One Size Does Not Fit All:
Multiple Strategies for Reducing Collection-System Odors

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Odor complaints emanating from sewage collection systems can often create more public relations headaches for wastewater utilities than large odor sources generated by treatment plants because of the number of point sources. Geographical distribution, topography, property limitations, and proximity to residences or businesses all play roles in determining the nuisance factor these odors create.

No single technical approach can combat these complaints, and yet reducing upstream odors can reduce odor control requirements in the receiving treatment facilities and mitigate collateral problems, such as corrosion induced by high hydrogen sulfide levels.

There are several techniques for minimizing odors in the collection system piping and pump stations, including on-line chemical additions for pH control, removal of gravity drop manholes, covering open-channel flows, solids reduction, vapor phase scrubbing, and biofiltration. A coordinated strategy for collection-system odor control not only provides a cost-effective means of dealing with point odor sources but improves the useful life of the piping and equipment and makes the system a better neighbor to the customers it serves.

Identifying the Problem: (The "Why Does it Stink So Bad?" Phase)

Cataloging and quantifying odors is a science unto itself. It's critical not only to identify the noxious constituents but their prevalence so that the proper control strategies can be applied.

In collection systems, there are no single "silver bullets" which will minimize or eliminate odors because the nature of the odors can vary in the pipeline, at the pump station, and on the way to the treatment plant, and also because a single collection system often has many points of odor release. Strategies for controlling these odors are outlined in Table 1.

Since the overall solution for any given collection-system odor problem may be a combination of physical and chemical abatement approaches, the key first step is to assess the odor sources. While mercaptans, ammonia compounds, and various volatile organic compounds (VOCs) are contributors to most odors, hydrogen sulfide (H_2S) remains the most identifiable marker in most complaints—and it takes very little of it to be noticed. Only 0.00047 ppm is the H_2S odor threshold. In order of ascending order of complexity (and cost), here are three approaches to characterizing odors:

- Grab bag sampling for specific pollutants
- Empanelling odor "sniffers" using the ASTM Standard E679.91, *Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration of Limits*
- Air modeling using EPA Screen Model 3.0

All three approaches seek to establish the baseline conditions to be treated. In the past, odor-control systems design was primarily based on controlling hydrogen sulfide, since it is a major source of wastewater odors, but the variable nature of wastewater means that many potential odor-causing compounds could exist at each unit process. Relying only on the measurement of hydrogen sulfide can lead to invalid conclusions, particularly if there are significant concentrations of other odor-causing compounds.

Because the need to control odors is driven by the detection of odors by people living or working in the area of the source, using the human nose to evaluate odor samples gives the most reliable results. By using an odor panel made up of individuals who have been tested for their odor sensitivity, the "smelliness" of the odor source can be determined.

This "smelliness" is quantified by the D/T, or dilution-to-threshold ratio. The D/T is the dilution at which half the members of the odor panel would be unable to detect the odor. A D/T value of 100 means that if an odor sample is diluted with clean air at a ratio of one part odor sample to 100 parts clean air, half the people on the odor panel would be able to detect an odor and the other half would not. A D/T value of 1 is the point at which the average person can detect an odor in an otherwise clean environment.

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The results of the sensory analysis alone can not be used to determine whether an odor source is an odor problem. Even if an odor source has a high D/T, if the release rate of the odor is low, the odor may not be a problem.

The release rate for a point source depends on the volume of air being discharged. The release rate for area sources depends on the surface area of the odor source and the air-flow rate from any aeration that is taking place.

The U.S. EPA Screen Model, Version 3.0, is frequently used to determine the dispersion of each odor source in the atmosphere. The results of the modeling indicate the potential for each odor source to travel off site.

Local weather conditions have the most impact on the dispersion of an odor in the atmosphere. During calm conditions, less mixing of an odor with the surrounding air occurs, so the odor will transport further than during windy conditions, when mixing dilutes the odor more quickly. The model provides a good indication of average odor concentrations during atmospheric conditions that last at least one hour.

Since it is known that peak concentrations of odor can occur in puffs, some method of evaluating peak odor conditions is needed. In order to determine the peak condition, the odor concentrations found during sampling are multiplied by a peaking factor of 3 for point sources and 10 for area sources. The peaking factors are determined based on previous plume dispersion study results.

Air modeling is typically applied to plant settings but can be used on large pump stations where there is significant exposed liquid surface area, such as adjoining flow equalization, screw lift wells, and grit removal chambers.

Table 1: Odor Control Strategies

Physical Abatement	Chemical Abatement
Remove or minimize odor sources	Reduce odor constituents in wastewater stream
Contain odor sources	Reduce odor constituents concentration that off gas into the environment (i.e., commonly referred to as "scrubbing")

Evaluating Solution Alternatives (The "Finding the Fix" Phase)

Using the presence of H_2S off-gassing from the influent wastewater as the primary criteria, the application of the various abatement methods in Table 2 are categorized according to their effectiveness – effectiveness being measured by the reduction in perceived odors by the public.

The challenge in selecting effective solutions is finding the balance between:

- Capital costs
- Life-cycle operating costs
- Operability and maintainability of the collection system components with odor control in place

The applications presented may be used singly or in combination with one another to maximize odor reduction potential.

Table 2 - Perceived Odor Reduction Effectiveness Based on Influent H_2S in Air

	Odor Control Method	Applications	H_2S Inlet (ppmv)	Perceived Effectiveness (% Reduction)
Physical Abatement	Covers	Open channels, wet wells	> 0.0005	75-95
	Reduce Gravity Drops	Collection gravity piping	> 0.0005	50-75
	Repair/Remove ARV's	Force mains, steep gravity piping	> 0.0005	75-100
	Extend Pump Cycles	Pump stations, force mains	> 0.0005	50-75
Chemical Abatement	On-line Addition	Gravity piping, force mains, wet wells	0.1 – 1.0 mg/L (1)	80-90
	Wet Scrubbing	Larger channels, wet wells	10 – 200	95-99
	Dry Scrubbing	Small channels, wet wells, post-wet scrubber	< 10	95-99
	Ozonation	Small channels, wet wells, MHs, "still air" spaces	< 100	95-99
	Biofilters	Channels, wet wells	10 – 150	90-99

(1) Total sulfides in solution in wastewater

Odor Abatement Applications (The "Problem Solving" Phase)

Understanding that multi-pronged approaches are needed with most collection system odor problems, here are the applications that have proven effectiveness:

Physical Abatement

Installation of Covers: Perhaps the simplest, most cost-effective of all approaches is reducing the exposed surface area of wastewater flows by installing covers. Regardless of measured H_2S levels, covers can provide a physical barrier to releases and can channel odors to other systems designed to mitigate them. Excellent results have been obtained by specifying 6061-T6 and 6063-T6 grade aluminum alloy fabrications, field-cut to cover structures such as influent channels, screw lifts, wet wells, open flow metering vaults (e.g., Parshall fumes), and splitter boxes.

For existing pumping facilities, consideration must be given to:

- Access to equipment and instruments – operation, maintenance, clearances, possible submergence at high flows, expected loads on covers, sealing to reduce leakage
- Electrical area classification – enclosed area often goes from being unclassified to Division

Continued on page 28

Continued from page 27

2 or 1 per National Electrical Code (NEC – NFPA 70) because of heightened concentration of flammable/combustible gases, additional costs for explosion-proof wiring and enclosures and intrinsically safe devices (including combustible gas detection)

- Confined space – volume of enclosed space and access/egress is reduced, possibly requiring different access methods and classification for life safety entry procedures, special ventilation, and alarming

In some rare instances, enclosing spaces can accelerate corrosion of unprotected ferrous metals and concrete by concentrating and extending detention times of ambient H_2S levels. Evaluating present coatings and surface features (such as exposed rebar, spalling concrete) should be performed and appropriate finish treatments applied before installing the covers.

Covers have these added benefits:

- Creating a more aesthetic appearance - particularly if there are open structures that are visible to adjacent property owners
- Reducing the volume of trash, vegetation, etc. that can find their way into these structures
- Preventing unauthorized entry – vandalism and accident prevention particularly when covers are secured
- Reduction of air volumes over exposed wastewater flow which might subsequently be treated by scrubbing.

Reduction of Gravity Drops in Piping: For piping systems exceeding 1-percent slope, gravity drops are often installed to reduce velocities which can scour pipe, particularly if there is significant grit entrainment in the wastewater stream. Prudent design seeks to limit these velocities to a maximum of 8 to 10 feet per second.

Depending on topography that the collection piping is threaded through, some gravity drops can have significant releases of H_2S as the flow cascades down through the manhole structure, creating dissolution from liquid to vapor phases. Pipes that flow less than full can exacerbate this release with the mixing from air above the liquid level traveling at the same velocity as the wastewater. This turbulent mixing tends to create high H_2S concentrations immediately before and after the drops, often resulting in pronounced corrosion of unlined ferrous piping at these locations—particularly in the pipe crown that can lead to pipe failure (and a resulting spill).

Gravity drops installed on long runs of shallow-sloped pipe where detentions can exceed eight hours can be particularly problematic, with very low pH flows, and in warm climates where the effluent can turn anaerobic, more rapidly yielding higher levels of H_2S. Aside from minimizing grit introduction, reducing the number and invert differences within gravity drops limits:

- Off-gassing of odor constituents
- Off-gassing of explosive vapor mixtures from combustible or flammable liquids/solids in the wastewater
- Corrosion of piping and structures around the drops
- Releases of odors through vented manholes (i.e., no air/vacuum release valve installed)

Where drops can not be eliminated, good results have been obtained by constructing separate vent standpipes with air/vacuum release devices in lieu of perforated manhole lids and, depending on proximity to public receptors, installing canister-type odor control devices. These devices employ carbon or potassium permanganate for adsorption, require periodic media checking and replacement. In locations where average H_2S levels are less than 20 ppmv, these units can be cost-effective.

Repair or Elimination of Faulty Air Release Devices: Air release and air/vacuum release valves perform the valuable function of removing entrained air, primarily in force mains, which can increase head conditions if left uncontrolled; however, they are frequently misapplied because of the following errors:

- They are improperly sized because of lack of proper surge analysis on the force main.
- They are installed in locations that are not high points in the system, or they are con-

nected to the pipe in such a way that they flood, rendering them ineffective.

- All internals are not constructed of corrosion-resistant materials, such as 304 or 316L stainless steel, making them prone to failure.
- They are not checked or maintained, often being found frozen in an open position due to corrosion or a blockage, allowing odors to be released.

Minimizing the number of air relief valves, installing combination air/vacuum relief valves, and (where hydraulically possible) installing vacuum relief (only) valves are the options.

Extension of Pumping Cycles: On the surface, this approach may seem to be compromised by increased energy use, but the concept is to reduce motor starts as well as shorten detention time in the pipeline. Oversized pumping capacity or actual flows that are dramatically below the predicted design conditions can result in pumps short-cycling, which places stress on motors by increasing winding temperatures. As a precaution, most pump starts are limited by time delays to preserve motor life and reliability.

When flow is stopped or velocities fall below about 4 feet per second, however, aggregation of solids can occur apart from the liquid (dependent on pipe slope) and the wastewater can turn septic, generating more odors. As detention time increases, sulfates are reduced as anaerobic conditions prevail and more H_2S comes out of equilibrium into the air.

Maintaining aerobic conditions in the force main can also allow for chemical addition to reduce dissolved sulfides. In pump stations with pumps of varying capacities, matching average daily flows to the right pump or pump combination can allow pumps to operate over longer cycles with the lowest horsepower available.

Where even the smallest pump's operation for baseline flows results in more than four starts per hour, variable frequency drives (VFDs) should be considered, especially if an existing motor starter needs to be replaced, because a VFD can serve as the starter. Also, throttling "lead" pumps or adding smaller pumps to handle the average daily base load should be considered.

Chemical Abatement

Chemical abatement of odors can be grouped into two categories: reduction of soluble H_2S in the effluent and reduction of odorants already released into the air above the waterline. Because of the specific density of H_2S, its heavier gaseous form tends to travel at the same velocity as the pipeline flow.

On-line Chemical Addition: Adding chemicals to the wastewater stream can either reduce dissolved sulfides or oxidize sulfides back to sulfate. Reducing the proportion of dissolved H_2S usually is accomplished by raising the pH (theoretically at a pH of 9, no H_2S gas is released). Based on pipeline detentions exceeding two hours, warmer temperatures in quiescent conditions, and increasing dissolved oxygen (DO) depletion rates with H_2S (in solution) above 0.1 mg/L, chemical additions may be appropriate to minimize dissolved sulfides.

Caustic (NaOH) is commonly used to oxidize sulfides and provides the bonus advantage of slowing down the corrosion rate on ferrous substrates. Sodium hypochlorite (NaOCl) is sometimes employed, but there must be significant chlorine residuals present for odor compounds to be oxidized.

Iron salts (ferrous sulfate or ferric chloride), calcium nitrate compounds, and hydrogen peroxide are all used to oxidize sulfides that are formed back to sulfate by introducing a cation to form a sulfide precipitate. The end result is to convert a portion of total sulfides from soluble to insoluble where it can't be released as H_2S gas.

Iron salts are acids which can be extremely corrosive to pipe walls and structural components, so care must be taken to feed directly into the waste stream. Also prior to effective mixing, H_2S will be generated at the feed point,

Continued on page 30

Continued from page 29
so that location should not be exhausted to ambient, creating a point odor source. Since both compounds are coagulants, solids will also tend to be precipitated and adequate horizontal flow velocities (>4 feet per second) are required to prevent settling.

Odor Scrubbing: Four primary types of odor scrubbing have been found particularly effective in reducing H_2S and VOC odors in collection systems:

1) *Wet Chemical Scrubbing.* Conventional scrubbers employ a vapor phase chemical reaction with H_2S and other air-stream constituents to remove the noxious contaminants. Packed bed tower single- and multi-stage configurations employ "wet chemistry" by circulating water containing typically NaOH and/or NaOCl over an inert, synthetic media through which the odorous air is passed in a counterflow direction.

For sulfur-related compounds, alkaline scrubbing, normally with sodium hydroxide and sodium hypochlorite, can be employed. For nitrogen-based off-gases, acid scrubbing is employed. As the recirculated chemicals come in contact with the foul air, the contaminants in the air are transferred to the liquid. The spent liquid is then wasted.

For pump-station applications, wet scrubbers have become more modular in design for airflows less than 5,000 cubic feet per minute, with the fans, recirculation pump, and often the chemical storage incorporated on a single skid. While footprint and height requirements (typically a minimum of 10 feet of media packing "travel circuit" is specified to attain adequate contact time) and the need for freeze protection in colder climes must be considered, wet scrubbers can address the highest influent airstream loadings (up to 200 ppmv) with the greatest removal efficiency (between 95 and 99.9 percent, based on H_2S in the exiting airstream). They also enjoy the longest history of proven performance, with many reputable manufacturers in the field.

For owners steering away from handling hazardous chemicals, there are a number of low- and non-toxic proprietary scrubber solutions available, although unit cost tends to be markedly higher.

2) *Dry Chemical Scrubbing (Carbon adsorption).* Activated carbon and (or in concert with) potassium permanganate are used primarily as media for removing concentrations of H_2S below 10 ppmv, mercaptans, and "polishing" VOCs that may not be removed using conventional wet scrubbers. The media are depleted over time as the contaminants are adsorbed, eventually requiring replacement or regeneration.

Because of the labor and material costs to replace or regenerate media (which involves physically removing the entire media volume), adsorption devices are best applied where average concentrations are low and inlet "spikes" are infrequent; however, the capital costs for carbon adsorbers are relatively inexpensive compared to other scrubber technologies.

3) *Ozonation.* For applications where air volume is relatively small or static, such as a wet well, submersible pump station, or enclosed screenings structure, this technology combines water, ozone, and air to produce a hydroxyl ion fog. The micron-sized water droplets, in concert with ozone, precipitate reactions with bacteria, VOCs, and H_2S as they disperse throughout the air space. Reaction byproducts are entrained as neutral (6 to 8 pH) condensibles.

In addition to eliminating the chemical costs and handling risks associated with conventional wet scrubbers, ozone systems break down grease and biofilms and can impede sulfide corrosion. Units have small footprints, low energy requirements, and short contact times (about five seconds); they are pre-packaged modules that are easy to install.

Applications treating up to 100 ppmv H_2S have been successfully operated. The water source must be clean because hard water or re-use quality can foul the atomizing nozzles with deposits.

Ozone units should not be used in conjunction with biofilters because incomplete chemical reactions may suppress bacteria in the media. These units are least effective on odor streams containing high levels of carbon dioxide (above 800 ppmv) or ammonia compounds (above 200 ppmv).

4) *Biofiltration.* Biofiltration uses a biological process to remove odorous compounds from foul air. Two types of biofilters can be used: bed and tower. The maximum capacity of tower biofilters is limited by the maximum available tower size, while the bed type can be constructed as large as necessary, assuming that space is available.

Biofiltration has the advantage of requiring little maintenance and having no chemical cost. Because odor reduction is accomplished through a biological process, conditions that promote the growth of odor-removing bacteria must be maintained. The bed material must be continually wetted, and some source of trace nutrients must be available in order to achieve acceptable removal efficiencies.

The biofilter bed can be constructed of several different materials. Compost-type materials (organic media) are typically used, but inorganic and synthetic media are also available. Inorganic media resemble lava rocks and are imbedded with the necessary trace nutrients.

Inorganic media have several significant advantages. The minimum detention time required for synthetic media is 20 to 40 seconds, depending on loading, while organic media require a one-minute residence time or longer. The depth of inorganic media beds can be up to 6 feet, while organic beds are limited to 3 feet; so the use of inorganic media results in significantly smaller biofilters—an important consideration when installing new odor-control units at an existing wastewater treatment plant.

Other advantages of inorganic media are much longer life (10 years compared to three years), a long media warranty (10 years), and the ability to regenerate the media rather than replace it.

One disadvantage of biofilters, assuming a bed type is used, is the space required. A typical design will require 1 square foot for every 1 to 3 cubic feet per minute of air. The area can become quite large where a high volume of air requires treatment.

Another disadvantage: Due to the bed-type construction, the biofilter becomes an area odor source. Little dispersion exists over the surface of the bed, so the required percent removals from biofiltration are greater than wet scrubbing.

Finally, due to the fact that biofiltration is a biological process, the removal efficiencies can be inconsistent.

Conclusions and Summary

Odor control in the various components of a collection system can require a multi-pronged strategy to minimize releases and the complaints that go with them. While odor science is also multi-tiered, basic grab samples of air and wastewater can be analyzed for H_2S in most municipal streams to yield a starting point for selecting a control scheme.

Reducing the exposed surface area of wastewater flows by installing covers is simple, yet effective. Shortening or eliminating gravity drops in piping minimizes H_2S dissolution in turbulent flow conditions. Repair or elimination of air release valves, or replacing them with vacuum reliefs where hydraulically feasible, reduces point odor releases. Extending pump cycles can prevent flows from stagnating into anaerobic conditions.

Where flows fall within certain parameters for velocity, DO, and temperature, there are pipeline chemical candidates which can either reduce dissolved sulfides outright or oxidize them back to sulfates. Many of these chemicals, such as FeCl, NaOH, and NaOCl, are already in use in most plants.

Scrubbing can employ these chemicals as well to treat noxious releases at pump stations, but because of space constraints, equipment maintenance and operating costs, and chemical costs and the associated hazards of handling them, many owners are turning to technologies like biofiltration and ozonation, which have lower life-cycle costs, particularly when odor contaminant loadings are low to moderate.