What's That Smell?!? Chemical Treatment for Odor Control Applications

by Calvin Horst

What do expensive cheese, fine wine and wastewater have in common? To the initiated, the olfactory experience can tell you a lot about the qualities of each. Unlike cheese and wine though, wastewater odors do not typically elicit feelings of decadence and affluence. They do, however, remind us of the vital role our wastewater treatment and conveyance systems play in ensuring public health and quality of life. But where do these odors come from, and how can we ensure that fugitive emissions don't adversely impact the life experience of our constituents? This article will answer these questions and more!

Hydrogen Sulfide

There are a variety of odorous compounds that exist in wastewater systems, but the most impactful is hydrogen sulfide. Hydrogen sulfide is a soluble, corrosive and colorless sulfur-based gas that smells of rotten eggs. In addition to the corrosion impact hydrogen sulfide can have on infrastructure and equipment, it is detectable by the human nose at extremely low concentrations and becomes increasingly dangerous to human health as the concentration of the gas increases.

Hydrogen sulfide is formed in wastewater conveyance systems when the biologically active wastewater runs out of dissolved oxygen to support cellular respiration of aerobic bacteria. This is most evident in pressurized lines that don't allow for oxygen exchange but can also occur in long, quiescent, gravity lines, or lines with excessively high biochemical oxygen demand (BOD). In these situations, the sulfate-reducing bacteria become dominant in the wastewater. These bacteria use the oxygen on sulfate molecules for respiration, stripping them off the sulfate, which results in sulfide. This is where hydrogen sulfide comes from.

Sulfide can exist in any one of three forms in wastewater. We have already mentioned hydrogen sulfide, which has the chemical formula H_2S and sulfide, which has the chemical formula $S^{=}$. The third form is bisulfide (HS^{-}) that, like sulfide, is not volatile, meaning it cannot be directly released into the atmosphere to create odor issues and contribute to corrosion.

Of course, not all hydrogen sulfide odor issues are the same. There are certain characteristics that are favorable for the formation of sulfide. Some of these characteristics are immutable, like the physical dimensions of a collections system, while others can be changed or influenced in some way. For example, the influent stream to a pump station that is known to contain sulfide will be more problematic if the wet well level is kept too low, allowing the influent stream to cascade in, creating excessive turbulence. In this scenario some amount of hydrogen sulfide release could be mitigated simply by raising the wet well level to allow for a gentler entry and reduced turbulence.

Other variable characteristics that contribute to the formation and release of hydrogen sulfide are shown in ***Table 1***.

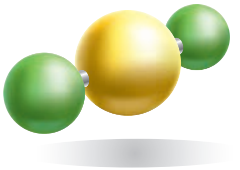

Table 1. Variable Characteristics That Contribute to the Formation and Release of Hydrogen Sulfide.

Characteristic	Contribution to H_2S Formation/Release
Wastewater BOD	Provides extra food for the biology.
Temperature	Higher temperatures reduce the solubility of water and increase biological activity.
Wastewater flow rate	Lower flow rates allow wastewater to spend more time in pressure mains.
pH	Three forms of sulfide (H_2S, $S^{=}$ and HS^{-}) exist at various equilibriums with one another depending on pH.
Baseline dissolved oxygen	Used by microorganisms to break down wastes; once depleted, organisms use oxygen bound to sulfate, releasing sulfide.

Most of these parameters can be easily measured or manipulated to help control wastewater odors with chemical treatment, but before discussing how to approach an odor control problem we should establish some basic odor control principles to help us think about our approach.

Basic Odor Control Principles

Following are four basic principles to remember when developing an odor control solution:

1. Odor control chemicals treat the water they are metered into, not water that went before or is coming after.
2. The amount of odor control chemical required is dependent on the amount of sulfide being generated.
3. The amount of sulfide generated in a fixed volume of wastewater is dependent on how quickly new wastewater enters the pipe afterward.
4. Wastewater flow patterns and chemistry are repeatable and follow fixed patterns.

These principles are generally true, but there may be exceptions based on application-specific conditions.

Designing an Odor Control Program

There are a few basic dosing strategies generally used when designing a chemical odor control program. The first and simplest is to set a sufficiently high, continuous chemical dose rate to achieve odor control. Due to the diurnal nature of wastewater flows and the resulting sulfide generation rates, this approach necessarily results in either periods of chemical overfeed (wasted dollars) or underfeed (poor performance). The argument for dose rate optimization is clear and the repeatable pattern of wastewater flows may make other dosing strategies clear, but before discussing those, let's talk a bit more about how to approach chemical dose rate optimization.

Dose Rate Optimization

To optimize a chemical dose rate, one first must establish a goal. Simply put we need to know what we are optimizing against. The two most common factors are budget and hydrogen sulfide concentration. In most cases the goal is not simply to optimize against budget or hydrogen sulfide, but rather to strike the best balance between those (and possibly other) parameters. For simplicity we will assume that we are only optimizing against the two parameters

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of budget and hydrogen sulfide and nothing else. For example, we are assuming a practitioner has unlimited time available to devote toward optimization and therefore labor time is not a factor.

The next step is to figure out what it is that we hope to accomplish exactly; in other words, what is our odor control goal? Is the utility concerned about infrastructure preservation? Or do we need to address a particularly sensitive odor control application? Odor control targets should align with the outcome the practitioner is trying to achieve.

Let's consider infrastructure preservation. The USEPA has indicated that the corrosion rate of wastewater infrastructure is not directly proportional to the amount of dissolved sulfide in the wastewater, but rather it is proportional to the flux of hydrogen sulfide from the wastewater to the sewer walls (*USEPA, 1991*). Therefore, a minimum target of dissolved sulfide in wastewater may not be adequate for achieving corrosion control objectives. However, a study conducted by Evoqua Water Technologies in partnership with Sanitation District 1 in Kentucky (*Goossens et al., 2016*) revealed that concrete coupons maintained in a treated portion (3.6 parts per million by volume [ppmv] H_2S) of the evaluated collection system had a 22% higher compressive strength after 24 months than those maintained in an untreated portion (68.5 ppmv H_2S) of the collection system. It may be obvious, but this indicates that an atmospheric concentration target for hydrogen sulfide, rather than a wastewater concentration target, is better suited for corrosion mitigation purposes.

Atmospheric hydrogen sulfide is what causes odor issues and is therefore a perfect measurement for odor mitigation as well. Remember, the human nose can detect hydrogen sulfide at levels as low as 2 parts per billion by volume (ppbv). If we are looking at an odor control application with a sizable buffer area before the first odor receptor (nose), then perhaps 75 ppmv is an appropriate target.

Taking it a step further, budget should also be a consideration when establishing a target. It will cost more to treat to 10 ppmv than 100 ppmv in the same application using the same chemistry.

Now that we have defined our parameters for optimization and know we are optimizing against two factors, we've introduced the opportunity for variability based on individual sentiment. What I mean is that depending on who is optimizing, they may favor slightly better odor control over a slightly lower spend or vice versa. Fortunately, the repeatable pattern of wastewater flow rates makes it simple to optimize one time and then make seasonal adjustments up or down. What this looks like in practice depends on which other dosing strategy the practitioner has elected to use, the other two most common being dosing proportionally to the wastewater flow rate when a flow signal is available and dosing on a known dose curve developed leveraging the repeatable pattern of wastewater flows.

The Problem with Direct Feedback Control

The question often comes up about optimizing chemical dose rates through a feedback loop with measured hydrogen sulfide concentration. This may be marginally effective for a narrow set of applications where the odor control chemical is added at the point where the odor issue exists (i.e., point source applications) if the chemical treatment is very fast acting; however, most odor control applications do not work this way. Once odor comes out of the wastewater, it is difficult to get it back in. In other words, odor control chemicals are generally added upstream from the odor issue.

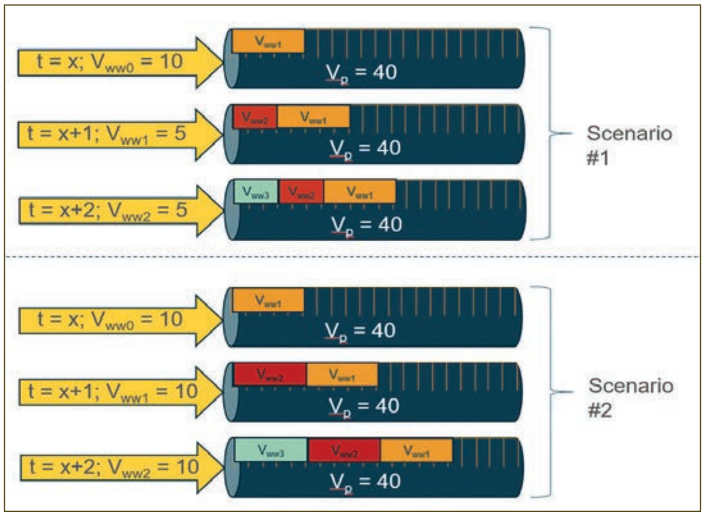

Figure 1. Odor control chemical demand is dependent on how quickly wastewater comes in after the chemical is added. *Calvin Horst*

To understand why direct feedback control with measured hydrogen sulfide concentrations does not work, it is helpful to remember the four odor control principals from earlier while referencing the simplified pressure main image depicted in ***Figure 1***.

In Scenario #1, a wastewater volume of 10 units (V_{ww0} = 10) enters the system at time index 1 (t = x). The amount of time this wastewater spends in the pipe, and therefore how much odor control chemical is required, depends on how quickly more wastewater comes in afterward. In Scenario #1 the 10 units at time index 1 are followed by five units at time index 2 and another five units at time index 3. In this case the first wastewater to enter the pipe is 20 volume units (10+5+5) into the 40-unit pipe at time index 3.

In Scenario #2, 10 volume units enter the pipe at time index 1, followed by another 10 units at time index 2, and another 10 units at time index 3. In Scenario #2 the first wastewater to enter the pipe is 30 volume units (10+10+10) through the 40-unit pipe at time index 3 and is closer to exiting the pipe in the same amount of time as Scenario #1.

In the example in ***Figure 1***, if the pattern were to continue and assuming all other wastewater characteristics were the same, the wastewater in Scenario #1 spends more time in the pipe, allowing more time for the biology to consume the dissolved oxygen and then the oxygen bound to sulfate, ultimately generating more sulfide. Put more plainly, the amount of odor control chemical that needs to be fed at time index 1 depends on how much wastewater comes in at time index 2, time index 3, and so on until it exits the pipe.

Again, thank goodness for repeatable wastewater flow patterns! Given the technical knowledge required to determine an objective, evaluate a collection system for the variety of odor control solutions available, and then effectively optimize the system to balance budget and control, it is no wonder the answer to many odor control issues is to "turn up the chemical."

Monitoring and Control

Optimization is only one aspect of an odor control program. Ongoing monitoring and control can be just as dicey of a proposition. Collection systems are complex and manifolded arrays of piping with wastewater coming from many different directions into a common point.

I have run across multiple odor control applications where high hydrogen sulfide concentrations in the air space were measured while wet samples revealed no sulfide and high treatment chemical residuals. In each of these cases an unknown and untreated line was feeding into the monitoring point. It took a bit of detective work (and time) to solve those problems, by systematically sampling the wastewater over the course of many hours to confirm the suspicion.

Advances in technology have made this type of work a bit easier. Imagine sitting at a desk monitoring a stream of hydrogen sulfide concentration data on your computer or manipulating chemical dose rates on a smartphone in response.

That is just what the Village of Wolcott, New York, was able to achieve in the following case study.

Case Study: Village of Wolcott

The Village of Wolcott is a rural town in upstate New York with a particularly interesting odor control application. The village previously maintained and operated their own wastewater treatment plant. In an effort to centralize wastewater treatment and better utilize resources, the village developed an agreement to shift treatment to a neighboring utility.

The Village of Wolcott converted their treatment plant into a large pump station, sending 200,000 gallons of wastewater per day, 5.7 miles to the neighboring utility, which allowed plenty of time for the wastewater to go anoxic and generate odors. Hydrogen sulfide concentrations up to 1,000 ppmv were measured at the last air relief valve (ARV 7) before the treatment plant. Ultimately ARV 7 and a section of pipe had to be replaced due to corrosion. Because of this, the receiving utility required that the Village of Wolcott's flows be treated for odors and corrosion prior to entering their plant.

Of course, it is not that simple. Eventually, plans were made for the receiving utility to tie into the Village of Wolcott line. To resolve the odor issues, the Village of Wolcott installed an advanced dosing system – the Versadose LT by Evoqua Water Technologies ***(Figure 2)*** – at their pump station to meter odor control chemicals. In addition, a remote hydrogen sulfide monitor was installed at ARV 7, the last air release valve before the treatment plant. This configuration allowed the Village of Wolcott to effectively optimize their own wastewater flow while visualizing odor issues coming in from other untreated flows!

The Village of Wolcott's advanced dosing system is a programmable logic controller (PLC) that automatically adjusts dose rates proportionately to changes in wastewater flow rates, adjusts dose rates for changes in wastewater temperature, and reduces the chemical feed rate when significant inflow and infiltration is measured. Any of the setpoints for these adjustments can be made remotely from any internet-enabled device, saving the village valuable labor-time resources and preventing corrosion at the ARV 7! The remote hydrogen sulfide monitor continuously measures the hydrogen sulfide concentration at ARV 7 and will notify service providers if the concentration exceeds configurable average or high concentration setpoints. This combination allows the Village of Wolcott to operate as a good neighbor to the receiving utility and residents living around ARV 7, while ensuring they do not exceed their budget targets!

Figure 2. Village of Wolcott advanced dosing controller. *Todd Gaignat*

Calvin Horst is a veteran of the U.S. Navy's nuclear power program having served aboard a fast attack submarine. After completing his education in chemical and nuclear engineering Calvin began working for Evoqua Water Technologies in 2013. Calvin has eight years of experience developing and optimizing chemical and capital odor control solutions. He may be reached at calvin.horst@evoqua.com.

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