dimensional stability, channelling, need for frequent replacement and poor odor removal.
Design of the biofilter started in 2000. Biorem was pre-selected in 2001 due to company's experience in building biofilters using Biosorbens media in sewage treatment plants. A contractor was selected the same year and construction of the first phase of biofilter was completed in 2003.

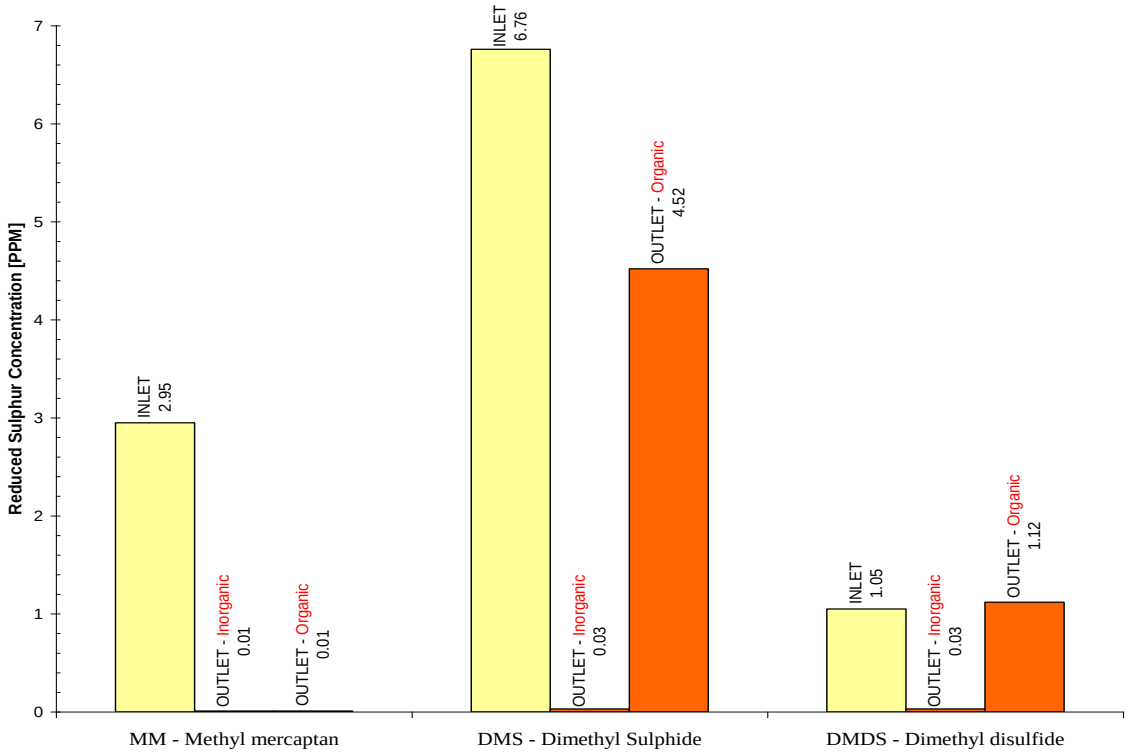

Figure 1: Comparison of Biosorbens® (Inorganic, 40s EBRT) Performance with Organic Media (60s EBRT)

Figure 2: XLD High Performance Engineered Media

Plant Description and Odor Sources

The City of Broomfield had a population of 65,000 in 2014. It is served by Broomfield Water Reclamation Facility, which uses a three-stage Modified Ludzak-Ettinger process for removal of nutrients and carbonaceous contaminants. A special feature of the plant is the use of Integrated

Fixed Film Activated Sludge (IFFAS) process for aeration, which reduces total residence time and plant footprint. The plant has a maximum monthly capacity of 45,500 m^3/d (12 MGD), and consists of three parallel trains of 15,200 m^3/ (4 MGD) each. The basic process consists of grit removal, screening, primary clarification, pre-anoxic zone, anoxic zone and aerobic treatment. Internal recycle of process stream from aerobic to anoxic enhances total nitrogen removal. Biomass is settled in secondary clarification. A portion is recycled and balance is digested, dewatered and composted for use as a soil amendment.

Figure 3 shows an aerial photograph of the facility. The biofilters can be seen in the middle of the picture (dark, rectangular). Note the presence of residences next to the plant boundary.

Figure 4 (Tetra Tech, 2014), shows most of the air pick-up points and blowers for transferring odorous air to the biofilters. The sources are varied and range from headwork to sludge dewatering and storage. In addition, air is collected above the inlet and outlet channels of anoxic zones. About 2/3rd of the flow is from headwork and primary, and balance from sludge processing and storage. Odor vectors include hydrogen sulfide, methyl mercaptan, dimethyl sulfide and dimethyl disulfide, although other less odorous organic sulfur compounds such as carbonyl sulfide are also present.

Figure 3: Broomfield Water Reclamation Facility

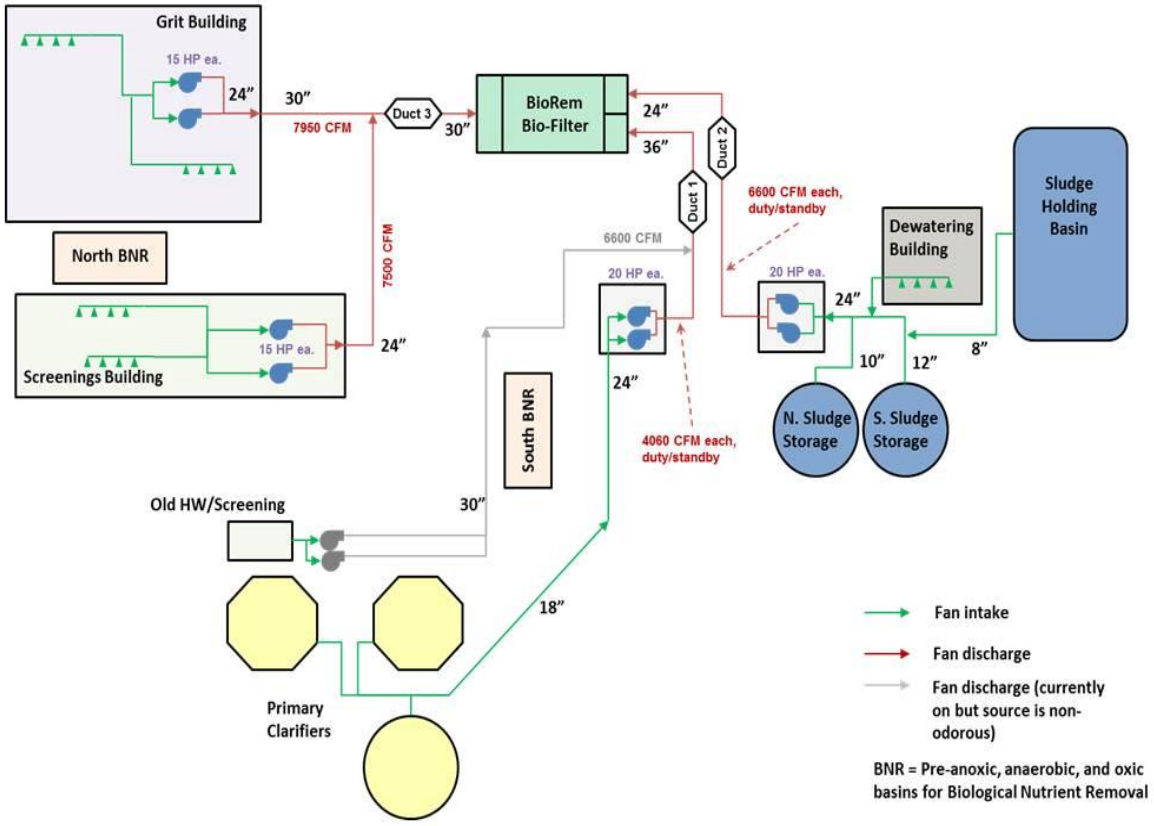

Figure 4: Odor Sources and Collection Points

BIOFILTER SYSTEM DESCRIPTION

The plant was designed for an ultimate capacity of 14.16 m^3/s, but sufficient media was added at the start to provide treatment for 10.4 m3/s at 22s EBRT. Media was added in 2008 to enable the system to operate at the design flow of 14.16 m^3/s at 25s EBRT. Table 1 presents initial and expansion design parameters for the biofilter. The concrete biofilter is approximately 18 m long by 11.6 m wide. An air plenum is provided on one side of the biofilter tank, where humidification is performed using plant water sprays. Humidified air enters the media bed through slats in the flooring, and discharged from the surface, which is open to atmosphere. The surface of the media is covered with a layer of wood chips for moisture absorption during rain events. A steam boiler is provided for direct steam injection into the air to raise temperature during the winter months.

Table 1: Design Parameters for Broomfield Biofilter

Process Parameter	**Value**	
	2003 Initial Design	**2008 Upgrade**
Duty:	Continuous	Continuous
Climate:	Outdoors	Outdoors
Total Air Flow Volume:	10.4 m^3/s	14.16 m^3/s
Type of Contaminant:	H_2S and Odors	H_2S and Odors
Average Inlet Conc.:	10 ppm H_2S	10 ppm H_2S
Maximum Inlet Conc.:	25 ppm H_2S	25 ppm H_2S
Removal Required:	>95% H_2S removal >90% Odor removal	>95% H_2S removal >90% Odor removal
Biofiltration Media	Biosorbens® Engineered Media	
Media Volume:	224.27 m^3	354.53 m^3
Media Depth:	1.07 m	1.58 m
Empty Bed Residence Time:	22 seconds	25 seconds

SYSTEM PERFORMANCE

The system was commissioned and media condition and microbial activity was monitored soon after start, which indicated that the biofilter was maturing as anticipated. A test program at the site (Brown and Caldwell, 2007) used Jerome for hydrogen sulfide measurement and Nasal Ranger for odor. Hydrogen sulfide concentration was in the range of 0-20 ppbv on the media surface. Odor values around the facility and at different plant boundaries show insignificant levels. This was despite the fact that smoke tests showed non-uniform air distribution in the biofilter.

The biofilter capacity was expanded after addition of media to a height of 1.58 m in 2008. A recent campaign in 2015 proved that removal of H2S and total odour remains high, although the flow rate was measured at 9.97 m^3/s versus design capacity of 14.16m^3/s. Results are shown in Table 2:

Table 2 – July 2015 Biofilter Test Results at the BWRF				
Sample Location	Air Flows (m^3/s)	H_2S Concentration Measurements (ppm)		Total Odor via Odor Panel Evaluation
		Maximum	Average	DT
Biofilter Inlet #1 (0.91 m)	4.12	4	1.52	3,100
Biofilter Inlet #2 (0.61 m)	3.17	1	0.05	2,400
Biofilter Inlet #3 (0.76 m)	2.68	3	0.84	3,900
Flow-Weighted Biofilter Inlet Values	9.97	2.8	0.87	3,092
Biofilter Outlet	9.97	<0.01	<0.01	100
Removal Efficiency (%)	N/A	>99%	>99%	97%

Long term performance for H_2S and odor removal is presented in Tables 3 and 4 respectively. These tables compare July 2015 data with results from July 2011 and 2014 and September 2010. The July 2015 data is consistent with results from prior studies and confirms that Biorem biofilter is still exceeding the specified performance standards for H_2S concentration and odor reduction.

Table 3 – Comparison of H_2S Concentration Measurements (ppm)				
Sample Location	Tetra Tech Test Results-July 2015	Tetra Tech Test Results-June 2014	Tetra Tech Test Results-July 2011	Webster Test Results-September 2010
Biofilter Inlet #1 (0.91 m)	< 0.01[1]	0.32	0.8	0.1
Biofilter Inlet #2 (0.61 m)	< 0.01[1]	0.15	16	22
Biofilter Inlet #3 (0.76 m)	< 0.01[1]	0.24	1.6	2.6
Flow-Weighted Biofilter Inlet Values	0.001	0.26	8.1	6.4
Biofilter Outlet	< 0.01	< 0.01	< 0.01	0.003
Removal Efficiency (%)	> 99%	> 99%	99.93%	99.97%

Notes: *Measurements were taken from the first minute of the 24-hour OdaLog testing within each biofilter inlet.*

Organic sulfur compounds, including methyl mercaptan, dimethyl sulfide, dimethyl disulfide, carbonyl sulfide and carbon disulfide were measured (Webster, 2010). At a total inlet concentration of 700 ppbv, none of these compounds was detected in the outlet. In 2015 tests, the previous performance was confirmed as only carbonyl sulfide and dimethyl sulfide were measured in the outlet at a concentration which was approximately 5 ppbv above the Method Detection Limit of 5 ppbv for both compounds.

OPERATIONAL EXPERIENCE

The biofilter has operated in a trouble free manner since start up. The biological process worked well even during winter months and steam use was discontinued without impact on odor removal. The system has dramatically improved odor environment in the vicinity of the plant. Only one odor complaint was received related to the wastewater treatment plant in 2014 and none in 2013. Similarly, one odor complaint relating to the plant was received in 2012. Note that the complaints did not appear to be related to biofilter but other operations at the plant.

Media Aging Experience

Biorem guarantees a ten year media life. Therefore, condition of the portion of Broomfield media installed in 2004 was of great interest. Samples were taken by Broomfield personnel at a

depth of 0.71m to arrive at the 2004 media zone. Figure 5 shows a picture of the media. The coating is visible and predominantly uniform. The fines content is low.
Important media properties were measured and results are as follows:

Table 4 – Comparison of Total Odor Reduction via Odor Panel Evaluation, Dilution to Threshold (DT)				
Sample Location	Tetra Tech Test Results-July 2015	Tetra Tech Test Results-June 2014	Tetra Tech Test Results-July 2011	Webster Test Results-September 2010
Biofilter Inlet #1 (0.91 m)	3,100	2,900	290	1,000
Biofilter Inlet #2 (0.61 m)	2,400	2,700	5,900	8,200
Biofilter Inlet #3 (0.76 m)	3,900	3,300	3,000	4,300
Flow-Weighted Biofilter Inlet Values	3092	2,935	2,992	4,643
Biofilter Outlet	100	110	200	130
Removal Efficiency (%)	97%	96%	93%	97%

Moisture content, dry media weight basis	29.4%
pH	7.91
Total Nitrogen, mg/Kg of media	8.6
Total Phosphorus, mg/Kg of media	0.5
Sulfate, mg/Kg of media	29.8
Particles <2 mm, media weight percent	7%

These characteristics are within Biorem's targets, except that ten years of irrigation has resulted in a relatively low nutrient content due to the leaching effect. Nevertheless, sufficient nutrient concentration remains to support microbial growth. The pH of 7.9 indicates excellent buffer capacity. This neutralizes sulfuric acid produced by oxidation of reduced sulfur compounds, and maintains optimum conditions for growth of heterotrophs essential for treatment of organic sulfur compounds. High coating integrity means excellent capability for retaining contaminants to make these available for biodegradation. The low fines content is surprising, given that the media is covered with a layer of wood chips, which tend to generate fines. The media continues to be well suited to support growth of both chemiautotrophic and heterotrophic microorganisms.

Figure 6 shows a micrograph of Biosorbens® media. Presence of a diverse and dense microbial population is visible. This diversity is primarily responsible for the high degree of removal of a wide variety of contaminants by engineered media.

Figure 5: A picture of the 2004 Biosorbens® media, sampled September 2015

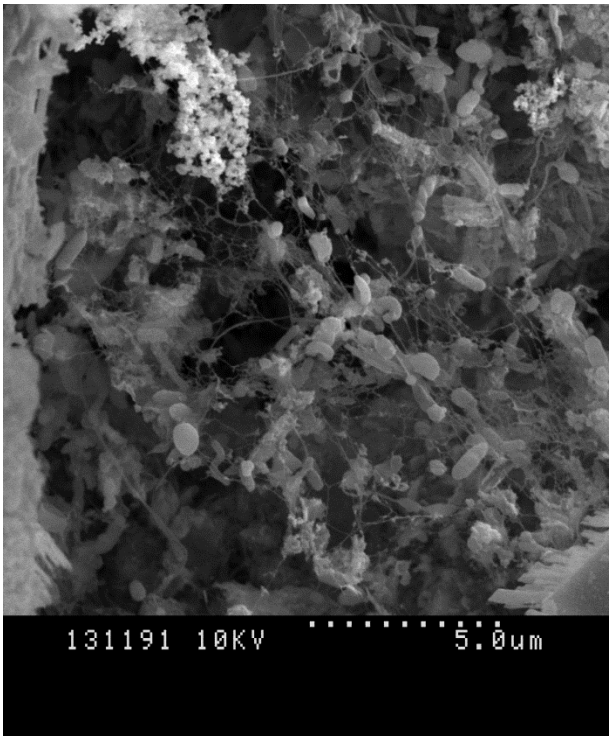

Figure 6: Microbial Growth on Biosorbens® Surface

Based on these investigations, we believe that the engineered media in the Broomfield biofilter would provide excellent performance for another ten years or more.

CONCLUSIONS

At Broomfield, replacement of organic media biofilter with an engineered media biofilter resulted in a dramatic improvement in performance and media life. Whereas the compost media exhibited channeling problems after only one year of operation with a drop in performance, the engineered media has maintained peak performance with negligible loss in quality. Excellent performance for another ten year is possible.

Experience at Broomfield proves that a properly built and operated engineered media biofilter will continue to exceed design performance on a consistent basis. A high quality engineered media such as Biosorbens® will remain viable well after its design life, resulting in significant additional cost savings compared with organic media biofilters.

REFERENCES

Brown and Caldwell, City of Broomfield BWRF, Odor Control Study Report, January 2007

Tetra Tech, City of Broomfield BWRF, Biofilter Performance Evaluation, 2011, 2014, 2015

Webster Environmental Associates, Inc., Broomfield BRF, Biofilter Performance Evaluation Report, October 2010