Biological Treatment of Collection System Odors

Cost-Effective Solution in a Coordinated Approach to Odor Control

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The Collier County Wastewater Department serves over 45,000 customers within a 135-square-mile area of Southwest Florida. The wastewater collection system includes more than 675 lift stations, with over 700 miles of gravity and force main pipes. Several hundred small lift stations feed into master and sub-master lift stations, which in turn pump the wastewater to the treatment plants.

The service area is divided into a north and south collection system, with water from the north service area treated at the 17.5-MGD North County Regional Water Reclamation Facility (NCRWRF) and water from the south collection system treated at the 16-MGD South County Regional Water Reclamation Facility (SCRWRF). By mid-year 2005, the combined treatment capacity will be expanded to 40.1 MGD.

Over the last couple of years the county's wastewater department officials have developed a growing concern for odor and corrosion problems in their collection system, triggered by rising costs for sewer rehabilitation work and complaints from citizens living near existing sewer lift stations. Similar to most wastewater collection systems in this area of the country, the Collier County sewer collection system is characterized by a number of factors known to create a potential for the development of an odorous and corrosive environment:

- Gravity sewer lines are regularly installed at a minimum slope of 0.33 percent to 0.40 percent, resulting in long detention times.
- The collected wastewater frequently needs to be re-pumped several times before it reaches a Water Reclamation Facility (WRF), thereby further increasing the detention time.
- Flow rates from areas currently under development are only a fraction of the design flow rates at built-out conditions.
- Average wastewater temperatures during the summer months range between 80 degrees and 90 degrees Fahrenheit.

In 2001, Collier County tasked the consulting engineering firm CDM Inc. to perform a system-wide odor and corrosion control study with the following goals:

- Investigate the potential for odor and corrosion problems throughout the collection system.
- Evaluate the county's existing odor control measures.
- Make recommendations on how to effectively prevent odor and corrosion problems at lift stations and manhole locations.

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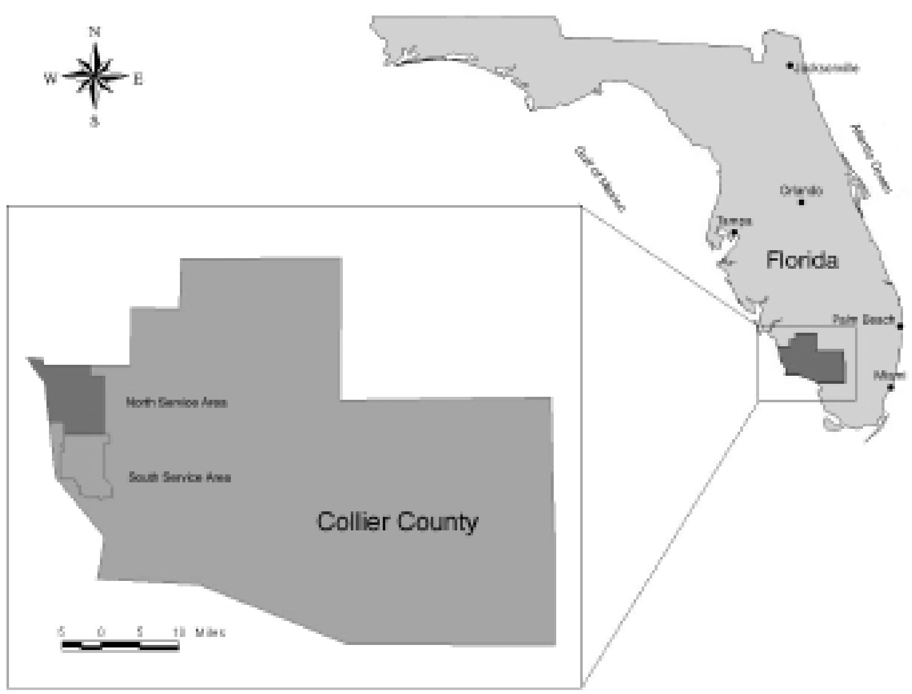
Figure 1: Location of Collier County



Methodology

The study was divided into the following four phases:

Phase I

The wastewater department identified 68 "hot spots" where odor and/or corrosion problems had been observed in the past. During the first phase of the study, these 68 locations were inspected for corrosion. The headspace hydrogen sulfide (H_2S) concentration was measured using a Multi Gas Detector. The H_2S removal efficiency of existing air stream odor control systems was tested using a Jerome Hydrogen Sulfide Gas Analyzer capable of measuring H_2S concentrations as low as 1 part per billion (ppb) in situ. The maximum recommended concentration is 50 ppb.

Dissolved H_2S concentrations in the wastewater stream were measured using open detector tubes immersed in the water for several minutes. A lead reagent in the detector tube causes a brown stain when exposed to sulfide ions. The sulfide concentration in the water is directly related to the length of the reagent stained. The H_2S detection tubes used in the study ranged from 1 to 1,000 parts per

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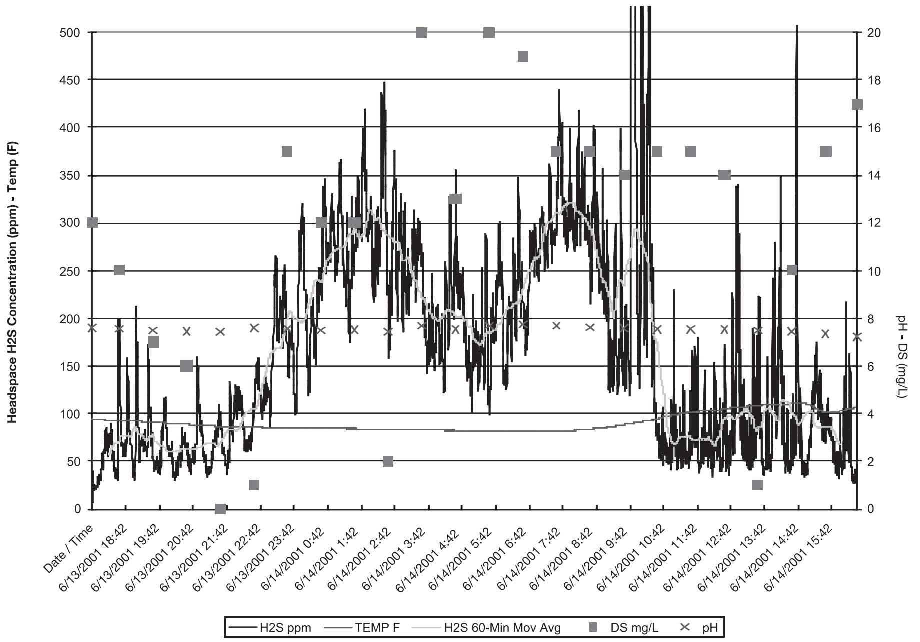

Figure 2: Typical Sampling Chart for Concurrent Liquid and Air Phase Sampling

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million (ppm) dissolved sulfides (DS).

The location of the lift station or manhole in question was evaluated in regard to its proximity to residential and commercial properties and its potential to trigger odor complaints. Based on the Phase I observations, 14 master pumping stations and their tributaries were identified as existing or potential problem areas and recommended for further investigation during Phase II.

Phase II

Phase II of the study included the inspection of the 14 master pumping station areas identified during Phase I. A total of 119 lift stations were inspected for the following parameters:

- Corrosion
- Headspace H_2S concentrations, carbon monoxide concentrations, methane concentrations, oxygen concentrations
- Air temperature
- DS concentrations, dissolved oxygen (DO) concentrations, pH, temperature, oxygen reduction potential (ORP)
- Monthly average flow rates

All collected data were transcribed into an Microsoft Access database for further evaluation. The data were then used to model the generation of DS in short reaches of the sewer system using a computer program developed by CDM Inc., which simulates the generation of DS in a wastewater. The model was intended as a tool to evaluate the cost effectiveness of various chemical applications for H_2S reduction, including hydrogen peroxide, sodium hypochlorite, and calcium nitrate.

Phase III

Phase III of the study focused on the following objectives:

1. To determine the correlation between DS concentrations in the liquid stream and H_2S concentrations in the headspace of a lift station.
2. To investigate the beneficial effects of forced ventilation on headspace H_2S concentrations.

For this purpose an OdaLog® Hydrogen Sulfide Logger was installed in the headspace of the lift station. The H_2S concentrations and the air temperature were continuously monitored for 24 hours. Hourly liquid phase samples were taken during the same time from the wastewater stream using an ISCO sampler. The samples were then analyzed for pH and for DO and DS concentrations.

The DS concentrations were correlated to the average H_2S concentration in the headspace during that sampling period using linear regression techniques. A statistically significant relationship between the two components would allow the establishment of maximum DS concentrations in the liquid stream in order to effectively control H_2S concentrations in the headspace.

In order to investigate the beneficial effects of forced ventilation on headspace H_2S concentrations, the above sampling procedure was applied to a lift station with an existing air-stream odor-control system. Samples were taken for two 24-hour periods—once with the ventilation system shut off and once with the ventilation system operating.

Phase IV

Phase IV of the study focused on the evaluation of different air-stream technologies applicable to sewer pumping stations. A total of nine different odor-control systems from the following categories were pilot tested for H_2S and odor removal efficiencies:

- Iron Sponge
- Iron Sponge followed by Granular Activated Carbon (GAC)
- Biofilters
- Bioscrubbers

In addition, GAC was tested for H_2S removal efficiencies. Due to the widespread use of carbon for odor treatment and the amount of available performance data, GAC was not tested for odor removal efficiencies. The H_2S removal efficiency for each unit was determined using a Jerome Hydrogen Sulfide Analyzer. Odor removal efficiencies were determined in accordance with ASTM E679.

Air samples were collected at the inlet and outlet of each unit and analyzed for Dilution to Threshold (D/T), Recognition Threshold (RT) and Hedonic Tone (HT). Each sample was thereby presented to an odor evaluation panel consisting of individual assessors who evaluated different dilution levels of each sample for recognition and HT. The D/T ratio is an estimate of the number of dilutions needed to make actual odor emission just detectable. The RT value is the dilution ratio at which the assessor first detects an odor's character.

All samples were analyzed by St Croix Sensory Inc., Lake Elmo, Minnesota. Each of the technologies was then subjected to a 20-year present-worth analysis based on H_2S concentration and airflow.

Results

DS Modeling

The data collected during Phase II of the study were applied to a computer model in order to predict the generation of DS in short reaches of the collection system. Although the model could be calibrated successfully for some areas, in most cases the predicted DS concentrations could not be matched with the values observed in the field. After all the model's input parameters were checked, the pump station flow rates could not be established accurately. A comparison of the reported flows into and out of a pumping station showed discrepancies of up to 400 percent. It was concluded that the established model could not be applied to predict the efficiency of DS-reducing chemicals for the county sewer collection system.

The evaluation of the collected data revealed unusually high concentrations of sulfides along with high pH values in one particular branch of the collection system. The elevated concentrations of both DS and pH were caused by the disposal of excess water from the degasifiers located at the county's reverse-osmosis water treatment plant (Pumping Station No. 154.00).

Sampling at various locations between the water treatment plant and the receiving NCRWRF revealed that the pH remained at elevated levels solution all the way to the NCRWRF, thereby keeping any DS in solution. CDM was therefore able to recommend that chemical feed facilities located along the route between Pumping Station 154.00 and the NCRWRF be relocated elsewhere in the collection system where they would be of greater benefit.

Correlation between DS and Headspace H_2S Concentrations

None of the observed correlation coefficients between DS concentrations in the liquid stream and H_2S concentrations in the headspace was greater than 0.2. It was therefore concluded that there was no statistically significant direct relationship between the two parameters based on the collected data.

Effects of Ventilation on Headspace H_2S Concentrations

Two master pumping stations were investigated to demonstrate the positive effects of forced ventilation on headspace H_2S concentrations. Pumping Station No. 318 was ventilated at a rate of 4.6 air changes per hour (ACH). While average DS concentrations in the liquid stream were approximately constant, the average H_2S concentration was reduced from 128 ppm with no forced ventilation to 18 ppm with forced ventilation. Pumping Station No. 316 was ventilated at 2.5 ACH. At this location average H_2S concentrations were reduced from 112 ppm with no forced ventilation to 10 ppm with forced ventilation.

Evaluation of Different Air-Stream Treatment Technologies

Iron Sponge followed by GAC

Iron sponge media is composed of wood chips impregnated with ferric oxide. The media reacts with H_2S to produce stable sulfur compounds, most of which are removed from the media as leachate. Two units, one with a rated capacity of 650 cubic feet per minute (cfm) and one with a rated capacity of 265 cfm were tested for performance. Each iron sponge system was equipped with a second GAC stage for additional air treatment.

While the H_2S removal efficiencies across the iron sponge media was >99.9 percent, the odor removal efficiencies across the iron sponge media was in the range of 69 percent to 76 percent. The overall odor removal rates across both stages were in the range of 70 percent to 97 percent.

Biofiltration Systems

Testing results for two different biofilter

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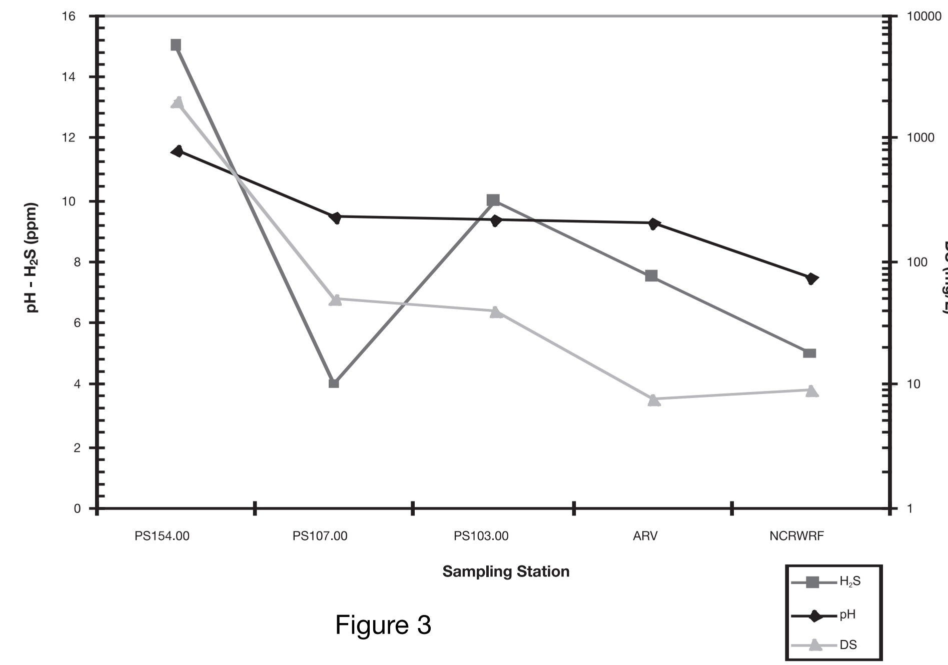

Figure 3

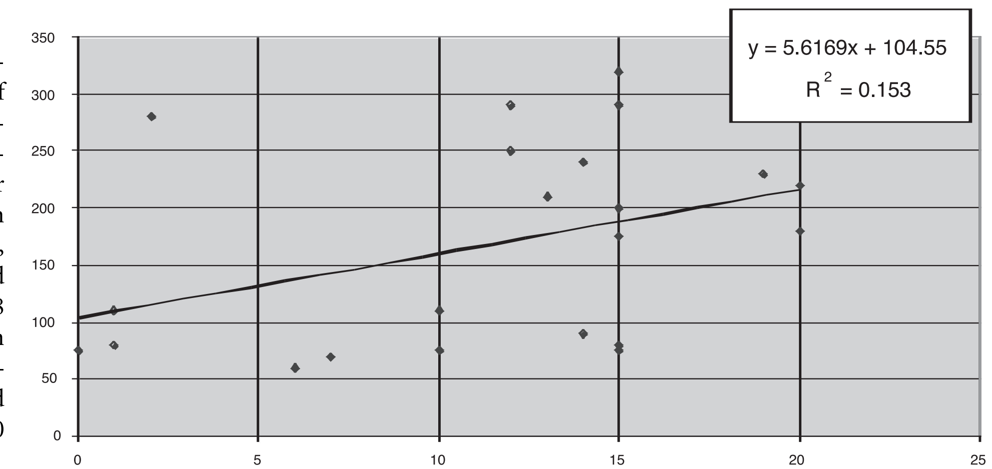

Figure 4: Typical Correlation between DS and H_2S Concentrations

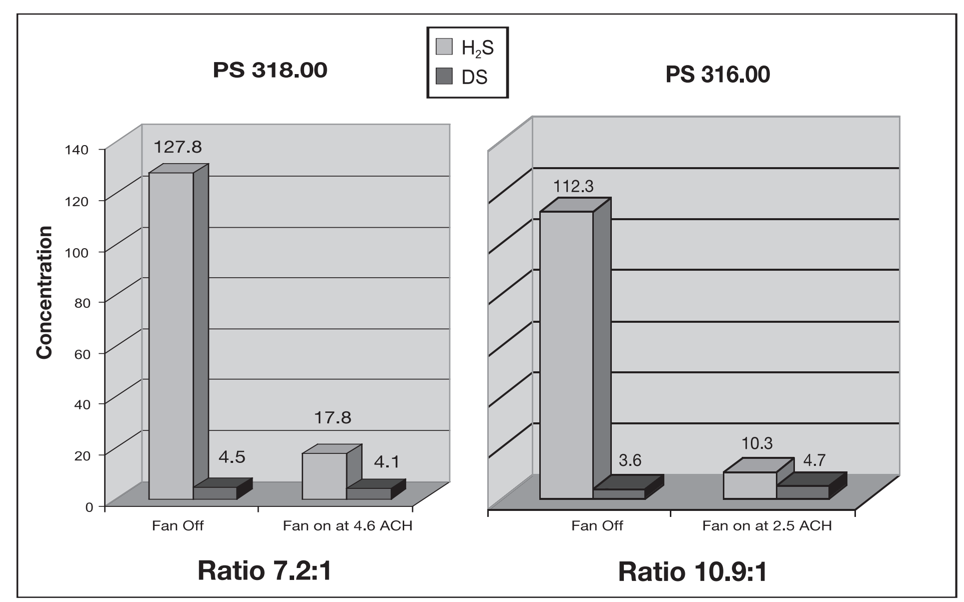

Figure 5: Effects of Forced Ventilation on Headspace H_2S Concentrations

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systems are presented in the tables on this page. The first system was a two-stage biofiltration system with proprietary inorganic media at the bottom and proprietary organic media at the bottom of the up-flow vessel. Two irrigation systems provided water and nutrients to each media component. The rated design capacity was 350 cfm.

The second system was a one-stage down-flow unit designed to treat 330 to 550 cfm of foul air. The unit was designed as a down-flow system. Foul air was first introduced to an external conditioning (humidification) chamber, then through a plenum at the top of the reactor, through the media to an exhaust plenum, fan and exhaust stack.

Sampling Location	Test No.	DT	RT	HT	H_2S (ppm)
Inlet to Iron Sponge Unit	1	1400	940	N/A	25
Outlet from Iron Sponge Unit	1	1900	1100	-2.0	0.003
Inlet to Iron Sponge Unit	2	7400	3800	N/A	110
Outlet from Iron Sponge Unit	2	2300	1300	-3.8	0.065
Outlet from GAC Unit	2	1500	760	-4.0	0.028

Table 1: Testing Results for Iron Sponge Followed by GAC (650 cfm Rated Capacity)

Sampling Location	DT	RT	HT	H_2S (ppm)
Inlet to Iron Sponge Unit	2500	1600	N/A	47
Outlet from Iron Sponge Unit	580	300	-2.4	0.019
Inlet to Iron Sponge Unit	8100	5100	N/A	193
Outlet from Iron Sponge Unit	2400	1200	-4.4	0.20
Outlet from GAC Unit	210	100	-2.8	0.27

Table 2: Testing Results for Iron Sponge Followed by GAC (265 cfm Rated Capacity)

Sampling Location	DT	RT	HT	H_2S (ppm)
Inlet to Biofilter	4500	2500	-4.9	20
Outlet from Biofilter	220	120	-3.1	0.002

Table 3: Testing Results for Biofiltration System No. 1

Sampling Location	DT	RT	HT	H_2S (ppm)
Inlet to Biofilter	1200	710	-3.6	1.4
Outlet from Biofilter	75	35	-3.6	0.017

Table 4: Testing Results for Biofiltration System No. 2

Sampling Location	DT	RT	HT	H_2S (ppm)
Inlet to Bioscrubber	5000	3400	-5.4	20
Outlet from Bioscrubber	590	400	-3.9	0.13

Table 5: Testing Results for Biofiltration System No. 2

The proprietary media was installed in an 89-inch diameter round vessel and packed at a four-foot height. An irrigation system comprised of continuously operated fine nozzles located at the top of the reactor provided water and nutrients to the system. Removal efficiencies for H_2S could be tested only for relatively low concentrations.

When tested, the unit was treating 291 cfm of foul air. The average contact time between the foul air and the media was 54 seconds. In both cases the removal efficiency for H_2S was greater than 99 percent. The observed odor removal efficiency was between 93 percent and 95 percent.

Bioscrubber System

A pilot biotrickling filter unit was tested for odor and H_2S removal efficiencies. The tested unit consisted of two compartments filled with inorganic proprietary media. The media in the upper compartment is intended to remove H_2S and other inorganic odorants. The media in the lower compartment is intended to remove organic odorants. Nutrients (nitrogen and phosphorous) were provided by chemical addition. Recirculated water was distributed at the top of the media, trickling downward countercurrent to the foul air. The tested unit had a rated capacity of 290 cfm.

Observed H_2S removal rates were 99.4 percent. The measured odor removal rate was 88 percent.

Economic Evaluation

A 20-year present-worth analysis was performed for the tested units based on the following economic factors:

- Interest rate: 8 percent
- Term: 20 years
- Inflation: 2 percent

Unit costs for consumables were assumed as follows:

- Electricity: \$0.08 / kilowatt-hour
- Water: \$1.44/1,000 gallons with minimum charge of \$12 per month
- Water meter: \$1,600 one-time charge
- Labor: \$30,000 per year

Costs for single-use activated carbon were taken from the existing contract between the county and General Carbon Corp. as \$0.79 per pound. Costs for biofilter and bioscrubber systems were obtained from the manufacturers. Iron sponge-based systems were not included in the analysis, since the observed odor removal rates were not consistent with the consultant's recommended minimum value.

Table 6 represents the lowest present-worth costs of the evaluated air-stream treatment technologies, based on influent H_2S concentrations and design flow rates between 100 cfm and 900 cfm. All costs are 2002 dollars.

Hydrogen Sulfide Concentration (ppm)	Design Flow Rate			
	100 cfm	250 cfm	500 cfm	900 cfm
1	Single-Use Carbon \$12,000	Single-Use Carbon \$21,000	Single-Use Carbon \$42,000	Single-Use Carbon \$67,000
5	Single-Use Carbon \$28,000	Biofilter \$54,000	Biofilter \$85,000	Biofilter \$119,000
20	Biofilter \$50,000	Biofilter \$54,000	Biofilter \$85,000	Biofilter \$119,000
50	Biofilter \$50,000	Biofilter \$54,000	Biofilter \$85,000	Biofilter \$119,000

Table 6: Lowest Present-Worth Costs (in 2002 Dollar Amounts) and Recommended Air-Stream Treatment Technologies

Conclusions from Study

Parts of the sewer collection system showed high pH values along with high DS concentrations caused by the disposal of chemicals at the county's water treatment plant. It was shown that the pH remained high enough to keep the DS in solution along the entire flow path. The discovery resulted in the removal of an existing calcium nitrate injection system and direct cost savings for the county.

It was demonstrated that forced ventilation, even at low levels, greatly reduces the presence of H_2S gas in a pumping station headspace. Increased ventilation and vapor-phase odor control was recommended for 12 of the investigated pumping stations. A goal of six to 12 air changes per hour was set for the project, based on the collected data and previous experiences.

After the four air-stream odor-control technologies were piloted at nine locations for their H_2S and odor removal efficiencies and subjected to a 20-year present-worth analysis based on intake H_2S concentrations and the desired design flow rate, it was concluded that single-use GAC was the most economical technology to treat low H_2S concentrations in the county's collection system. For inlet H_2S concentrations of 5 ppm or above, biofilter-based systems became the technology of choice.

The study resulted in a multi-year procurement for the Collier County Wastewater Department. After analyzing performance, service capabilities, price and other criteria, the county awarded the contract to USFilter for its ZABOCS™ two-stage inorganic media biofilter unit. Currently 31 biofilter units with capacities ranging from 75 cfm to 5,000 cfm have been installed at critical locations throughout the collection system.

Odor-Control Strategy

Today, Collier County uses a coordinated approach to odor control, balancing the use of monitoring, operational controls, chemical additives, biofilters and chemical scrubbers to achieve its goals. The county has adopted a "zero tolerance" policy for odor-control issues in the collection system and has developed a strategy that actively involves residents with odor complaints in the problem-solving process.

Customer satisfaction, corrosion concerns, and worker safety are the three main drivers for odor and corrosion control. Complaints received are logged and then investigated using a variety of monitoring tools that include a Jerome 631-X Hydrogen Sulfide Gas Analyzer and OdaLog Hydrogen Sulfide Loggers. These tools monitor odor levels inside and outside the well over several days. Once the timing and concentration of the odors are quantified, odors may be reduced by cleaning the wet well, cleaning the gravity system feeding the well and possibly raising the well level, and adding drop pipes to reduce turbulence.

Although these operational procedures usually reduce H_2S levels by as much as 50 percent, odors may still persist. In such cases, a biofilter is installed and chemical additives upstream are considered. The utility customer is kept apprised of the evaluation and decision-making process, with nearby homes factored into the decision.

In addition to biofilters for odor control in the collection system, Collier County uses chemical scrubbers for odor control at the treatment plants. Liquid-phase treatment (chemical addition to the wastewater) at strategic locations in the collection system helps stabilize odor levels at the biofilters and scrubbers and provides a means of controlling chemical cost at the scrubbers. The optimal balance of chemical usage (liquid-phase additives versus scrubber chemicals) is achieved by maintaining the H_2S levels at the headworks scrubbers in the vicinity of 50 ppm.

Chemical Addition

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The Odor Control Decision-Making Process Developed by the Collier County Wastewater Department

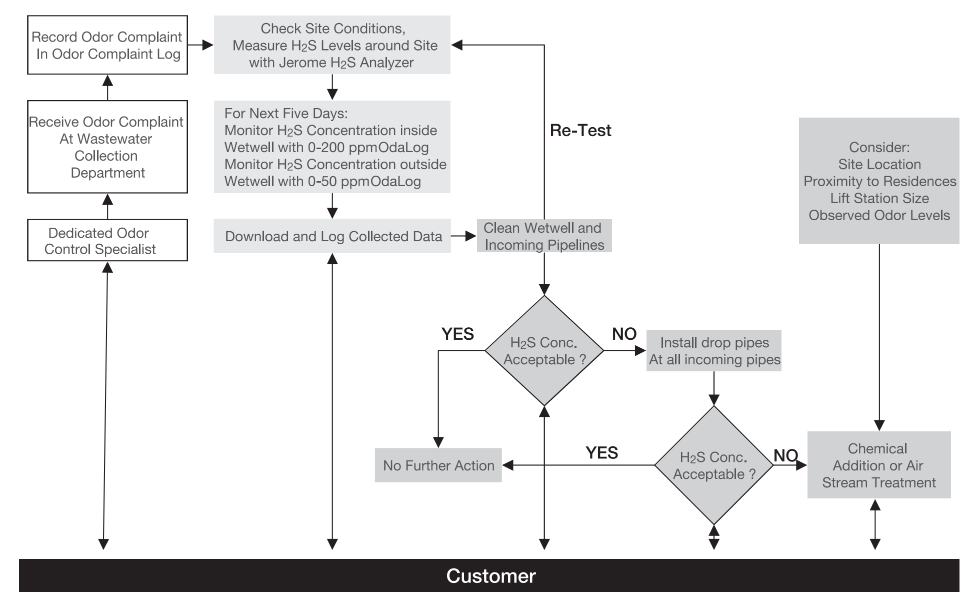

Figure 6: The Odor-Control Treatment Process Followed by the Collier County Wastewater Department

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A proprietary nitrate-based solution called Bioxide® process is injected into the collection system at 10 strategic locations to limit the H_2S loads on vapor-phase treatment systems installed at the treatment plants or at master and sub-master lift stations. Nitrate feed rates are adjusted to maintain H_2S concentrations at the chemical scrubbers below approximately 50 ppm or to maintain the average H_2S levels entering the biofilters located at master and sub-master lift stations at or below 100 ppm. It is possible to optimize the overall cost for effective odor control by balancing the addition of nitrate and the H_2S loading rates at the odor control systems.

Chemical addition is generally controlled manually and may be adjusted seasonally as needed. As depicted in Table 1, the county does not use a set formula for setting the chemical rates, but rather uses a trial-and-error process ultimately aimed at minimizing chemical cost while providing acceptable levels of odor control.

At Pump Station 302.00, the nitrate feed rate is controlled automatically using an advanced dosing controller. The controller adjusts the chemical feed rate according to either the wastewater flow or a pre-programmed dosing profile curve. The flow-proportioned injection of nitrate at Pump Station 302.00 has improved the daily fluctuation in odor levels, reduced chemical cost, and provided a steadier H_2S concentration to the SCRWRF headworks scrubbers. The county is considering installing similar automated controls at additional sites throughout the collection system.

Force Main From Pump Station	Force Main Flow Rate, gal/min	Nitrate Solution Injection Rate in Gallons per Day (gpd)	Force Main To Pump Station or WRF	Control Basis	Target
318.00	256	38	301.00	Manual	< 100 ppm at 301.00 Biofilter
306.00	914	91	302.00	Manual	< 100 ppm at 302.00 Biofilter
312.00	No data	0	302.00	N/A	
309.00	1,129	140	312.00	Manual	< 100 ppm at 312.00 Biofilter
310.00	692	23	312.00	Manual	
313.00	2,023	99	312.00	Manual	
302.00	2,718	226	SCRWRF Headworks	Automated Dosing Controller	< 35 ppm at South WRF Headworks Scrubber
103.00	750	194	NCRWRF Headworks	Manual	< 50 ppm at North WRF Headworks Scrubber
101.00	1,100	162	NCRWRF Headworks	Manual	< 50 ppm at North WRF Headworks Scrubber
105.06	355	50	NCRWRF Headworks	Manual	< 50 ppm at North WRF Headworks Scrubber

Table 7: Summary of Chemical Addition to Collection System

Summary

Collier County has developed the following odor-control strategy:

- Evaluate the odor sources, odor levels, and available odor-control technologies.
- Standardize on odor-control equipment design and suppliers.
- Balance upstream chemical addition with scrubber chemical costs.
- Have the equipment supplier provide regular service and maintenance, including spare and replacement parts.

This coordinated approach to odor control has proven effective. The CDM study provided the priorities and groundwork for implementing odor control in the collection system. Standardizing on chemical scrubber and biofilter designs greatly simplifies the purchasing process, equipment installation, operator training, spare parts, service and maintenance. Having laid the groundwork, Collier County officials are confident that they have the knowledge and resources ready to respond quickly and effectively to odor-control issues wherever they occur.

Acknowledgements

The authors wish to thank James Gammell and Steve Nagy of the Collier County Wastewater Department for their support throughout the project.

References

- *Camp Dresser & McKee Inc., 2002,* Odor Control Study for the Collier County Wastewater Collection System*, 132 p.*
- *Water Environment Federation,* Odor Control in Wastewater Treatment Plants*, WEF Manual of Practice No. 22, ASCE Manuals and Reports on Engineering Practice No. 82, Chapter 3, p. 35-54.*
- *Pomeroy, R.D., and J.D. Parkhurst,* The Forecasting of Sulfide Buildup Rates in Sewers, Progress in Water Technology*, 9 (3), 1977.*
- *EPA, 1985, Design Manual – Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants, EPA/625/1-85/018, p. 132.*
- *EPA, 1992,* Detection, Control, and Correction of Hydrogen Sulfide Corrosion in Existing Wastewater Systems*, EPA 832-R-92-001, p. 114.*