MULTI-STAGE ODOR CONTROL ALTERNATIVES FOR A REGIONAL WATER RECLAMATION FACILITY IN LAS VEGAS

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ABSTRACT

The Central Plant of the Clark County Water Reclamation District (District), with a current capacity of 110 million gallons per day (mgd), provides wastewater collection, treatment, and reclamation services to unincorporated areas of Clark County, Nevada. Driven by unrestrained development in the Las Vegas Valley, the District has ongoing projects to expand the capacity of the Central Plant by approximately 50 percent in the next two decades. The unrestrained development in the service area is evident within feet of the Central Plant fenceline as land immediately to the North, previously a golf course, has been re-zoned for residential development. Hundreds of houses have been constructed or are under construction within sight of the plant. As the hydraulic loading to the plant increases, the organic and biological loading will also increase along with the concentration of odorous compounds released from the various plant processes.

Air emissions and dispersion modeling was performed as part of a Facility Master Plan (FMP) to help in the development of air quality management strategies for the expanded facilities at the Central Plant. Modeling used hydrogen sulfide (H_2S) as a surrogate for total odors. The master plan identified the following H_2S sources, among others, as potential contributors to offsite odor nuisance: Biofilter No. 1 (Inlet Berm Box Biofilter), Biofilter No. 8 (Primary Clarifier Nos. 1-10 Biofilter), and Biofilter No. 7 (Headworks Biofilter). All three in-ground organic biofilters are located adjacent to the north plant fenceline. While the three biofilters effectively remove H_2S, exhibiting typical efficiencies of over 99%, increasing H_2S loads at the biofilter inlets are expected to result in shorter media lives, increased outlet H_2S concentrations, and possible odor nuisances to the new neighbors at the North.

Based on the above findings, as well as an investigation of odor control practices employed by other leading municipal utilities in the United States, the District decided to adopt a multi-barrier, proactive approach to ensure continued compliance with the nuisance prohibition provisions of the Clark County Air Quality Regulations (AQRs) and maintain long-term good-neighbor relations with the surrounding community. As a result, the District retained Carollo to conduct a detailed evaluation of alternative odor control improvements for Biofilter Nos. 1, 8, and 7. Alternatives involve the use of various odor control technologies, including foul air stream humidification, modular biofiltration, biotrickling filtration, carbon adsorption, and chemical scrubbing to enhance or replace the existing Biofilter Nos. 1, 8, and 7. Evaluation of alternatives is based on a decision matrix utilizing weight and rank factors for each evaluation criterion. Evaluation criteria include design H_2S and total odor removal efficiency, technology reliability, operational flexibility, automation, maintenance requirements, use of hazardous chemicals, capital and O&M costs, space requirements, site aesthetics, and sustainability. The objective of this paper is to present the findings of the detailed evaluation and describe a phased implementation of the recommended alternatives.

KEYWORKS

Wastewater treatment, odor, hydrogen sulfide, biofilter, activated carbon, chemical scrubber.

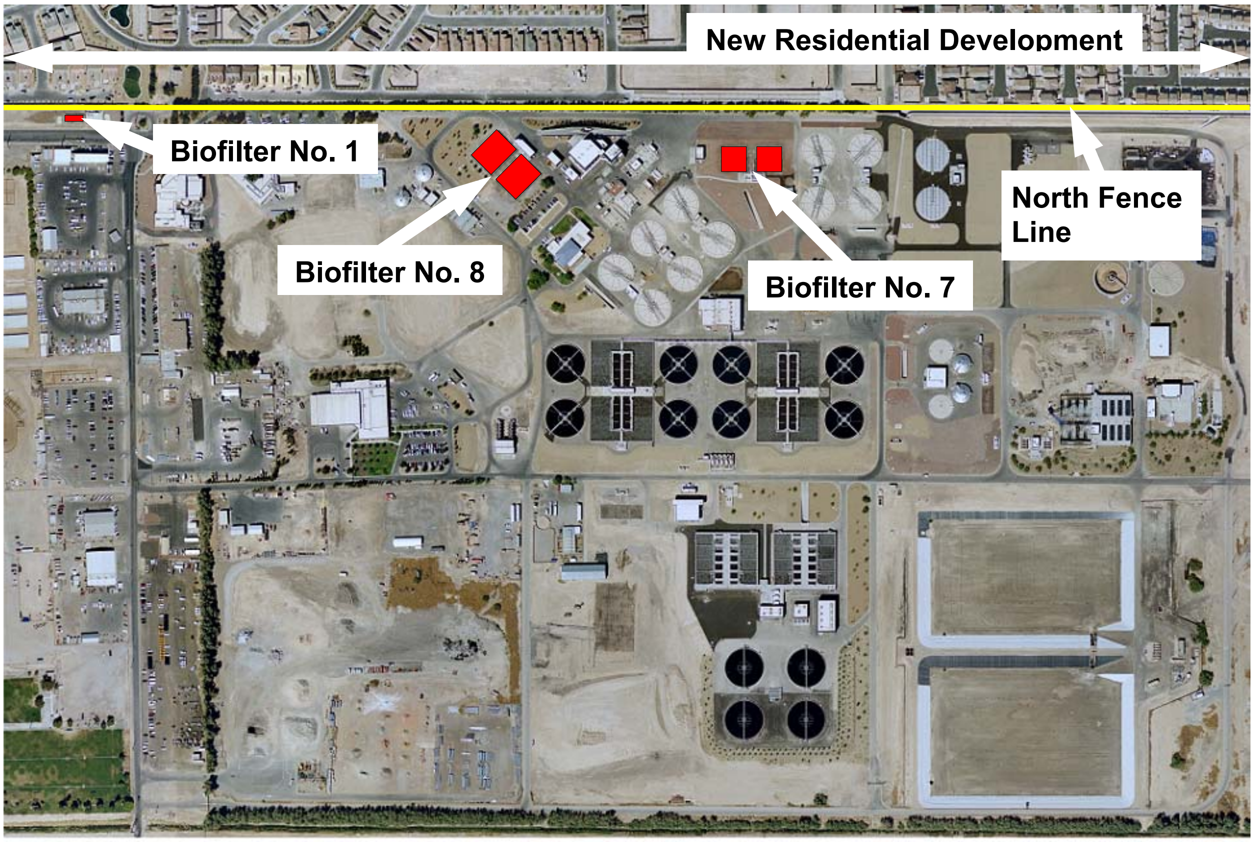
INTRODUCTION

Offensive odors associated with domestic wastewater are primarily due to H_2S, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. Because analytical quantification of all odor constituents is not practical, odor concentration is often reported in terms of the dilution-to-threshold ratio (D/T). D/T is defined as the volumes of clean air that must be mixed with one volume of the odorous air to produce a mixture with non-detectable odor. Although H_2S is not the only odorant of concern in wastewater systems, it is usually the most prevalent at plant headworks and primary treatment facilities and is a reliable surrogate for the odors emitted from these facilities. Therefore, H_2S is often identified as the highest priority target compound for removal in the odor control process.

The reported odor threshold for hydrogen sulfide is low, varying from 0.5 to 10 ppbv. The Air Quality Regulations (AQRs) of Clark County, which has jurisdiction of air quality programs in the Las Vegas Valley, prohibits nuisance conditions due to the release of air contaminants (Clark County AQRs, 2007). The AQRs define “nuisance” as “anything that is injurious to health, offensive to the senses, or an obstruction to the free use of property, so as to interfere with the reasonable or comfortable enjoyment of life or property.” The AQRs do not establish a numerical nuisance level for H_2S. However, the World Health Organization (WHO, 1981) has established a nuisance threshold level of 5 ppb for H_2S odors with a 30-minute averaging time. This is the target value that is used in this evaluation.

The Central Plant (Plant) of the Clark County Water Reclamation District (District) currently uses organic media in-ground biofilters to control odors emitted by influent structures, headworks, primary treatment structures, junction boxes, and solids handling facilities. Air emissions and dispersion modeling performed as part of the FMP identified the following H_2S sources as potential contributors to offsite odor nuisance: Biofilter No. 1 (Inlet Berm Box Biofilter), Biofilter No. 8 (Primary Clarifier Nos. 1-10 Biofilter), and Biofilter No. 7 (Headworks Biofilter). All three in-ground organic biofilters are located adjacent to the north plant fenceline. While the three biofilters effectively remove H_2S, exhibiting typical efficiencies of over 99%, increasing H_2S loads at the biofilter inlets are expected to result in increased outlet H_2S concentrations and frequent odor nuisances to the new coming residents at the North. Biofilter Nos. 1, 8, and 7 are shown in Figure 1. Other issues of concern include: (1) the biofilters are susceptible to peak inlet concentrations and media deterioration; (2) the high H_2S removal efficiencies observed are not likely representative of efficiencies for more recalcitrant odorants, including dimethyl sulfide and dimethyl disulfide.

Figure 1 - Biofilters of Concern in the Central Plant



The District decided to adopt a proactive approach to ensure continued compliance with regulatory nuisance provisions and maintain good long-term relations with the surrounding community. As a result, the District retained Carollo to conduct a detailed evaluation of alternative odor control improvements for Biofilter Nos. 1, 8, and 7. The evaluation considered a variety of odor control technologies in series to reduce H_2S and total odor concentrations to acceptable levels and minimize odor nuisances at the North fence line. This report provides a summary of the evaluation.

Existing Berm Box Odor Control System

The Berm Box (also known as the Flow Splitting Structure) is located at the northwest corner of the Central Plant. The Berm Box consists of an interceptor junction structure that controls the hydraulic grade line of wastewater entering the plant. Foul air is pumped from the enclosed Berm Box structure and incoming interceptor headspaces at a rate of 3,000 cubic feet per minute (cfm), and vented to organic-media Biofilter No. 1. Based on previous sampling and emission modeling, the estimated mean/peak H_2S concentration in the Biofilter No. 1 inlet is 40/65 ppm, while the estimated inlet mean/peak odor concentration is 6,250 and 7,600 D/T. AQR allows a

95 percent credit for removal across the biofilter, so H_2S concentrations in excess of 2 ppm could occur on a regular basis. Residential development is underway adjacent to Biofilter No. 1, clearly indicating a potential for nuisance odors. 1.

Existing Primary Clarifier Nos. 1-10 Odor Control System

Approximately 62,700 cfm of foul air is collected from Primary Clarifier Nos. 1-10 and associated ancillary structures. Foul air is treated by an organic media biofilter (Biofilter No. 8) and released to the atmosphere. Biofilter No. 8 also receives foul air from Aerated Grit Basin Nos. 1-4. Based on previous sampling and emission modeling, the estimated mean/peak H_2S concentration in the Biofilter No. 8 inlet is 20/30 ppm, while the estimated inlet mean/peak odor concentration is 6,600 and 12,000 D/T. If 95 percent removal is achieved through the biofilter, H_2S concentrations in excess of 0.8 ppm could occur on a regular basis. Residential development is underway approximately 200 feet from the existing Biofilter No. 8, clearly indicating a potential for nuisance odors

Existing Headworks Odor Control System

Approximately 82,700 cfm is exhausted from headworks structures, including the bar screens, Aerated Grit Basin Nos. 5 and 6, and the Grit/Screenings Building. Foul air is treated by an organic media biofilter (Biofilter No. 7) and released to the atmosphere. Biofilter No. 7 will also receive foul air from the new Aerated Grit Basin Nos. 7 and 8, which will contribute to increased odorant loads to the biofilter. Based on previous sampling and emission modeling, the estimated mean/peak H_2S concentration in the Biofilter No. 7 inlet is 5/10 ppm, while the estimated inlet mean/peak odor concentration is 4,100 and 5,600 D/T. If 95 percent removal is achieved through the biofilter, H_2S concentrations in excess of 0.1 ppm could occur on a regular basis, indicating a potential for nuisance odors.

METHODOLOGY

Applicable Odor Control Technologies

The following odor control technologies were considered in the development of odor control alternatives. Each type of technology offers benefits depending on the type of odors in the foul air and the level of odor removal required. Often, these technologies are combined to leverage the strengths of each technology and provide a multi-stage odor control system.

Traditional In-Ground Biofilters

In-ground, open-top biofiltration is the technology currently used at the Central Plant. Foul air passes through a 3 to 5 ft thick media before it is released to the atmosphere at the top of the media. Typically, a loading rate of 2-4 cfm/sf is used, resulting in an empty bed residence time (EBRT) of 60 to 90 seconds through the organic media.

Due to the long retention times, biofilters can sorb and degrade a range of odorous compounds including H_2S, other reduced sulfur compounds, ammonia, amines, VOCs, and fatty acids.

Biofilters are best suited for the removal of low to moderate H_2S loadings (15 ppmv or less). Higher inlet H_2S concentrations can lead to overgrowth of H_2S oxidizing bacteria, media acidification, and clogging. Other considerations associated with traditional biofilters are: (1) biofilters have the largest footprint per cfm of air compared to any odor control technology; (2) biofilters emit a musty, earthy odor, which may be detectable; (3) the organic media requires replacement every 3-5 years; (4) open-top biofilters are susceptible to extreme weather conditions, e.g., high and low temperatures, precipitation, etc, and (5) large in-ground biofilters are typically used as single-stage odor control systems.

Maintaining adequate moisture in an open-top biofilter media is critical, especially in the dry and hot Las Vegas weather. The duct spray atomizers and surface sprinklers used in the existing biofilters do not provide consistent moisture and are prone to scaling. Installation of packed-bed humidification towers upstream of existing biofilters was considered in this evaluation as a method to improve the biofilter performance. Covering the biofilters to maintain moisture was also considered. Covering the biofilters and collection of the outlet air also allows the use of biofilters in multistage odor control systems.

Deep Bed Biofilters

Deep bed biofilters utilize the same treatment process as traditional in-ground biofilters, except they feature media bed depths of up to 18 feet. The deep media bed allows for significantly reduced surface area compared to traditional in-ground organic media biofilters. The systems can be open top, or covered. Common media include lava rock, engineered media, and natural organic media. Deep bed biofilters can also contain more than one media layer in the same unit for enhanced odor control performance.

Modular Biofilters

Modular biofilters typically include humidification, inlet fans, duct connections, and media, all in one package. Modular biofilters are available from numerous vendors, including US Filter, Biorem, and Shaw Environmental. Typical modular biofilters can receive up to 4,000 cfm of foul air at an EBRT of 10-20 seconds. Modular biofilter performance is comparable to that of organic biofilter performance; however, lower EBRTs in modular biofilters limit the removal of complex odorants.

Biotrickling Filters

In biotrickling filters, foul air passes through an inert medium (e.g., polypropylene, polyurethane, lava rock, etc.) that supports attached microbial growth. A recirculating solution (secondary effluent or a proprietary nutrient solution) trickles through the medium facilitating pollutant absorption from the gas phase, providing moisture and nutrients to the biofilm, regulating the pH, and removing waste products. Typical components of a biotrickling filter include an FRP tower with media bed(s) and spray nozzles, a recirculation pump, and a pH meter. Many manufacturers guarantee a media life of 10 years. Manufacturers with a proven record of successful biotrickling filter installations include Bioway and US Filter.

The optimum H_2S inlet range for a biotrickling filter is 5 to 400 ppmv with typical EBRTs of 10 - 20 seconds, or about 20% to 30% of the retention time of in-ground biofilters. The combination of low pH and low air retention times observed in a biotrickling filter limit the removal of more complex odorants in biotrickling filters. Compared to biofilters, biotrickling biofilters are equally efficient in removing H_2S, but not as efficient in removing total odor. Biotrickling filtration is an excellent choice as a roughing stage upstream of biofiltration or carbon adsorption, as it can extend the life of the biofilter or carbon media, regulate peak inlet concentrations, and provide moisture to the biofilter.

Carbon Adsorption Odor Control Systems

In carbon adsorption, foul air passes through a bed of activated carbon where pollutants are removed by surface adhesion. Activated carbon has the ability to adsorb a variety of odorants including H_2S, other reduced sulfur compounds, amines, volatile organic compounds (VOCs), and fatty acids. The advantages of activated carbon for odor control include high efficiencies, small footprints, and simplicity of operation. The main disadvantage is high costs associated with the regular regeneration or replacement of the carbon media.

Three main categories of activated carbon-based media are currently available for odor control: virgin carbons, chemically-impregnated carbons, and catalytic carbons. Virgin carbons have low capacity for H_2S and high capacity for larger hydrophobic molecules, e.g., VOCs. However, when hydrogen sulfide, mercaptans, and other small molecules are removed prior to carbon adsorption, virgin activated carbon provides an effective and cheaper alternative compared to impregnated and catalytic carbons.

Pelletized virgin activated carbon is the recommended type of carbon media in this evaluation. This media exhibits a capacity for residual H_2S of approximately 0.04 g H_2S/g carbon. The carbon adsorbers in this study are designed for a superficial air velocity of approximately 60 feet per minute (fpm) and an empty bed residence time of approximately 3 seconds.
Because moisture in the foul air competes with odorants for sorptive surface on a virgin activated carbon, this evaluation considered polypropylene and stainless steel pad mist eliminators upstream of carbon adsorbers.

Chemical Odor Control Systems

Chemical scrubbers utilize pH-controlled absorption and chemical oxidation to remove odorants from foul air. In a packed-bed chemical scrubber foul air passes through a bed of plastic media, where it contacts the scrubbing solution. The scrubbing solution is collected and recirculated through the media. The most common scrubbing solution for H_2S removal contains sodium hydroxide (caustic) and sodium hypochlorite (bleach). Fresh chemical is automatically added by metering pumps controlled by pH and ORP probes to meet fluctuations in the inlet H_2S loading rates. One-stage packed-bed scrubbers are effective in removing H_2S but not as effective in removing more complex odorants.

Despite its effectiveness, chemical scrubbing poses a number of challenges related to operational complexity and use of hazardous chemicals. This study evaluated use of chemical scrubbers at the Primary Clarifier Nos. 1-10 and Headworks odor control systems. Chemical scrubbing was not considered for the Berm Box odor control system. The design EBRT for the one-stage chemical scrubbers was approximately 1.0 second, while the design pressure drop across a packed tower was 4.0 inches WC.

Methodology of Alternatives Evaluation

Specific alternatives were developed for each odor control system (i.e., Berm Box, Primary Clarifier Nos. 1-10, and Headworks). Evaluation of alternatives utilized a decision matrix. Selection criteria for this project included the following:

- H_2S removal efficiency: What percent of the inlet H_2S would be removed overall?
- Total odor removal efficiency: What percent of the inlet D/T would be removed overall?
- Reliability: Would the process/equipment consistently meet or exceed requirements?
- Operational flexibility: How easy could the operation of the equipment be changed to meet changing load conditions?
- Space requirements: How much area would be required?
- Automation: How much automation would be required?
- Process monitoring: How much monitoring would be required?
- Capital cost: How much would the equipment cost?
- Operational cost: How much would equipment operation cost annually?
- Operator attention: How much time would the operator spend to keep the process/equipment work properly?
- Maintenance attention: How much maintenance would be required?
- Site aesthetics: How aesthetically pleasing would the finished structures and equipment be?
- Constructability: Would the process equipment be difficult to install?
- Media replacement: What would be the requirements for media replacement?

A 3-step weighting/ranking process was implemented as follows:

- Step 1: Each criterion was assigned a “Weight” factor between 1 and 5 relative to the specific component being evaluated, where “5” is considered very important and “1” is considered not very important.
- Step 2: Each criterion was given a “Rank” factor between 1 and 5 relative to the specific component being evaluated, where “5” is considered best (i.e., cheapest, easiest, etc.) and “1” is considered worst.
- Step 3: An overall process evaluation matrix was developed, where the individual “Weight” and “Rank” factors were multiplied, and total points determined for each process and/or equipment component being evaluated.

Alternative recommendations were based on the highest total score.

RESULTS

Berm Box Odor Control Alternatives

Four alternatives were developed for odor control improvements at the Berm Box. Alternatives comprised combinations of biofiltration and carbon adsorption only. Chemical scrubbing was not considered due to the risk associated with handling chemicals outside the plant boundary. All alternatives included fan enclosure for sound noise attenuation. The four alternatives are summarized below. A schematic of the alternatives is presented in Figure 2.

Alternative 1: Organic Media Biofiltration - Carbon Adsorption

This alternative would involve covering Biofilter No. 1 with a flat aluminum cover and installing two 4,000 cfm carbon adsorbers (one standby) downstream of the covered biofilter. The proposed design included a fan and mist eliminator per carbon adsorber.

Alternative 2: Engineered Media Biofiltration - Carbon Adsorption

This alternative would involve replacement of the organic media of Biofilter No. 1 with an engineered media, covering the biofilter, and installing two - 4,000 cfm carbon adsorbers (one standby) downstream of the covered biofilter. The proposed design included a fan and mist eliminator per carbon adsorber.

Alternative 3: Modular Biofiltration - Carbon Adsorption

This alternative would involve replacement of the existing biofilter with two - 4,000 cfm modular biofilters (one standby) containing engineered media and installation of two - 4,000 cfm carbon adsorbers (one standby) downstream of the modular biofilters. The proposed design included a fan and mist eliminator per carbon adsorber.

Alternative 4: Dual-Media Modular Biofiltration - Carbon Adsorption

This alternative would involve replacement of the existing biofilter with a dual-media modular biofilter containing organic media on top of a lava rock layer, and installation of two 4,000 cfm carbon adsorbers (one standby) downstream of the modular biofilters. The proposed design included a fan and mist eliminator per carbon adsorber.

Anticipated Performance for the Berm Box Odor Control Alternatives

A summary of anticipated odor control alternatives for the Berm Box is provided in Table 1. Based on the table, Alternative 4 would result in the lowest outlet H_2S concentrations, while Alternative 2 would result in the lowest outlet total odor concentrations.

Figure 2 - Schematic of Berm Box Odor Control Alternatives

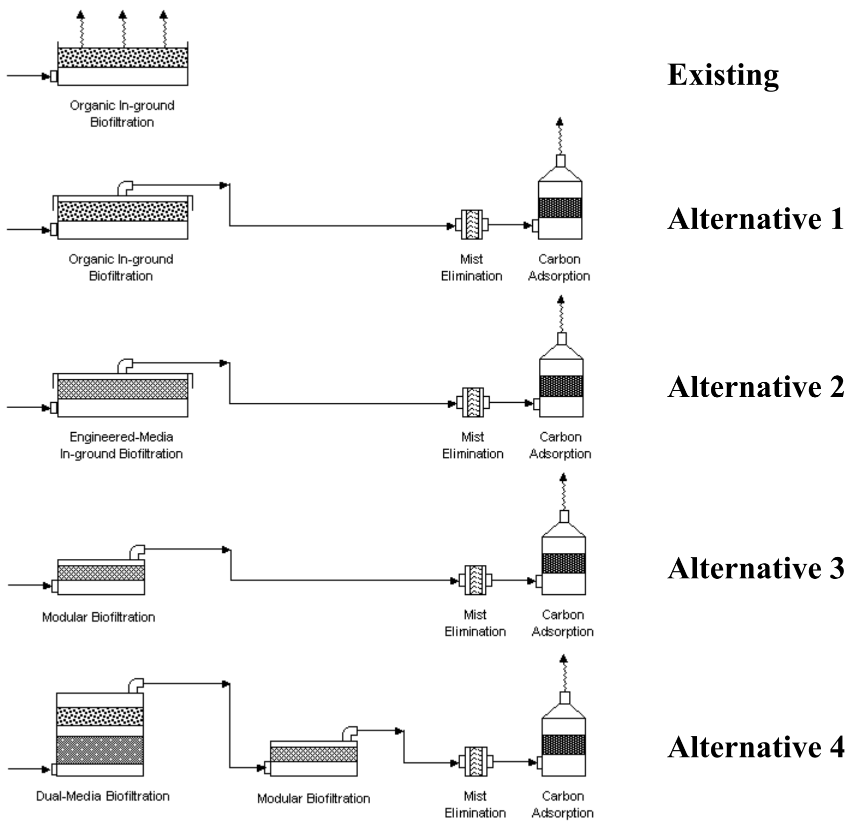


Table 1 - Anticipated Performance for Berm Box Odor Control Alternatives

System	Design Mean/ Peak Inlet H_2S (ppm)[1]	Design Mean/Peak Inlet Odor (D/T)[2]	Anticipated Mean/Peak Outlet H_2S (ppb)[3, 4]	Anticipated Mean/Peak Outlet Odor (D/T)[3]	Anticipated Mean H_2S Removal Efficiency	Anticipated Mean Odor Removal Efficiency
Existing	40 / 65	6,250 / 7,600	800 / 1,300	938 / 1,140	98.00%	85.00%
Alternative 1	40 / 65	6,250 / 7,600	16 / 26	47 / 57	99.96%	99.25%
Alternative 2	40 / 65	6,250 / 7,600	8 / 13	31 / 38	99.98%	99.50%
Alternative 3	40 / 65	6,250 / 7,600	24 / 39	78 / 95	99.94%	98.75%
Alternative 4	40 / 65	6,250 / 7,600	3 / 5	63 / 76	99.99%	99.00%

[1] Design inlet H_2S concentrations based on actual Plant data.
[2] Based on actual data from 1997.
[3] Based on published performance data for similar systems and operating conditions and accounting for media deterioration and performance decline over time.

Construction Cost Estimate for the Berm Box Odor Control Alternatives

Construction cost estimates for the Berm Box odor control alternatives were as follows:

- Alternative 1: $981,000
- Alternative 2: $1,192,000
- Alternative 3: $1,652,000
- Alternative 4: $1,776,000

Evaluation of the Berm Box Odor Control Alternatives

Table 2 summarizes the evaluation of the Berm Box odor control alternatives based on a selection criteria weighting/ranking process.

Table 2 - Evaluation Matrix for the Berm Box Odor Control Alternatives

Criterion	Weight[1]	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
		Rank[2]	Score	Rank[2]	Score	Rank[2]	Score	Rank[2]	Score
H_2S Removal Efficiency	5	4	20	4	20	4	20	5	25
Total Odor Removal Efficiency	5	4	20	4	20	4	20	4	20
Reliability	4	4	16	5	20	4	16	4	16
Operational Flexibility	3	3	9	3	9	3	9	3	9
Space Requirements	2	3	6	3	6	4	8	4	8
Automation	2	3	6	3	6	4	8	4	8
Process Monitoring	3	3	9	3	9	4	12	4	12
Capital Cost	4	5	20	4	16	3	12	2	8
Operational Cost	3	3	9	4	12	4	12	5	15
Operator Attention	4	2	8	2	8	4	16	3	12
Maintenance Attention	4	1	4	1	4	3	12	4	16
Site Aesthetics	2	3	6	3	6	3	6	3	6
Constructability	3	2	6	2	6	4	12	4	12
Media Replacement	4	1	4	1	4	3	12	4	16
Total Score		**143**		**146**		**175**		**183**	

[1] A weight value of 1 denotes "not very important"; a weight value of 5 denotes "very important".
[2] A rank value of 1 denotes "worst"; a rank value of 5 denotes "best".

Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternatives

Four alternatives were developed for the Primary Clarifier Nos. 1-10 and Headworks odor control systems. Each alternative would ultimately involve three phases of odor control. The phased approach would allow the District to implement an alternative on an as-need basis, which would provide flexibility in meeting air quality requirements and minimizing odor nuisances. The developed alternatives for the Primary Clarifier Nos. 1-10 and Headworks odor control systems are similar and are discussed in parallel in the following paragraphs.

Alternative 1: Biotrickling Filtration - Humidification - Organic Media Biofiltration - Carbon Adsorption

A schematic of Alternative 1 for the Primary Clarifier Nos. 1-10 and Headworks odor control systems is presented in Figure 3.

- Phase 1 - Installation of 13,000-cfm packed tower humidifiers upstream of the existing biofilters. Each humidifier would feature a dedicated FRP fan.
- Phase 2 - Installation of 13,000-cfm biotrickling filters upstream of the packed tower humidifiers.
- Phase 3 - Installation of a cover on the existing biofilters and installation of carbon adsorbers downstream of the covered biofilters.

Alternative 2: Humidification - Modular Biofiltration - Carbon Adsorption

A schematic of Alternative 2 for the Primary Clarifier Nos. 1-10 and Headworks odor control systems is presented in Figure 4.

- Phase 1 - Installation of 13,000-cfm packed tower humidifiers upstream of the existing biofilters.
- Phase 2 - Replacement of the existing biofilters with 4,000-cfm modular biofilters. Each modular biofilter would feature a dedicated FRP fan.
- Phase 3 - Installation of 13,000-cfm carbon adsorbers downstream of the modular biofilters. Each carbon adsorber would feature a dedicated FRP fan.

Alternative 3: Modular Biofiltration - Chemical Scrubbing - Carbon Adsorption

A schematic of Alternative 3 for the Primary Clarifier Nos. 1-10 and Headworks odor control systems is presented in Figure 5.

- Phase 1 - Replacement of the existing biofilters with 4,000-cfm modular biofilters. Each modular biofilter would feature a dedicated FRP fan.

- Phase 2 - Installation of 13,000-cfm carbon adsorbers downstream of the modular biofilters. Each carbon adsorber would feature a dedicated FRP fan.
- Phase 3 - Installation of 13,000-cfm packed bed chemical scrubbers between the modular biofilters and the carbon adsorbers.

Alternative 4: Deep Bed Biofiltration - Chemical Scrubbing - Carbon Adsorption

A schematic of Alternative 4 for the Primary Clarifier Nos. 1-10 and Headworks odor control systems is presented in Figure 6.

- Phase 1 - Replacement of the existing biofilters with two-cell deep-bed biofilters.
- Phase 2 - Installation of 13,000-cfm carbon adsorbers downstream of the deep-bed biofilters. Each carbon adsorber would feature a dedicated FRP fan.
- Phase 3 - Installation of 13,000-cfm packed bed chemical scrubbers between the deep-bed biofilters and the carbon adsorbers. Each packed-bed scrubber would feature a dedicated FRP fan.

Figure 3 - Schematic of Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternative 1

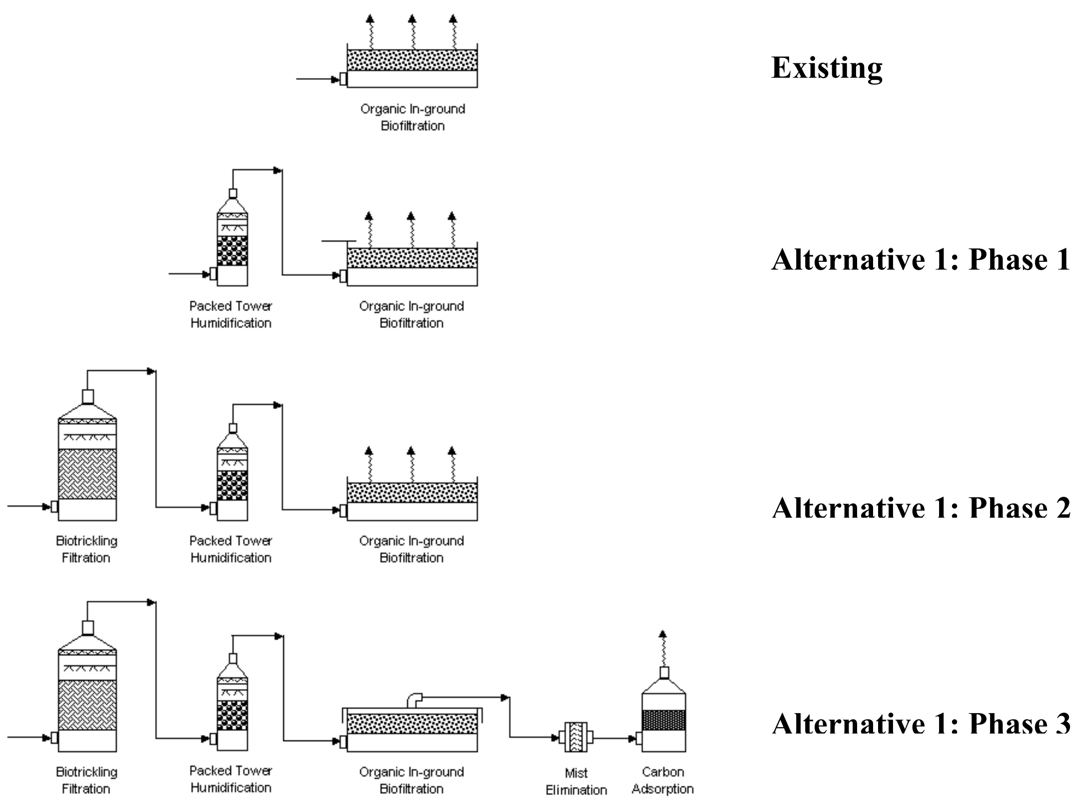


Figure 4 - Schematic of Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternative 2

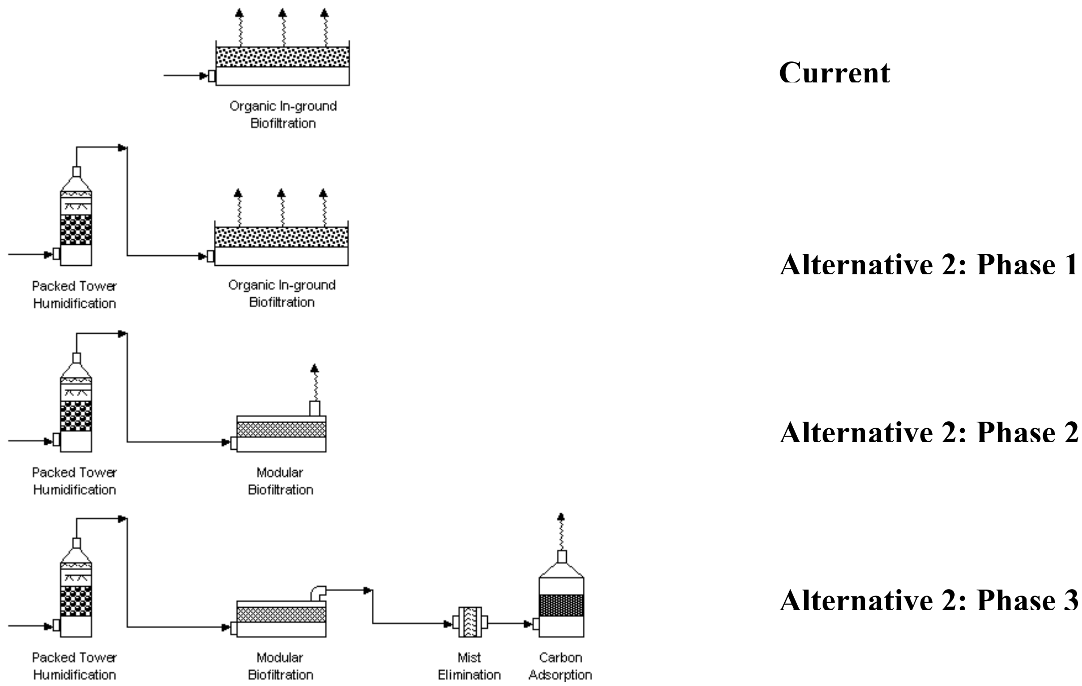


Figure 5 - Schematic of Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternative 3

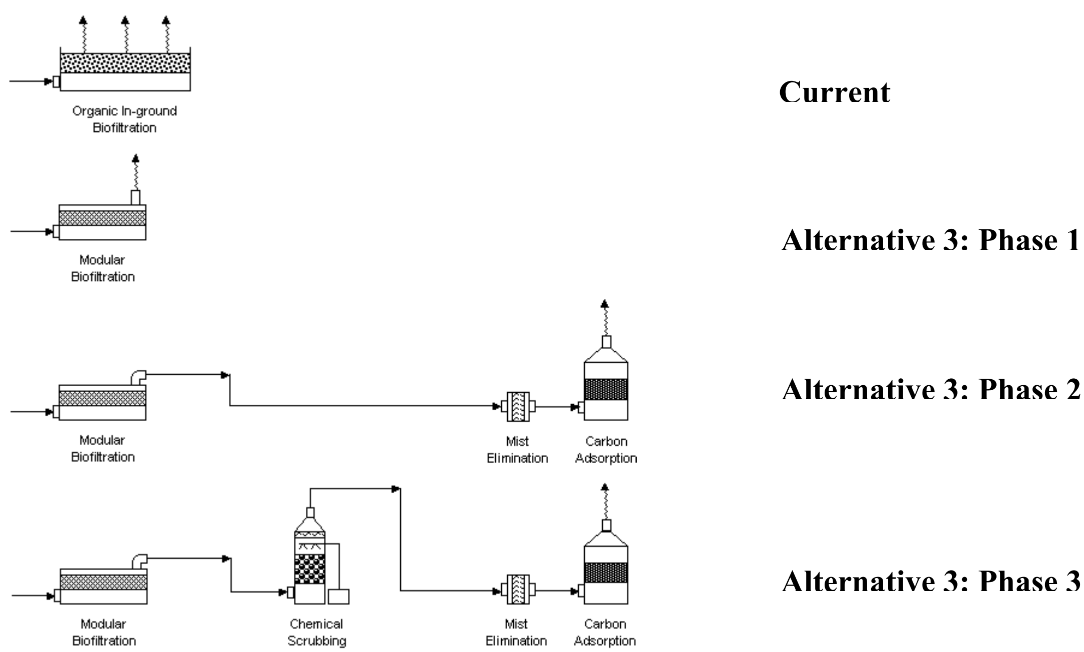
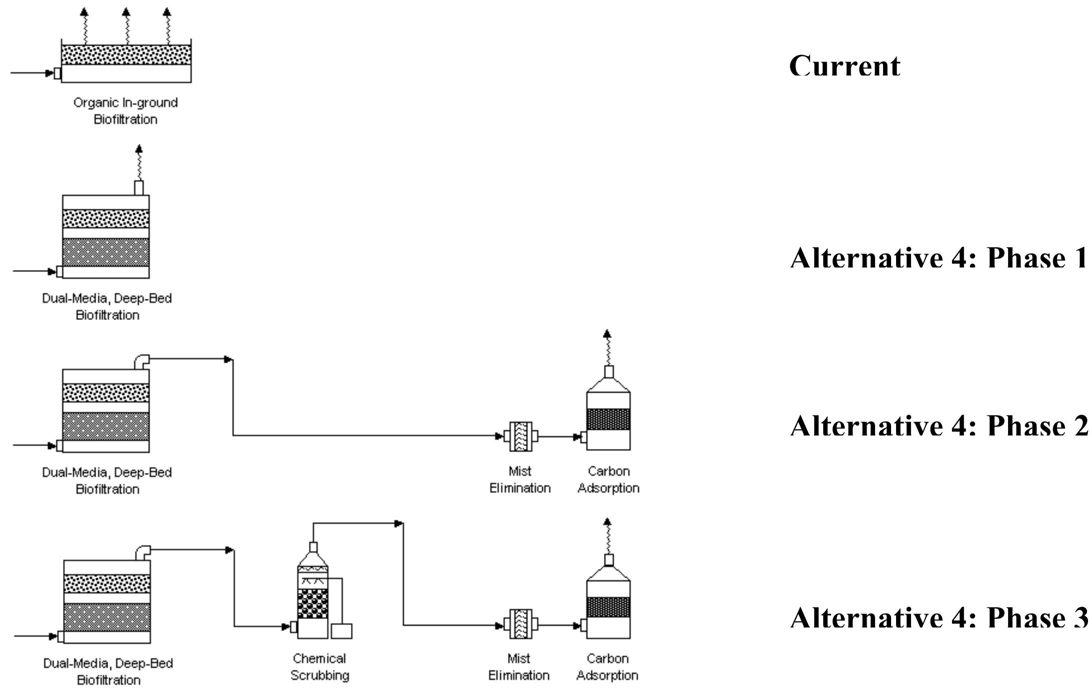


Figure 6 - Schematic of Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternative 4



Anticipated Performance for the Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternatives

Summaries of anticipated odor control alternatives for the Primary Clarifier Nos. 1-10 and Headworks are provided in Tables 3 and 4, respectively. Based on the Table 3, Alternative 1 would ultimately result in the lowest outlet H_2S concentrations at the Primary Clarifier Nos. 1-10 odor control system, while Alternative 4 would result in the lowest outlet total odor concentration. Based on the Table 4, Alternative 1 would ultimately result in the lowest outlet H_2S concentrations at the Headworks odor control system, while Alternative 4 would result in the lowest outlet total odor concentration.

Table 3 - Anticipated Performance for Primary Clarifier Nos. 1-10 Odor Control Alternatives

System	Design Mean/ Peak Inlet H_2S (ppm)[1]	Design Mean/Peak Inlet Odor (D/T)[2]	Anticipated Mean/Peak Outlet H_2S (ppb)[3, 4]	Anticipated Mean/Peak Outlet Odor (D/T)[3]	Anticipated Mean H_2S Removal Efficiency	Anticipated Mean Odor Removal Efficiency
Existing	20 / 30	6,600 / 12,000	400 / 600	1,320 / 2,400	98.00%	80.00%
Alternative 1						
Phase 1	20 / 30	6,600 / 12,000	180 / 270	890 / 1,620	99.10%	86.50%
Phase 2	20 / 30	6,600 / 12,000	5 / 8	310 / 570	99.97%	95.28%
Phase 3	20 / 30	6,600 / 12,000	0 / 0	16 / 28	100.00%	99.76%
Alternative 2						
Phase 1	20 / 30	6,600 / 12,000	180 / 270	890 / 1,620	99.10%	86.50%
Phase 2	20 / 30	6,600 / 12,000	540 / 810	1,490 / 2,700	97.30%	77.50%
Phase 3	20 / 30	6,600 / 12,000	11 / 16	74 / 140	99.95%	98.88%
Alternative 3						
Phase 1	20 / 30	6,600 / 12,000	540 / 810	1,490 / 2,700	97.30%	77.50%
Phase 2	20 / 30	6,600 / 12,000	11 / 16	74 / 140	99.95%	98.88%
Phase 3	20 / 30	6,600 / 12,000	2 / 3	17 / 30	99.99%	99.75%
Alternative 4						
Phase 1	20 / 30	6,600 / 12,000	180 / 270	590 / 1,080	99.10%	91.00%
Phase 2	20 / 30	6,600 / 12,000	4 / 5	30 / 54	99.98%	99.55%
Phase 3	20 / 30	6,600 / 12,000	1 / 1	7 / 12	100.00%	99.90%

[1] Design inlet H_2S concentrations based on actual Plant data.
[2] Based on actual data from 1997.
[3] Based on published performance data for similar systems and operating conditions and accounting for media deterioration and performance decline over time.

Table 4 - Anticipated Performance for Headworks Odor Control Alternatives

System	Design Mean/ Peak Inlet H_2S (ppm)[1]	Design Mean/Peak Inlet Odor (D/T)[2]	Anticipated Mean/Peak Outlet H_2S (ppb)[3, 4]	Anticipated Mean/Peak Outlet Odor (D/T)[3]	Anticipated Mean H_2S Removal Efficiency	Anticipated Mean Odor Removal Efficiency
Existing	5 / 10	4,100 / 5,600	100 / 200	820 / 1,120	98.00%	80.00%
Alternative 1						
Phase 1	5 / 10	4,100 / 5,600	45 / 90	550 / 760	99.10%	86.50%
Phase 2	5 / 10	4,100 / 5,600	1 / 3	190 / 270	99.97%	95.28%
Phase 3	5 / 10	4,100 / 5,600	0 / 0	10 / /13	100.00%	99.76%
Alternative 2						
Phase 1	5 / 10	4,100 / 5,600	45 / 90	550 / 760	99.10%	86.50%
Phase 2	5 / 10	4,100 / 5,600	140 / 270	920 / 1,260	97.30%	77.50%
Phase 3	5 / 10	4,100 / 5,600	3 / 5	46 / 63	99.95%	98.88%
Alternative 3						
Phase 1	5 / 10	4,100 / 5,600	140 / 270	920 / 1,260	97.30%	77.50%
Phase 2	5 / 10	4,100 / 5,600	3 / 5	46 / 63	99.95%	98.88%
Phase 3	5 / 10	4,100 / 5,600	0 / 1	10 / 14	99.99%	99.75%
Alternative 4						
Phase 1	5 / 10	4,100 / 5,600	45 / 90	370 / 500	99.10%	91.00%
Phase 2	5 / 10	4,100 / 5,600	1 / 2	18 / 25	99.98%	99.55%
Phase 3	5 / 10	4,100 / 5,600	0 / 0	4 / 6	100.00%	99.90%

[1] Design inlet H_2S concentrations based on actual Plant data.
[2] Based on actual data from 1997.
[3] Based on published performance data for similar systems and operating conditions and accounting for media deterioration and performance decline over time.

Construction Cost Estimates for the Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternatives

Construction cost estimates for the Primary Clarifier Nos. 1-10 and Headworks odor control alternatives are summarized in Table 5.

Table 5 - Construction Cost Estimates for Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternatives

Alternative	Primary Clarifier Nos. 1-10	Headworks
1	$14,852,000	$18,552,000
2	$9,836,000	$14,312,000
3	$9,938,000	$15,814,000
4	$8,087,000	$13,134,000

Evaluation of the Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternatives

Table 6 summarizes the evaluation of odor control alternatives based on a selection criteria weighting/ranking process. Because the alternatives developed for the Primary Clarifier Nos. 1-10 and the Headworks odor control systems are similar, Table 4 refers to both systems.

Table 6 - Evaluation Matrix for Primary Clarifier Nos. 1-10 and Headworks Odor Control Alternatives

		Alternative 1		Alternative 2		Alternative 3		Alternative 4	
Criterion	Weight[1]	Rank[2]	Score	Rank[2]	Score	Rank[2]	Score	Rank[2]	Score
H_2S Removal Efficiency	5	4	20	4	20	4	20	5	25
Total Odor Removal Efficiency	5	4	20	4	20	4	20	5	25
Reliability	4	4	16	5	20	4	16	4	16
Operational Flexibility	3	3	9	3	9	3	9	3	9
Space Requirements	2	3	6	3	6	4	8	5	10
Automation	2	3	6	3	6	4	8	4	8
Process Monitoring	3	3	9	3	9	4	12	3	9
Capital Cost	4	3	12	4	16	4	16	4	16
Operational Cost	3	3	9	4	12	3	9	4	12
Operator Attention	4	2	8	2	8	4	16	3	12
Maintenance Attention	4	1	4	1	4	3	12	3	12
Site Aesthetics	2	3	6	3	6	3	6	4	8
Constructability	3	2	6	2	6	4	12	4	12
Media Replacement	4	1	4	1	4	3	12	3	12
Total Score		**135**		**146**		**176**		**186**	

[1] A weight value of 1 denotes "not very important"; a weight value of 5 denotes "very important".
[2] A rank value of 1 denotes "worst"; a rank value of 5 denotes "best".

CONCLUSIONS

Berm Box Odor Control System

Based on the evaluation presented herein, Alternative 4 - modular dual-media biofiltration with inert and organic media followed by carbon adsorption would provide the most benefits for the Berm Box odor control system.

Primary Clarifier Nos. 1-10 Odor Control System

Based on the evaluation presented herein, phased Alternative 4 - dual-media deep-bed biofiltration followed by packed bed chemical scrubbing and carbon adsorption would provide the most benefits and flexibility for the Primary Clarifier Nos. 1-10 odor control system.

Headworks Odor Control System

Based on the evaluation presented herein, phased Alternative 4 - dual-media deep-bed biofiltration followed by packed bed chemical scrubbing and carbon adsorption would provide the most benefits and flexibility for the Headworks odor control system.

REFERENCES

Clark County Air Quality Regulations (AQR), Clark County Department of Air Quality and Environmental Management (CCDAQEM). http://www.accessclarkcounty.com/daqem/aq/regs/regs.html, accessed February 16, 2007.

World Health Organization (WHO). (1981) Hydrogen sulfide. Environmental Health Criteria No. 19, WHO, Geneva.