USING A 33,000-CFM LAVA ROCK BIOFILTER FOR ODOR CONTROL: FROM DESIGN TO FULL SCALE OPERATION

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ABSTRACT

The Manteca Wastewater Quality Control Facility (WQCF) is a 6.5-million gallons per day (mgd) rated activated sludge plant. The WQCF treats typical municipal wastewater generated in the City of Manteca, California and the neighboring City of Lathrop. The plant also receives seasonal discharges from a local food processor. Over the last few years, the Manteca WQCF underwent a $60-million expansion to increase its capacity from 6.5 to 9.87 mgd. Part of this expansion included the construction of a new influent pump station with two mechanical screens, and a new dewatering building with two centrifugal dewatering systems. Because housing developments within the City of Manteca are encroaching upon the plant, and a new regional softball complex was constructed nearby, an odor control system needed to be designed and built during the plant expansion to ensure that potential odor complaints from neighbors would be minimized. Foul air from the influent pump station and the dewatering building is conveyed through large ducts into a new open bed lava rock-based biofilter near the influent pump station. The biofilter is composed of five beds, including one used as standby. The four duty beds were designed to treat 33,000 cubic feet per minute of foul air. Approximately 2,100 cubic yards of lava rock were needed for the biofilter. To the authors' knowledge, this open bed lava rock biofilter is the first and largest full scale biofilter of this type in the nation.

KEYWORDS

Biofilter, biofiltration, odor control, lava rock, biotrickling filter, wastewater treatment plant, hydrogen sulfide, sustainability.

BACKGROUND

The Manteca Wastewater Quality Control Facility (WQCF), located in Manteca (California), is a 6.5-million gallons per day (mgd) rated activated sludge plant. The WQCF treats typical municipal wastewater generated in the City of Manteca and the neighboring City of Lathrop. The plant also receives seasonal discharges from a local food processor. The Manteca WQCF underwent a $60-million expansion in 2002-2004 to increase its capacity from 6.5 to 9.87 mgd. Part of this expansion consisted of constructing a new influent pump station with two mechanical screens and a new dewatering building with two centrifugal dewatering systems. Because housing developments within the City of Manteca are encroaching upon the plant, and a new regional softball complex was constructed nearby, an odor control system needed to be designed and built during the plant expansion to ensure that potential odor complaints from neighbors would be minimized. Previously, odors were treated at the influent pump station by the addition of ferric chloride to remove hydrogen sulfide. The biofilter will treat foul air generated at the influent pump station and the sludge dewatering facility, and thus, improve and increase reliability of odor removal performance at the plant.

This paper focuses on the design, construction, including challenges and issues, operation, and maintenance of the odor control biofilter at the Manteca WQCF.

DESIGN PHASE

A discussion of the odor control technology selection process and subsequent design features is provided below.

Use of Biofilters for Odor Control

Biofiltration is the process of utilizing microorganisms in a moist porous material through which air is passed to biodegrade objectionable constituents in the air to carbon dioxide and water. Biofiltration is not only more cost effective, but also more environmentally sustainable compared to traditional technologies such as chemical scrubbing. For these reasons, biofiltration has become increasingly present in wastewater treatment plants. Biofilters can degrade hydrogen sulfide and organic sulfides, amines and ammonia, and a large range of volatile organic compounds. The contaminants are removed and treated by two processes: adsorption of gaseous constituents and biodegradation by microorganisms. The primary byproducts of biofilter reactions are water, carbon dioxide, salts, and acids. No soil or groundwater pollution occurs as a result of biofiltration when a liner is installed at the bottom of the biofilters.

Odor Control Selection

Biofiltration was chosen for odor control at the Manteca WQCF for its ease of operation, maintenance, lack of chemical requirements, simple appearance, and low capital and O&M costs. Early in the project, an odor control study compared biofiltration to more conventional odor control technologies such as air scrubbers. The conclusions from the study indicated that biofiltration was the most cost-effective odor control technology provided land and footprint were not limited.

Source of Foul Air

It was determined that the air from the new influent pump station (both the dry well and wet well) and from the future dewatering building were most responsible for odor issues at the plant. The wet well is where all the raw sewage from the sewer collection system ends and therefore is the location where the greatest number of odor issues are expected. Hydrogen sulfide and mercaptans are the main odorous compounds detected near raw sewage. The dry well was expected to contain some odors, but not to the same order of magnitude as the wet well. The dewatering building is where all the digested sludge will be dewatered by mechanical centrifuges, before being discharged onto a belt conveyor. The digested sludge, sludge cake, and centrate from the centrifuge will all generate odors. The future dewatering building will be located near the influent pump station. The proximity of these two buildings and the proximity of available land facilitated the selection of a location for the biofilter, thus reducing the length of necessary air ducting and associated energy requirements.

Design of the Biofilter

Key components in the biofilter design are presented as follows.

Design Air Flow

The biofilter was designed to treat air from the pump station dry well, wet well, and from the dewatering building. The number of air changes per hour was selected based on the National Fire Protection Association (NFPA) "NFPA 820: Standard for Fire Protection in Wastewater Treatment and Collection Facilities" manual. The number of air changes per hour was selected as 12 for the wet well, and 6 for the dry well and dewatering building. Because the volume of the wet well, dry well, and dewatering building were approximately 43,200, 129,600, and 115,000 cubic-feet (cf) respectively, the air flow from each area was 8,600, 13,000, and 11,500 cubic-feet per min (cfm), for a total of 33,100 cfm. Air from the pump station dry well was not expected to be odorous because the physical separation from the wet well and thus the raw wastewater. However, foul air could still move from the wet well to the dry well through a door left open, and the City did not want to take any risk of odor complaint from neighbors. It was therefore decided to treat all the air from the pump station. The incremental construction and O&M costs were relatively small compared to that of the pump station, and were deemed acceptable and worth the investment.

Loading Rate and Empty-Bed Residence Time

According to the literature, typical biofilter loading rates range from 2 to 8 cfm/ft^2. A loading rate of 3 cfm per square-foot of biofilter was selected for the Manteca application. The biofilter bed area was then calculated using the total air flowrate to be treated and the loading rate. The filter bed media depth was chosen to obtain a 100-second empty bed residence time in the media. This residence time was chosen to be higher than those reported in the literature for other types of media, because of the inorganic nature of lava rock.

The principal design criteria for the biofilter are summarized in Table 1.

Table 1 - Biofilter Design Criteria

Parameter	Unit	Value
Dewatering building air volume	cf	115,000
Air flow from dewatering building assuming 6 volume changes per hour	cfm	11,500
Influent pump station air volume	cf	172,800
Air flow from influent pump station assuming 6 volume changes for the dry well and 12 volume changes for the wet well	cfm	21,600
Total air flow	cfm	33,100
Loading rate	cfm/ft^2	3.0
Minimum media area	ft^2	11,030
Actual media area[a]	ft^2	13,800
Empty-bed residence time	sec	100
Media depth (lava rock)	ft	4.0
Number of beds	-	5
Bed width[b]	ft	36
Bed length[b]	ft	80

[a] Four out of five bays assumed to be operating.

[b] Based on available land surface.

Media Selection

The biofilter media provides attachment surfaces and sometimes nutrients for the microbial population. The biofilter media must be highly porous and have high water retention capabilities. Composted organic material and wood chips were not chosen because of the short lifetime of such media: both tend to degrade over time and produce fines, which can clog the biofilter. Such organic media usually need to be replaced every 2-5 years. After considering alternatives such as soil and mixed media, lava rock was selected. Lava rock is a porous volcanic rock often used in landscaping. The selection was based considering lava rock's high porosity, light weight (bulk density of 0.83), relatively high water retention capability with a lifetime longer than organic media. The biofilter media was designed as a 4-foot layer of lava rock. At the time of the design, lava rock had been successfully used as a biofilter media, but only in bench scale and pilot scale applications.

Biofilter System Components

The designed biofilter system includes an air blower, in-line spray humidifier, air distribution system (liner, gravel, and perforated pipe), biofilter media, media containment structure, sprinkler system, and drainage collection system. A description of the biofilter beds configuration and equipment components is provided below.

Biofilter Beds Configuration

The overall shape of the biofilter was based on the required surface area, and the available land. The biofilter was divided into five parallel beds, under the assumption that four out of the five beds will be in operation at any time (redundancy is required for downtime and microbial acclimation periods). For biofilter containment, 10-inch thick corrosion-resistant reinforced concrete walls were used. The bottom of the biofilter is at a depth of 5 feet below ground level, which is above the maximum groundwater level in the area. The top of the biofilter walls are approximately 2 feet above ground level.

Humidifier

To prevent media dry-out and subsequent biofilter failure, water needs to be added to the media on a regular basis. A dry media would make the odor-removal performance of the biofilter decrease due to the reduced viability of the microbial population. Two means of water addition were chosen for the design: sprinklers for surface irrigation to prevent surface dry-out, and an in-line spray humidification system within the air duct to prevent internal dry-out. The sprinkler system was designed for a uniform water distribution on the biofilter surface with automatic operation. In-line spray humidification was used to saturate the foul air within the air conveyance manifold shortly before the air enters the biofilter. The in-line humidification system was installed immediately downstream of the blower (see Figure 1). Although the biofilter media must remain moist, it should not become saturated. Saturation creates malodorous anaerobic zones and increases blower back pressure. If too much moisture is applied to the biofilter, nutrient wash-out may also occur. The biofilter media is most stable when a net excess of water is applied; therefore, drainage water is likely to be generated. Collection of drainage was included in the design. The biofilter drainage water is collected in a 6-inch diameter corrugated perforated HDPE pipe and routed to the plant headworks. Both the water used for irrigation and the water used for in-line humidification are tertiary filtered effluent. Being treated effluent, the water contains nutrients (nitrates, ammonia, and phosphates) necessary for biological growth in the biofilter media.

Figure 1 – Blower and In-line Humidification System

Air Distribution System

Foul air, after being humidified, is conveyed to the biofilter media in corrosion-resistant HDPE pipes. Pipes within the biofilter are laid in 2 feet of washed/screened ¾-inch gravel. The bottom of the biofilter has a

1.3% slope to allow gravity drainage of applied water and collection of drainage. A reinforced polypropylene liner is used to prevent groundwater contamination. A 3-inch layer of pea gravel over the liner protects the liner from potential punctures. Air distribution pipes are 10-inch in diameter spaced 44 inches apart, with 5/8-inch holes every 4 inches. The air distribution system was designed to ensure uniform application of the foul air to the biofilter media. Over 3000 ft of pipe ranging from 10-inch diameter to 48-inch diameter were used for the air distribution system. Pipe sizes were selected based on a maximum air velocity of 2800 feet per minute.

CONSTRUCTION PHASE

Most of the biofilter construction went as planned. However, a few challenges were met with regards to lava rock supply, installation of lava rock in the biofilter, and the cracking of concrete coating. Each is discussed below.

Lava Rock Supply

A total of approximately 2,100 cubic yards of lava rock was needed for the biofilter. Characteristics of the desired lava rock were listed in the contract technical specifications. The lava rock was specified as red lava rock, with a minimum porosity of 50%, and a rock-size of ¾- inch. Out of the three potential California-based suppliers listed in the specifications, none was able to deliver the necessary quantity of specified lava rock for the project. The other suppliers were located out-of-state and thus considered too expensive to use. The contractor was then allowed to use ½-inch lava rock (See Table 2 and Figure 2). In addition, the porosity and solubility tests requirements were waived.

Table 2 – Lava Rock Size Distribution

US Standard Sieve Size	Percent by Weight Passing	
	Specified	Accepted
1-inch	100	99
3/4-inch	15-30	78
1/2-inch	5-15	24
3/8-inch	0-10	7
No.4	0-5	4

Figure 2 – Detail of the Lava Rock

Lava Rock Installation

To prevent breakage of the lava rock and damage to the air distribution system in the biofilter, no heavy mechanical equipment could be used during the installation of the lava rock. To install the lava rock safely, a directional mobile belt conveyor was used (see Figure 3). The mobile conveyor was moved so that lava rock was discharged uniformly throughout the biofilter. Doing so was critical to prevent rock breakage and subsequent clogging of the biofilter by lava rock fragment and fines.

Figure 3 – Lava Rock being installed using a belt conveyor

Concrete Coating Cracks

To protect the biofilter concrete walls from degradation by acids generated in the biofilter media, all the interior walls were treated with a vinyl ester coating. The coating was applied after the required concrete curing period. Despite this, cracks began appearing shortly after the coating was applied (See Figure 4). It appeared that the coating cracks were due to the cracking of the concrete underneath. The coating specified may have been too brittle and unable to "bridge" cracks or preparation of the concrete surface may have been incomplete. The crack repairs involved patching with vinyl ester coating, and filling with polysulfide caulking. No further cracking was detected after the repairs.

Figure 4 – Coating cracks

Smoke Testing

During construction of the biofilter, two smoke tests were conducted to confirm uniformity of air distribution. The first smoke test was conducted upon completion of the air distribution system, before the pipes were covered with gravel and lava rock (see Figure 5). The second smoke test was performed after the distribution pipes were covered with 2 feet of gravel. Both tests were successful and demonstrated a uniform air distribution within each biofilter bed.

Figure 5 – First Smoke Test in a Biofilter Bed

OPERATION AND MAINTENANCE

One of the principal advantages of biofiltration for odor control is the low maintenance and operation requirements.

In terms of operation, the only inputs to the system are foul air and water. Air is continually conveyed from the influent pump station to the biofilter by a large blower. The surface sprinkler system is automatically set to operate a given amount of time each day while the in-line humidification is operating continuously when the air blower is on.

In terms of maintenance, weed control is the only task performed by the plant staff. Regular weed control is needed for two reasons: 1) Weeds can prevent air from circulating freely through the biofilter media, and 2) roots can generate cracks in the media, thus leading to short-circuiting, i.e. foul air flowing through the media without being treated. When the biofilter began operation in 2004, the plant staff was unaware that weed control was needed. Vegetation started growing on the biofilter surface very rapidly (see Figure 6) until weed control was implemented. At this time, weed control involves spraying the biofilter surface with a common herbicide. The spraying is accomplished on an as-needed basis, when vegetation appears on the biofilter. Over the last three years, application of herbicide has only been needed on a quarterly basis.

Figure 6 – Vegetation Growing on top of the Biofilter in 2004

BIOFILTER PERFORMANCE.

The biofilter has been in operation since the end of 2004. According to the plant chief operator, no odor can be detected on top of the biofilter. No air sampling analysis was ever deemed necessary by the plant as the biofilter seems to be operating properly. It should be noted that the current foul air sent to the biofilter only originates from the influent pump station and therefore the biofilter has been exposed to a lower loading rate. The loading rate will increase when the dewatering building is constructed and brought on-line. The plant staff is considering implementing changes to the air flow configuration from the dry well and wet well in the influent pump station. Despite 12 air changes per hour, air in the wet well remains still very odorous and corrosive while air in the dry well is most of the time odorless. The change would consist of increasing the number of air changes per hour in the wet well and decreasing that of the dry well. This change would lead to an increase in hydrogen sulfide load to the biofilter. The plant staff will be experimenting with air flow changes and their impact on biofilter performance, and air quality improvements in the wet well.

CONCLUSION

A 33,000-cfm lava rock biofilter was constructed to treat foul air from the new influent pump station and future dewatering building at the Manteca WQCF. Biofiltration was chosen because the technology is a sustainable process that requires no chemicals, and converts foul odors into water and carbon dioxide. The biofilter was constructed in 2004 and has been in operation since. Other than quarterly spraying of herbicide, maintenance requirements for the biofilter are largely non-inexistent. The biofilter is operating successfully and no odors can be detected according to plant staff. In late 2008, the new dewatering building will be constructed and brought on-line. The air flow to the biofilter will then reach the design air flow of 33,000 cfm, and no changes in performance are expected.