Controlling Wastewater Plant Odors —The Palm Beach Experience

– Karen Harrison, John Davis, Larry Johnson, and David Dalton –

Palm Beach County Water Utilities Department wished to control odor emissions from the Southern Region Water Reclamation Facility (WRF) in response to citizen concerns. Jordan, Jones and Goulding Inc. (JJG), an engineering consulting firm, was contracted to determine the source(s) of odors being emitted to the neighboring areas and to determine alternatives for odor abatement for the facility.

The primary goal of this project was to enhance community relations. The objectives were to determine the source(s) of odor emissions that could affect the plant's neighbors and to develop cost-effective control methods for these sources.

The WRF has a treatment capacity of 35 million gallons per day (MGD), based on three-month average daily flow, treating wastewater from a large part of Palm Beach County. The treatment processes include screening, grit removal, step-feed aeration, and final clarification.

A portion of the effluent is filtered, disinfected with chlorine, and distributed to the reuse water system. Effluent not distributed to the reuse water system is either used to sustain two wetlands adjacent to the plant site or injected into deep wells.

Sludge is thickened, anaerobically digested, and dewatered using belt filter presses. The dewatered cake solids are used on farmland or placed in a landfill.

The aeration basins are operated in the step-feed mode. Each of the four basins is divided into four passes. The return sludge is introduced at the head of the first pass of each basin. Raw wastewater is currently fed at the head of the first, second, and third passes.

Odor control was already in place for the headworks and the solids handling facilities at the plant. Treatment of the foul air at both locations is provided by two-stage, packed-bed caustic scrubber systems.

Public Participation

When odor studies are initiated because of complaints from the public, public participation can develop credibility and increase public confidence, offer the opportunity for public input, and encourage public understanding of the time required for implementation of the recommended improvements. Public participation usually consists of public meetings and meetings with a small focus group of individuals who are most impacted by the offsite odors.

Typically, the focus group consists of five to 10 people who are willing to devote some time to develop more comprehensive understanding of odor science and the recommendations of the study. In turn, focus group members become an important source of information for the community at large.

Because the offsite odors from WRF primarily affected two developments near the treatment plant, separate public meetings were held in each development. Two sets of public meetings were conducted during the study period.

The first set was held at the start of the study period and provided a general explanation of odor science. The steps involved in the odor study were discussed, and the goals and objectives of the study were presented. Citizens were also encouraged to keep odor logs to record the time and location that odors were detected.

The second set of meetings was held near the end of the study period. In these meetings, the study results were presented, a plan of action was reviewed, and the schedule was discussed. Each of the meetings was heavily publicized using posters and e-mail. Also, local news media published articles discussing the odor issues and describing the public presentations.

A focus group was formed that included representatives from the surrounding area. The two communities most impacted by the odors appointed members of the focus group to act as odor liaisons who were responsible for providing additional information to their community. The odor liaisons also collected odor log information, received complaints and suggestions from the community, and passed this information on to the county water utilities department.

In addition to the public meetings, three focus group meetings were held. In the first meeting, a detailed explanation of odor science and the steps involved in the study was presented. Additional discussion was held to gather information from the group on odor occurrences and times when the odor was more noticeable.

In the second focus group meeting, progress on the study was presented and some preliminary results were discussed. The third meeting included presentation of the results of the study and the expected improvement in offsite odors after completion of the initial Phase 1 project and the follow-up Phase 2 project.

Karen Harrison, P.E., and John Davis, P.E., are senior engineers in the Atlanta, Georgia office of Jordan, Jones and Goulding. Larry Johnson, P.E., is the Southern Region Water Reclamation Facility manager for the Palm Beach County Water Utilities Department. David Dalton is the operations & maintenance water reclamation manager, Palm Beach County Water Utilities Department. This article was presented as a technical paper at the 2007 Florida Water Resources Conference.

Because of the success of the public participation program, the water utilities department plans to continue meeting with the focus group during the design and construction of the Phase 1 and 2 projects. The department will present status reports to the focus group and allow further questions to be answered. Department officials also intend to add content to their Web site regarding the odor control project, allowing the public to easily follow the progress of the project.

Odor Study Procedure

The first step in performing an odor study is to identify all the potential odor sources. Identifying potential odor sources typically involves a walk-through of the plant and discussion with plant operating staff. There are two types of odor sources: point sources and area sources.

Point sources have a well-defined discharge point, such as exhaust vents or ventilation fans. Area sources are large areas such as basins, channels, and sludge storage areas. All potential odor sources should be sampled. It is not unusual to discover that a source that does not appear to be a significant source of odors at the site is actually causing significant offsite odors.

Point sources are sampled using a tube inserted into the air flow, and area sources are sampled using a floating hood. The air samples are collected in non-reactive bags and sent to a laboratory for analysis.

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	Top Sample Locations by D/T		Top Sample Locations by Odor Emission Rate	
	Source	*D/T*	*Source*	*OER cfm x 10^{-6}*
1	Aeration Basin Influent Channel	60,000	Aeration Basins	186.75
2	Aeration Basins	6,225	Headworks Scrubber Discharge	133.32
3	Headworks Scrubber Discharge	4,400	Aeration Basin Influent Channel	24.48
4	Return Sludge Wet Well	460	Solids Handling Bldg Scrubber Discharge	9.31
5	Mixed Liquor Splitter Box	320	Secondary Clarifiers	0.61
6	Secondary Clarifiers	240	Return Sludge Wet Well	0.07
7	Solids Handling Bldg Scrubber Discharge	240	Effluent Wet Well	0.03
8	Aeration Basin Effluent Box	220	Reuse Filters	0.03
9	Effluent Wet Well	190	Mixed Liquor Splitter Box	0.02
10	Reuse Filters	190	Aeration Basin Effluent Box	0.01

Table 1: Odor Sampling Results

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Two kinds of analysis are conducted on the samples: chemical and sensory. The chemical analysis determines the levels of common odorants in the sample, such as hydrogen sulfide and ammonia. Sensory analysis is conducted by an odor panel of individuals who have been tested for their sensitivity to odors.

The odor panelists are asked to smell the odor source in increasing concentrations and indicate at what concentration they can first detect an odor. In order to determine when an individual has actually detected an odor, each dilution is presented, along with two "blanks" that contain no odor. The odor panelist must choose which sample contains the odor. From this data, the dilution-to-threshold ratio (D/T) is determined. The D/T is a measure of how much an odor must be diluted before the average person can no longer smell it. Samples with higher D/T's have a stronger odor.

The odor panelists are also asked determine the odor intensity by comparing the strength of the original odor sample to the strength of butanol odor in varying concentrations. This data is determined by having the odor panelists compare various concentrations of butanol to the intensity of the collected sample. It is generally accepted that a higher intensity corresponds to a stronger odor.

The rate of change of odor intensity with varying dilutions is termed the persistency of the odor. The persistency, or "dose-response" function, is determined from intensity measurements of an odor at full strength and at other dilutions above the threshold level.

The plotted values, as logarithms, of the intensity and dilution ratio establish the dose-response function. The slope of the graph is used to determine the persistency of the odor for each sample and can indicate the primary odorant in the sample. Flatter slopes indicate odors that are more persistent, or linger longer in the atmosphere.

An exhaust rate is determined for each potential source. For point sources, the exhaust rate is generally equal to the capacity of the fan. For area sources, the exhaust rate is calculated based on turbulence and evaporation rates. The odor emission rate (OER) is calculated by multiplying the D/T times the exhaust rate.

An air dispersion computer model is used to determine how far each odor source transports offsite. Each odor source is modeled separately. The model inputs include odor emission rates for the odor sources, odor source dimensions and characteristics, and historic meteorological conditions.

Depending on the model used, either a transport distance for each odor source to reach the threshold odor level is calculated or D/T contours showing the location of peak D/T levels over a one year period are produced. Some models also produce frequency contours for specific D/T levels to indicate how often a particular odor level is experienced in a particular location. This information allows the offsite impact of each odor source to be assessed.

Transport of odors is very dependent on wind speed and air stability. Odors transport farther during times of low air speed and high stability because turbulence is not mixing the odor with the air and diluting the odor. These conditions often occur in the evening just after the sun sets, in the early morning, and during overcast days. This is why municipalities often log more odor complaints in the evenings and on rainy days.

After the transport distance is calculated for each odor source, the sources are prioritized. The odor source that transports the farthest is the highest priority for treatment, and those odor sources that do not transport off-site are not considered a priority. Each odor source is prioritized in order of transport distance, from highest to lowest.

The boundary objective of the odor control program is then established. The objective consists of an odor level, or D/T, at a particular location, often the property boundary or the nearest residence. The odor objective generally varies according to region and the sensitivity of the surrounding community.

Once the objective has been established, the required odor reduction to meet the objective is estimated and potential odor control methods are considered. The selection of suitable odor control methods must consider not only the total odor removal rate, but also the types of odorants that a particular technology can treat.

Odor Study Results

A survey of possible odor sources was conducted on site in conjunction with the plant staff. Areas throughout the plant were examined during the survey to identify potential odor sources, based on previous JJG experience at other wastewater facilities and the experience of operations staff at the WRF. Based upon the survey, 20 sample locations were selected, which included:

1. Headworks Scrubbers
2. Aerated Grit Tanks
3. Aeration Basin Influent Channel
4. Aerations Basins
5. Mixed Liquor Splitter Boxes
6. Secondary Clarifiers
7. Return Sludge Pump Station Wet Wells
8. Reuse Water Disk Filters
9. Sludge Wells at the Anaerobic Digesters
10. Ventilation Duct Discharging from the Solids Handling Building
11. A Sludge Truck Receiving Dewatered Sludge
12. Solids Handling Scrubber
13. Plant Drain Pump Station

Sample locations are shown in Figure 1.

During the site survey, some general issues that pose particular odor-related challenges were noted. Among these was the flat terrain of the WRF service area, which requires most wastewater flows to be pumped from a

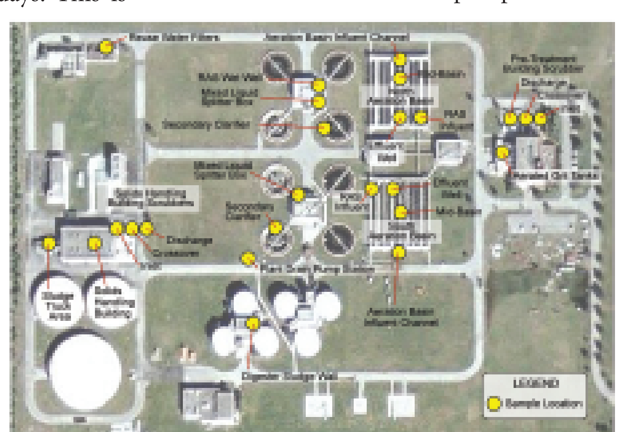

Figure 1: Odor Sample Locations

point near where they originate to the WRF.

The wastewater force mains that conduct the flows are almost entirely anaerobic, a condition which fosters the generation of odorous reduced-sulfur compounds within the wastewater. These compounds have little opportunity for release to the atmosphere until the wastewater reaches the open channels and basins of the WRF.

The county feeds Odo-Free, a proprietary solution of ferrous sulfate and ferric sulfate, into wastewater at the pumping stations that pump raw wastewater from the collection system into the WRF, and is pilot testing the PRI-SC system for odor and corrosion control in the collection system. These chemicals mitigate, to some degree, the release of the highly odorous reduced-sulfur compounds from the wastewater.

Air samples taken at the WRF were sent to St. Croix Sensory Inc. to have D/T, recognition threshold, and dose-response testing performed. All samples were analyzed using the standard presentation rate of 20 liters per minute.

Sampling was conducted on the identified potential odor sources at the plant. Table 1 presents the results of sampling for the 10 most significant sources of odor. The odor samples were also tested for specific odor-causing compounds. The results of these tests are shown in Table 2.

The modeling performed for this odor evaluation applied the U.S. Environmental Protection Agency (USEPA) Industrial Source Complex (ISC) dispersion model. The software used to complete the modeling was Breeze ISC GIS ProVersion 4.0.4, developed by Trinity Consultants Inc. The model output was used to predict the highest D/T level for a year of meteorological data over the area of analysis. The resulting peak D/T levels are shown graphically on odor contour plots.

The model results are presented based on peak D/T levels for the worst 15 seconds of the year at a particular location. Figure 2 shows the peak D/T contours for the WRF overall (all odor sources included). Figure 3 shows the peak D/T contours for the aeration basins, and Figure 4 shows the peak D/T contour for the headworks scrubber.

Two odor sources were found to have significant offsite odor impacts: the headworks scrubber discharge and the aeration basins (including the influent channel). Other odor sources within the WRF do not appear to have offsite impacts during typical operation of the plant.

The aeration basins have the most significant offsite impacts with peak offsite D/T levels from this source modeled at 300 to 400. The headworks scrubber odor emissions are reduced by the dispersion achieved by the discharge stack. Peak offsite D/T levels from this source were modeled to be around 100. This modeling result is based on normal scrubber operation.

To plan capital and operational improvements for reducing odor emissions from the WRF, odor sources were prioritized. As stated previously, initial odor samples and modeling results indicated that the aeration basins needed to be a priority for odor abatement, followed by the headworks scrubber. Other odor sources at the WRF were found to have little or no off-site impact.

Within the aeration basins, odor samples indicated that different areas had widely

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Figure 2
Baseline Peak D/T Contours
All Sources

Figure 3
Baseline Peak D/T Contours
Aeration Basin Sources

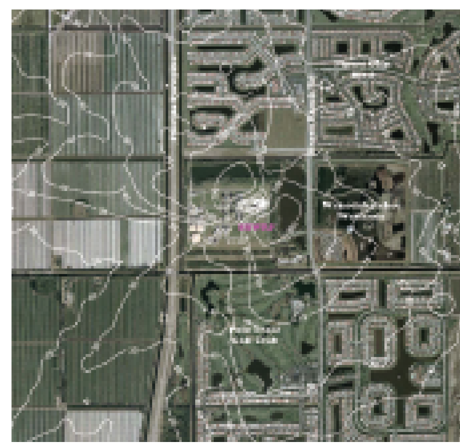

Figure 4
Baseline Peak D/T Contours
Headworks Scrubber

	Hydrogen Sulfide						Mercaptans						Ammonia	
	Field		Laboratory				Field		Laboratory				Field	
Location	1st Round	2nd Round	1st Round		2nd Round		1st Round	2nd Round	1st Round		2nd Round		1st Round	2nd Round
	ppm(v)	ppm(v)	mg/m³	ppm(v)	mg/m³	ppm(v)	ppm(v)	ppm(v)	mg/m³	ppm(v)	mg/m³	ppm(v)	ppm(v)	ppm(v)
Headworks Building - Scrubber														
Scrubber Inlet	45.0	13.0	56.0	40.0	41.0	29.0	Trace	Trace	0.65	0.33	0.89	0.45	ND	ND
Scrubber Crossover	5.8	2.5	6.6	4.7	4.5	3.2	Trace	Trace	0.71	0.36	0.91	0.46	0.5	0.6
Scrubber Discharge	1.5	1.0	1.7	1.2	1.6	1.1	NM	Trace	0.66	0.33	0.75	0.38	0.25	1.0
Aerated Grit Tank	>200	>200	130.0	94.0	690.0	500.0	1.50	Trace	7.60	3.90	13.00	6.70	ND	ND
Aeration Basin Influent Channel	120.0	13.0	190.0	130.0	9.6	6.9	0.10	1.00	2.70	1.40	2.30	1.20	ND	ND
Aeration Basin														
Area 1	31.0	3.1	120.0	88.0	0.81	0.58	1.00	0.25	7.80	3.90	1.20	0.59	ND	ND
Area 2	5.1	1.7	3.1	2.2	0.83	0.59	0.50	0.50	1.80	0.92	1.20	0.59	ND	ND
Effluent Weir	0.005	0.004	0.0097	0.0069	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mixed Liquor Splitter Box	0.004	0.120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Secondary Clarifiers	0.020	0.120	0.012	0.009	ND	ND	ND	ND	0.0068	0.0035	ND	ND	ND	0.2
Return Sludge Pump Station	0.008	0.140	ND	ND	0.0075	0.0054	ND	ND	0.024	0.012	0.028	0.014	ND	0.2
Reuse Water Filters	0.080	0.200	ND	ND	ND	ND	NM	ND	ND	ND	ND	ND	NM	0.3
Anaerobic Digesters	0.180	ND	LS	LS	ND	ND	NM	NM	LS	LS	ND	ND	NM	6.0
Solids Handling Building - Discharge Duct	0.003	0.130	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND	3.0	0.3
Dewatered Sludge in Truck	ND	0.130	ND	ND	ND	ND	NM	NM	ND	ND	0.010	0.0051	NM	95.0
Solids Handling Building - Scrubber														
Scrubber Inlet	0.006	0.230	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND	2.5	3.0
Scrubber Crossover	0.500	0.240	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND	ND	0.2
Scrubber Discharge	0.200	0.210	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND	ND	0.2
Plant Drain Pump Station	2.700	6.500	LS	LS	11.0	7.6	ND	NM	LS	LS	0.52	0.26	ND	0.3

bbreviations
D = Not Detected
M = Not Measured
S = Lost Sample

Table 2: Analytical Results

Figure 5
Peak D/T Contours After
Phase 1 Odor Improvements

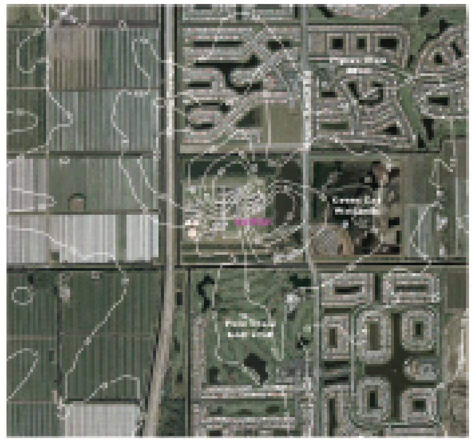

Figure 6
Peak D/T Contours After
Phase 2 Odor Improvements

Cost Estimates	**Phase 1**	**Phase 2**
Phase Capital Improvement Description	Aeration Basins Cover 25% Ductwork One Biofilter	Aeration Basins Cover 25% One Biofilter Headworks Carbon Polishing
Construction Cost	$3,700,000	2,600,000
Engineering, Legal, Admin. Costs (18%)	$670,000	$470,000
Contingency (30%)	$1,310,000	$920,000
Total Project Capital Costs w/ Contingency	**$5,680,000**	**$3,990,000**
Annual Labor Costs	$10,000/yr	$30,000/yr
Annual Power Costs	$40,000/yr	$120,000/yr
Annual Cost for Chemicals & Media Replacement	$25,000/yr	$70,000/yr

Table 3 - Estimating Capital and Operating Costs

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differing odor emissions. The data indicate that of the three aeration basin areas sampled, odor emissions were generally highest at the start of the first pass, for which four samples averaged 9,000 D/T, followed by the start of the second pass, for which four samples averaged 4,000 D/T. Finally, a single sample taken in the fourth pass was 790 D/T.

This pattern suggests that odor decreases through the aeration basins, and this conclusion is supported by odor samples taken at aeration basin effluent weirs, which averaged 170 D/T. Based on these odor measurements, priorities can be set for which aeration basin areas to address first in odor abatement planning. Some basin areas may not be significant odor sources.

The odor measurements show that the second most significant odor source at the WRF, the headworks scrubber, discharges treated air (at a rate of 30,300 cubic feet per minute) with an average D/T in the range of 4,000 to 5,000. The offsite impact of these odors is reduced by the dispersion achieved by the high-velocity discharge from the stack, which is 36 feet above the surrounding grade.

The scrubber typically removes more than 95 percent of hydrogen sulfide and approximately 65 percent of odor as measured by D/T when it is operating effectively. This level of hydrogen sulfide removal is consistent with expectations for this type of treatment technology.

The overall odor removal, however, is less than is often achieved with this technology, but this is explicable by the fact that significant amounts of mercaptans and other organic RSCs are present in the ventilation air from the WRF headworks. These compounds are difficult to remove in a chemical scrubber. The data indicate that the existing scrubber removes less than 10 percent of these compounds.

Recommendations

Three general methods for controlling the odor were explored:

1. Reduce hydrogen sulfide loads by adding chemicals to the collection system to reduce dissolved sulfides.
2. Adjust the operation of the plant to reduce odors.
3. Capture and treat odors.

Wet chemistry tests conducted in conjunction with the odor sample testing indicated that the addition of chemicals to the collection system successfully reduced the dissolved sulfides in the raw wastewater, but no corresponding reduction in odor emissions was observed. This can be explained by the analytical data, which indicates significant concentrations of odor-causing compounds other than hydrogen sulfide.

Adjustments in the operation of the plant were made in early 2007, and the impact on the odor emission rates is being measured. Operational changes currently being evaluated include relocating the return sludge feed point from the first pass of the aeration basin to some point upstream of the aeration basin.

The odor emissions from the aeration basins can be controlled by capturing and treating the foul air. A phased plan that involves covering portions of the aeration basins and treating the foul air using biofiltration has been developed in the event that the operational adjustments are unsuccessful in controlling odor emissions.

Phase 1 would involve covering 25 percent of each of the WRF's four aeration basins and ventilating the covered area at a rate that would ensure odor capture. Covers would be placed on the most odorous portions of each basin, which the sampling conducted in July and October indicated was the first pass of each basin. Additional sampling is currently underway to confirm that the first pass is the most odorous portion of each basin.

Alternative odor treatment technologies were considered, including chemical scrubbers and biofilters. Biofilters were determined to be the best choice for odor control for this source. Cost estimating for this phase was based upon sizing main runs of ductwork to accommodate Phase 2 improvements as well as Phase 1. Figure 5 shows the expected peak D/T contours after completion of the Phase 1 improvements.

Phase 2 would consist of covering an additional 25 percent of each aeration basin and adding another biofilter to treat the additional ventilation air. Ductwork constructed in Phase 1 will be in place to handle Phase 2, so little additional ductwork would be needed in Phase 2. Figure 6 shows the expected peak D/T contours after completion of the Phase 2 improvements.

The existing chemical scrubber at the headworks is being augmented by the addition of a second two-stage scrubber system. This will allow the detention time in the scrubber to be increased, increasing the efficiency of mercaptan removal, and will provide redundancy so that odor treatment is continued during regular maintenance of the scrubber systems.

Carbon polishing of the headworks scrubber outlets will be added to the Phase 2 improvements should the odor emission rate remain high after installation of the second scrubber system.

Estimated costs for the Phase 1 and Phase 2 improvements are shown in Table 3.