Odor Control – Solutions for Managing Emissions from Wastewater Treatment Facilities

George Simon, Charles Alix, and Vincente Arrebola

Table 1: Existing Odor Control Methods

Wastewater Treatment Process	Odor Control Method	Control System Status
Headworks (septage receiving, screening and grit removal)	Caustic wet scrubber	Note 1
Pure oxygenation tanks	None	N/A
Secondary clarifiers	None	N/A
Gravity sludge thickeners	Covered w/ caustic wet scrubber	Note 1
Anaerobic digestion	Methane flares	Operating as needed
Dewatering, drying beds & composting	None	N/A

Note 1: Scrubbers operating without caustic addition (plant effluent only)

Table 2: Sample Results from Odor Control System Outlets

Item Sampled	Headworks Scrubbers			Sludge Concentrator Scrubbers		
(ppbV)	Inlet	Outlet	Removal Efficiency	Inlet	Outlet	Removal Efficiency
Odor (D/T)	589,821	147,911	75%	29,323	1,639	94%
Ammonia	0 to 4	1 to 3	Note 1	0 - 4	0	> 99%
Hydrogen Sulfide	39,000	24,000	38%	1,300	340	73%
Carbonyl Sulfide	ND	11	0%	ND	ND	0%
Methyl Mercaptan	310	360	0%	35	31	11%
Ethyl Mercaptan	ND	ND	NA	ND	ND	NA
Dimethyl Sulfide	10	15	0%	11	7.6	36%
Carbonyl Disulfide	4.0	3.8	5%	6.0	3.2	47%
Dimethyl Disulfide	ND	ND	NA	ND	ND	NA

Note 1: On average ammonia unaffected by scrubbing

Table 3: Sample Results from Uncontrolled Sources

Item Sampled (ppbV)	Oxygenation Effluent Channel	Clarifier Settling Area	Clarifier Effluent Channel	Dewatering Truck Loading	Compost Pile	Drying Bed
Odor (D/T)	273	163	82	382,473	33,245	424
Ammonia	1	0	0	433	2,600	91
Hydrogen Sulfide	14	19	7.2	6,100	ND	6.8
Carbonyl Sulfide	19	9.3	7.2	ND	110	8.6
Methyl Mercaptan	2.5	3.5	ND	52	78	7.0
Ethyl Mercaptan	ND	ND	ND	7.4	ND	ND
Dimethyl Sulfide	47	1.4	4.7	ND	31	25
Carbonyl Disulfide	5.5	4.9	7.6	32	49	9
Dimethyl Disulfide	ND	ND	ND	ND	2,300	20

George Simon, P.E., is a senior project manager with the Charlotte, North Carolina, office of the engineering design firm MWH Americas. Charles Alix, P.E., is an air and odor knowledge community leader and senior project engineer with the firm's Charlotte office. Vicente Arrebola, P.E., is the assistant director for wastewater with the Miami-Dade Water & Sewer Department. This article was presented as a technical paper at the 2009 South Carolina Environmental Conference.

- Inventory and operational condition assessment of all existing emissions treatment systems.
- Sampling, quantification, and speciation for all potential odorous emission sources.
- Assessment of potential impacts to the surrounding community via atmospheric modeling.
- Assessment of acceptable odor concentrations surrounding the plants.
- Analysis of required improvements to meet odor goals.

Existing Conditions

Table 1 outlines the location, type, and current status of the existing odor control systems.

Emissions Sampling

Odor emissions were grouped into the following general process areas:

- Headworks and Septage Receiving Stations
- Aerated Pure-Oxygen Effluent Channels
- Secondary Clarifiers
- Sludge Concentrators and Pump Stations
- Dewatering Building
- Sludge Drying
- Sludge Composting

An emissions sampling and testing program was conducted to quantify the various emission sources. Samples were analyzed for odor concentration (D/T) using the forced choice dynamic dilution olfactometry method in accordance with ASTM E-679 and a presentation rate of 20 liters per minute.

Total reduced sulfur (TRS) was analyzed and consists of 20 sulfur compounds. TRS analysis used a gas chromograph equipped

Continued on page 32

Table 4: Dose Response Data

Emission Source	Dose Response Factors		Nuisance Odor Threshold (C)
	a	b	
Headworks	0.60	0.63	16
Pure oxygen discharge channel	0.66	0.73	10
Clarifier quiescent surface and wier	0.58	0.72	12
Sludge concentrators	0.62	0.63	15
Dewatering Building	0.68	0.60	15
New and old sludge drying beds	0.49	0.88	9
Compost piles	0.60	0.97	6

Table 5: Odor Goals for the South District Wastewater Treatment Plant

Criteria	Goal
Odor boundary	Nearest receptor for drying and composting operations. Facility fence line for all other operations.
Maximum boundary odor concentration	See **Table 4**
Averaging time for odor (duration)	10-minute
Number of allowable impacts at or exceeding nuisance odor concentration	Zero

Table 3: Sample Results from Uncontrolled Sources

Emissions Source	Odor Concentration (D/T) = (ou/m^3)	Emission velocity (m/sec)	Emission Rate From each (ou/sec)	Total Emission Rate (ou/sec)	Contribution to Facility Odor Emission
Headworks scrubber 1 & 2 outlet	147,911	9.34	907,481	1,814,962	96.6%

Continued from page 30
with a sulfur chemiluminescence detector per ASTM D 5504-01. Also conducted were ammonia testing using a Draeger® hand pump and colormetric tubes, ambient air monitoring of the facility perimeter, and continuous H_2S monitoring of select areas. Sample results are summarized in Tables 2 and 3.

At both the headworks and sludge concentration process areas where existing odor control and treatment is employed, all three available wet scrubbers were operating in series at the time of sampling and were operated only with chlorinated plant effluent (no caustic addition).

Dispersion Modeling

Specific odor regulations do not exist for this geography; however, it is the goal of the county to be a good neighbor and avoid nuisance odors in the surrounding community. To accomplish this goal, what constitutes a nuisance must be determined. This requires establishing the following:

- Nuisance odor concentration.
- A time interval (how long a time can neighbors be exposed to an odor).
- The number of times per year the nuisance odor threshold can be exceeded.

The relative strength of an odor determines the concentration at which a nuisance is generated. The measure of the strength of an odor is called odor intensity. It is measured against the strength of the odor caused by a known concentration of butanol. Odor intensity is quantified on a scale from 1 to 8, with 1 being weak and 8 being a strong odor.

Haug (1993) cited research by Duffee that concluded that odors with an intensity of 4 to 6 would likely cause a nuisance, and an intensity of 3.5 could be used as a complaint threshold. Data collected from the sampling effort includes dose response constants for each of the odor samples tested. These constants were then used to calculate the nuisance odor concentration based on an intensity of 3.5 using the following equation:

$$I = aC^b$$

Where:
I = Intensity
C = the odor concentration in Dilution to Threshold (D/T)
a and b = dose response constants determined by regression analysis of the intensity ratings of an odor panel to odor samples

Table 4 below presents the dose response data and the calculated odor concentration (D/T) that will generate a nuisance based on Duffee's intensity criteria of 3.5, and Table 5 outlines the odor goals for the facility.

The model used to predict the odor impacts is the U. S. Environmental Protection Agency's recommended model, AIRMOD, which uses local topographic and meteorological data as well as specific inputs such as emission data and onsite building heights to generate odor dispersion patterns. Five years of meteorological data was used to cover a wide range of atmospheric conditions and to avoid modeling in a year with unusual weather conditions.

The model provides results on an hourly basis, but it is reasonable to assume that a nuisance from an odor can be created in a shorter time duration than 60 minutes. For this study, a 10-minute duration was selected. It was felt that an odor persistent for 10 minutes would be both noticeable and constitute a nuisance. This time duration has been used successfully in several other studies and permit applications throughout the United States.

Research by Cramer (1959) recommends the use of the 1/5 power law to reduce the 60-minute averaging time dispersion models down to the 10 minutes used here. All odor concentrations calculated by the model are multiplied by the peak-to-mean coefficient to obtain the desired 10-minute concentration. The 1/5 power law equation is:

Peak-to-mean coefficient = $(t_o/t_1)^{1/5}$
t_o = initial (60-minute) averaging time
t_1 = desired averaging time (10-minutes)
$(60/10)^{1/5} = 1.43$

Odor concentrations collected during air sampling were used to create the emission input data. Presenting all of the emission input data would be too lengthy for this article, but Table 6 lists the emission rates used in the model for the headworks facility and provides a sample of the input emission data.

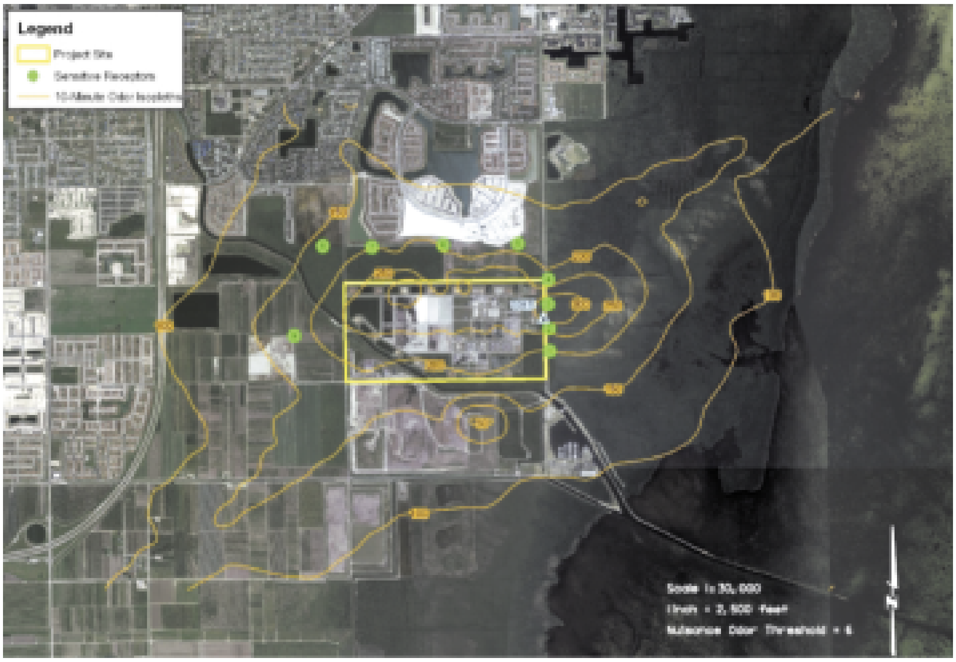

Figure 1: Highest Five-Year, 10-Minute Odor Concentrations from All Sources

Table 7: Odor Detection Limit

Compound	Odor Detection limit (ppmV)
Hydrogen Sulfide	0.0005
Methyl Mercaptan	0.0005
Dimethyl Sulfide	0.001

Table 8: Headworks Sampling Results – Caustic vs. Plant Effluent Only

Compound	South District WWTP Scrubber		Central District WWTP Scrubber		Recognition Threshold[1] (ppb)
	Inlet Conc. (ppb)	Outlet Conc. (ppb)	Inlet Conc. (ppb)	Outlet Conc. (ppb)	
Hydrogen Sulfide	39,000	24,000	51,000	17	4.7
Methyl Mercaptan	310	360	360	250	1.0
Dimethyl Sulfide	10	15	Not Detected	11	1.0

Note 1: recognition threshold reported by several researchers including AIHA, 1989; Moore et al., 1983; and Sullivan, 1969. This data can be found in several references including WEF manual of Practice 25 Control of Odors and Emissions from Wastewater Treatment Plant.

Model Results

The graphical representation of the odor results are illustrated in Figure 1 for the combination of all odor sources from the South District Plant. The lines overlaid on the figure are isopleths that show the maximum odor concentration predicted by the model. The model also examined odor concentrations at nine individual receptor locations (the nine green circles) and the number of times the nuisance threshold was met or exceeded.

Receptor locations were chosen because they represented actual or likely areas where the general public may routinely experience odors from the facility. It should be noted that model results showing concentrations for each individual odor source were also developed, but are not shown within this article. Model results indicate that the following sources do not contribute to any odors past the facility fence line:

- Oxygenation discharge channels;
- Secondary clarifiers;
- Sludge concentrator scrubber outlet
- Dewatering facility.

It is clear from examination of the modeling results that the emissions from the headworks scrubber outlet are the most significant source of offsite nuisance odors. The composting operation and drying beds also showed minimal odor impacts, but further odor control alternatives for these facilities were not investigated since they are to be phased out in the near future; therefore, only the headworks were examined for further odor control strategies.

Continued on page 34

Alternative 1 – Existing Scrubbers followed by Biofilter Polishing				
	Capital Costs	Annual O&M	20-yr NPV of O&M	Total Life Cycle Cost (Capital + 20YR O&M)
Existing Scrubbers w/ Rehab	$505,600	$74,000	$1,867,000	
New Biofilter	$1,021,500	$26,600	$671,200	
TOTAL				$4,065,400
Alternative 2 – Existing Scrubbers followed by Carbon Polishing				
Existing Scrubbers w/ Rehab	$505,600	$74,000	$1,867,000	
New Carbon	$1,678,100	$99,900	$2,520,600	
TOTAL				$6,571,400
Alternative 3 – New Biotrickling filters followed by Biofilter Polishing				
New Biotrickling Filters	$2,822,000	$28,500	$719,000	
New Biofilter	$1,021,500	$26,600	$671,200	
TOTAL				$5,233,800
Alternative 4 - New Biotrickling filters followed by Carbon Polishing				
New Biotrickling Filters	$2,822,000	$28,500	$719,000	
New Carbon	$1,678,100	$99,900	$2,520,600	
TOTAL				$7,739,800
Alternative 5 – New Carbon Sized for Full Treatment				
New Carbon	$1,915,600	$297,617	$7,509,100	
TOTAL				$9,424,700

Table 9: Opinion of Probable Cost for Odor Control Alternatives

Continued from page 33

Discussion

As noted previously, odors from wastewater treatment plants are complex combinations of several compounds. As would be expected, hydrogen sulfide is a significant contributor to odorous emissions, but other compounds such as methyl mercaptan and dimethyl sulfide are persistent through the treatment process and can provide a significant contribution to odor. Table 7 shows the odor detection limit for these compounds:

The presence of these compounds is worth noting because, while the caustic scrubbers common to all three plants can be very effective at removing hydrogen sulfide, they are much less effective at reducing these other compounds. Thus, overall odor exhausted from a caustic scrubber may still be significant enough to impact the surrounding community.

At the time of sampling, the headworks scrubbers at the South District Treatment Plant were not using chemical addition to reduce the hydrogen sulfide, but it is vital to note that hydrogen sulfide is not the only significant odor-causing compound at the headworks. Two other compounds, methyl mercaptan and dimethyl sulfide, were also present.

Air sampling was also performed at the Central District Wastewater Treatment Plant headworks scrubber outlets, where chemicals were introduced to the scrubber. While the hydrogen sulfide concentration is reduced in the air stream by 99.97 percent, the odor is still very high (114,263 D/T). Table 8 presents this information.

From Table 8 it can be seen that chemical addition to the scrubbers at the Central District Plant significantly reduced hydrogen sulfide but had little or no effect on either methyl mercaptan or dimethyl sulfide. Both of these compounds are very odorous with recognition thresholds lower than that for hydrogen sulfide.

There are other technologies that will remove these compounds effectively and can provide a polishing step and significantly reduce overall odor; however, these technologies generally function best if hydrogen sulfide first is reduced significantly. They include, but are not limited to, biofilters, carbon scrubbers, and bio-trickling filters.

Based on the results of the model and the data collected, the headworks emissions must be treated in a two-step process. The first step will reduce the hydrogen sulfide concentration significantly, and the second polishing step will reduce the remaining odor. After preliminary screening, the following technologies were evaluated for potential use at the headworks:

First Stage Control (H_2S Removal) options

- Biotrickling Filter
- Existing chemical wet scrubbers
- Carbon filter without a second stage

Second Stage Control options

- Biofilter
- Carbon Filter

Conclusions

It should be noted that ventilation and emissions capture are critical components of a successful odor control strategy. For example, the headworks screen room and grit room sit atop the covered screening and aerated grit channels. The headspace above the wastewater acts as the air collection duct. Floor openings in the screen and grit room consist of open grates only, and thus there is no way to balance flow from each of the rooms.

As a result, most of the room air is collected from the grit room while air remains stagnant in the screen room—a situation that forces workers to leave doors open to the outside and between rooms, creating a significant opportunity for fugitive odors to escape. Revised intake louvers that allow fresh air to sweep past workers and collection points with balancing dampers will be needed to adjust the air collection. Similar air collection issues were found at all the plants.

Five odor control alternatives were developed using the recommended technologies for treating emissions at the headworks. Estimates of capital costs were prepared based on 2007 costs as a part of the planning effort. They are order-of-magnitude estimates, defined by the American Association of Cost Engineers as estimates developed without detailed engineering data and using techniques such as cost curves and scaling factors from similar projects. Overall expected level is generally accepted at +30 percent to -20 percent.

The costs presented in this evaluation include estimated construction dollars; contingencies; and legal, administration, and engineering fees. Construction costs are based on preliminary layouts of each alternative. Capital cost estimates for all existing scrubbers systems include replacement of the chemical metering pumps and the electrical motor control centers providing power to the existing wet scrubber odor control systems.

All new technologies were sized so that they can be located in an 80' x 60' area available adjacent to existing odor control buildings. Table 9 presents the opinion of probable cost for each of the odor control alternatives. Alternative No. 1, rehabilitation of the existing wet scrubbers followed by polishing with a new biofilter, was the recommended alternative.

References

- Cramer, H.E.(1959) Engineering Estimates of Atmospheric Dispersal Capacity. Amer.ind. Agr. Assoc. J., 20 (3) 183-189
- Haug, R.T., (1993). The Practical Handbook of Compost Engineering, Boca Raton, FL: Lewis Publisher