WHITEPAPER

Smart H_2S control in wastewater

Solve odor, corrosion, and worker safety challenges with data-driven and proactive H_2S control strategies

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Introduction

Hydrogen sulfide (H_2S) poses a dual-edged challenge in wastewater systems.

Firstly, the toxic gas leads to immediate issues as foul odors impact nearby communities and jeopardize the safety of workers.

Secondly, the corrosive nature of H_2S has significant long-term consequences for valuable sewer assets. Without proper intervention, sewer assets such as concrete pipes may deteriorate within a mere 10-20 years instead of their expected lifespan of 50-100 years.

Utilities possess many tools and techniques for mitigating H_2S, but struggle to optimize these activities due to a lack of reliable insights into the true scale and dynamics of their problems. Consequently, utilities have acknowledged the necessity of better data as an enabler of proactive and efficient H_2S control.

H_2S already presents a major challenge, but with ongoing trends such as centralized wastewater treatment processes and separation of stormwater in mind, this challenge will only intensify.

This whitepaper aims to provide a practical framework for how to implement smart H_2S control strategies. It serves as a guide for wastewater professionals seeking to adopt a smarter approach to solving odor, corrosion, and worker safety challenges caused by elevated H_2S levels.

We hope you will enjoy the whitepaper, and that the insights can help you on your path towards a better and more sustainable management of sewer infrastructure assets.

Sincerely,
The SulfiLogger team

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1. Understanding H_2S

H_2S, a toxic and foul-smelling gas, is an unwanted and costly challenge in wastewater systems. Understanding why and where H_2S is formed is a crucial knowledge when setting up effective mitigation strategies.

Why and where is H_2S formed?

Hydrogen sulfide (H_2S) is a byproduct of microbial activity during the decomposition of organic matter in wastewater and it is primarily formed through the metabolic processes of sulfate-reducing bacteria (SRB) under oxygen-free conditions. Various organic compounds present in wastewater, such as sulfates and sulfites, serve as energy sources for SRB, resulting in the production of H_2S.

In wastewater systems, H_2S is primarily formed when sewage is pumped to higher ground in pressurized systems as the lack of oxygen creates an environment favorable to the growth of SRB and thus promotes the formation of H_2S. In addition, H_2S may also form in stagnant wells or enclosed spaces; in areas with limited flow or areas with a lack of oxygen.

The value of liquid-phase insights

H_2S is formed in the wastewater but is rarely a problem as long as it stays in the liquid phase. It is only once it is released into the atmosphere its presence becomes critical and odor, corrosion, and worker-safety challenges occur. This degassing can occur anywhere in the gravity system - and the level of degassing depends on several local conditions.

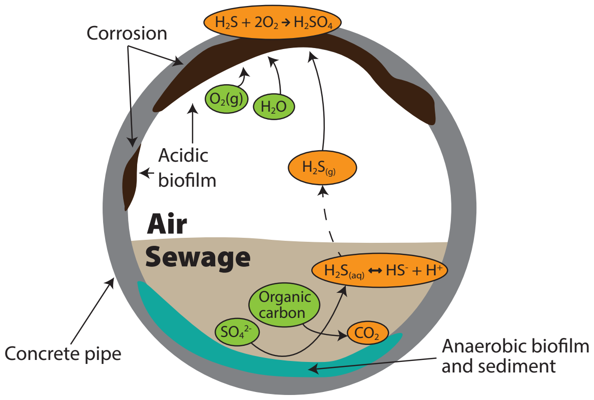


Figure 1 - Conceptualization of how H_2S leads to corrosion damages. Dissolved H_2S in the sewage is oxidized into sulfuric acid, which causes concrete pipes to corrode.

By knowing the H_2S concentrations in the liquid, utilities gain valuable insights into the extent of H_2S related challenges that may arise downstream in the network. With this knowledge, potential areas of concern can be identified, allowing for proactive measures.

Did you know?

H_2S is typically formed in pressurized pipes, but may also form in stagnant wells or basins.

Factors influencing the formation of H_2S

H_2S concentrations in wastewater are not constant - they fluctuate. Several factors contribute to these fluctuations and understanding them is crucial for implementing effective H_2S control strategies.

One key factor is the composition of the sewage and its Chemical Oxygen Demand (COD). Residential and industrial discharges differ both in their organic content and discharge patterns. Industrial sewage often results in higher levels of H_2S production.

Retention times also play a crucial role. Longer retention times allow for more microbial activity and organic decomposition, increasing the potential for H_2S formation.

Ventilation and turbulence influence H_2S levels as well. The rate and frequency of wastewater pumping can affect the mixing of liquid and gas phases, impacting the level of degassing.

pH also has an impact. Acidic wastewater provides a favorable environment for the formation, solubility, and release of H_2S, while sulfide will exist as HS^- and S^{2-} rather than as H_2S in alkaline wastewater.

As for temperatures, higher temperatures generally promote increased microbial activity, which results in higher rates of H_2S production.

Short- and long-term challenges

Elevated H_2S loads causes significant short- and long-term challenges in wastewater networks.

H_2S degassing causes immediate issues as the pungent odor impacts the quality of life for nearby residents and may lead to odor complaints. This degassing also poses a health hazard, and protecting sewer workers from hazards requires implementing proper safety measures, including training, personal protective equipment (PPE), and effective monitoring systems.

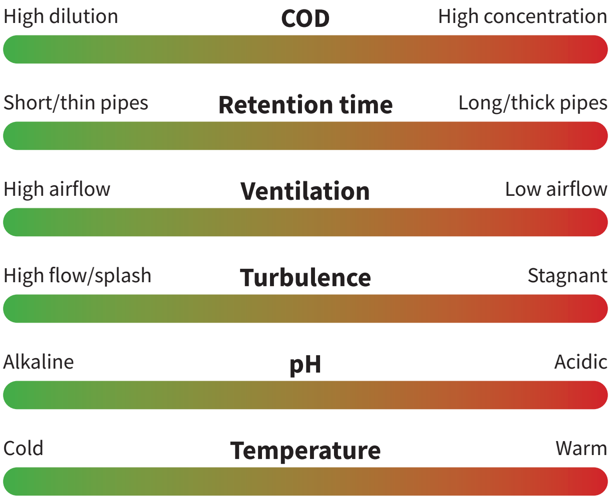


Figure 2 - Factors influencing the formation of H_2S.

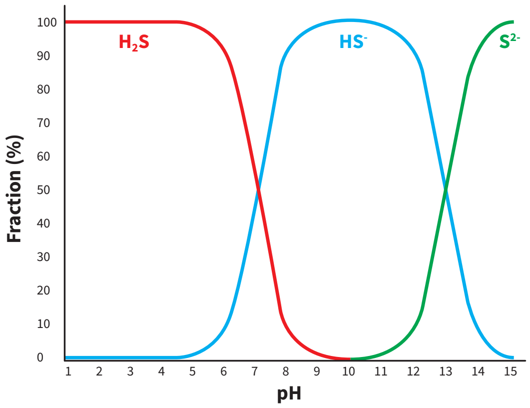


Figure 3 - The 3 forms of sulfides depending on pH.

On a longer timeframe, elevated H_2S loads causes extensive corrosion damages on infrastructure and equipment, resulting in a drastic decrease in the expected lifespan of valuable assets and a higher risk of unexpected pipe collapse or other maintenance issues.

By now, it should be clear that H_2S is a complex and dynamic challenge that is impacted by many factors. In the next section, we explore tools and techniques utilities have at their disposal for understanding that challenge.

2. Measuring H_2S

Before taking any action against H_2S, it is important to first understand the problem. Accurate data is essential for optimizing control strategies, but reliably estimating fluctuating H_2S levels in extreme environments is not straightforward.

The challenge of measuring H_2S

The extreme environments in wastewater systems present challenging conditions for reliably measuring H_2S using traditional methods. This section provides an overview of the benefits and shortcomings of different measurement methods.

Gas loggers

Although H_2S is formed and transported in the wastewater, it is typically measured in the air. These measurements are suitable for confirming local odor incidents but are affected by many factors including flow, ventilation, and turbulence. This limitation makes gas loggers an unreliable input for advanced H_2S control applications.

Grab samples and lab analysis

Grab sampling is a commonly used method for reliably measuring not only H_2S but also total sulfide in wastewater. Although accurate, this approach is labor-intensive, time-consuming, and it only provides a delayed snapshot.

Visual sewer inspections

TV or surface pH inspections provide valuable snapshot insights into how H_2S induced corrosion has impacted a particular sewer line. This method is unfortunately costly, time-consuming, and retrospective in nature.

The power of continuous data

H_2S levels are affected by many factors and fluctuate regularly. That is why spot measurements may be insufficient for understanding H_2S challenges.

Residential odor complaints

While not a traditional measurement approach per se, odor complaints do provide valuable community feedback. The drawback is that this feedback is retrospective, and unreliable as malodors can arise due to other causes.

Hydraulic modeling

Hydraulic software modeling solutions aim to provide a grand overview of H_2S challenges in wastewater systems and identify critical areas where H_2S concentrations may be higher.

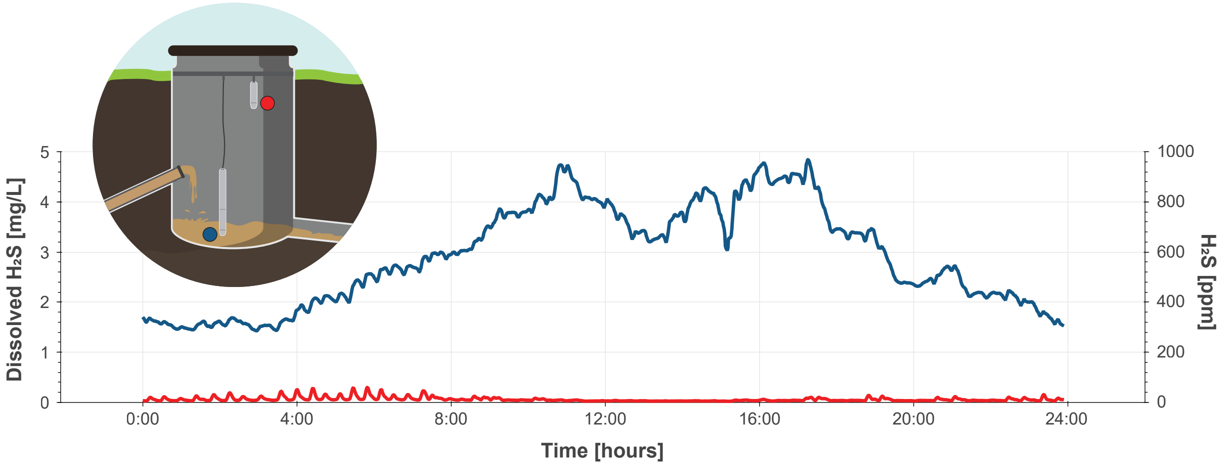


Figure 4 - Comparison of liquid and gas-phase H_2S sensor data from within the same sewer manhole. The gas logger is unable to capture all the variations in H_2S levels as shown in the liquid-phase measurements.

Hydraulic models have limitations as they may not fully capture all the complex factors impacting H_2S formation in the real world. Calibration with reliable liquid-phase sensors may overcome this limitation.

The key to reliable insights

Liquid-phase sensors

A new method - liquid-phase measurements - offer a versatile and reliable solution for reliably monitoring H_2S in wastewater systems.

By directly measuring H_2S concentrations in the liquid, the measurements are unaffected by the local conditions in a well or manhole. These sensors can be deployed directly in wastewater streams, enabling accurate and continuous monitoring at various locations within the system. By measuring dissolved H_2S, the data obtained reflects the full H_2S potential that can be released to the air anywhere in the gravity system. With liquid-phase measurements, utilities can overcome the limitations of traditional H_2S measurement techniques.

These measurements enable the implementation of odor and corrosion control strategies that are proactive, data-driven, and cost-effective.

In the next section, we explore different techniques for mitigating H_2S related challenges in wastewater systems.

Figure 5 - Example of a liquid-phase H_2S sensor.

3. Mitigating H_2S

H_2S is a complex challenge, and effective odor and corrosion control requires a multi-faceted approach combining both design of the sewer network as well as operational control mechanisms.

This section presents a framework for H_2S mitigation activities depending on the type of activity and the purpose. Some initiatives may belong to multiple quadrants (i.e. pipe pigging). In these cases, they have been categorized based on whether the primary expense relates to construction (CapEx) or operations (OpEx).

1) Limiting H_2S formation through design & construction

Pipe sizing

Inadequate pipe sizing increases hydraulic retention times which favor the formation of H_2S. By ensuring appropriate force main pipe sizing in the design of new pumping stations, the potential for H_2S formation reduces.

Pipe pigging

Biofilm buildup in sewer pipes provides a favorable environment for SRB. Regular pipe pigging removes these deposits, which helps to limit H_2S formation.

2) Eliminating formed H_2S through design & construction

Filters

Filters can play a crucial role in eliminating or preventing H_2S using various technologies. Some commonly used technologies include activated carbon filters, biological filters, iron oxide filters, biofilters, and clamshell filters.

Ventilation

Providing (active or passive) ventilation helps disperse and dilute H_2S concentrations, reducing the potential for adverse effects on infrastructure and worker safety.

Stripping

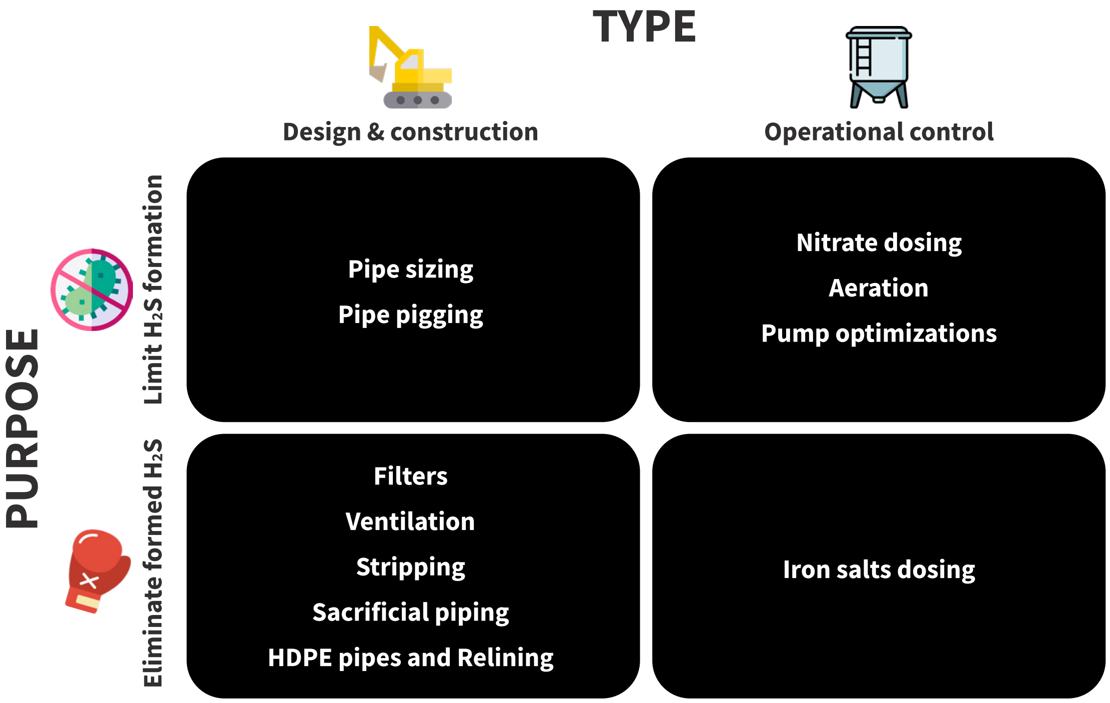
Stripping involves the use of air or chemicals to strip H_2S from wastewater before it reaches critical points in the sewer system. This process can be accomplished using packed towers or chemical scrubbers.

Sacrificial piping

Sacrificial piping involves the use of low-cost, sacrificial materials for sewer lines in H_2S-prone areas. The sacrificial material extends the lifespan of the sewer infrastructure and reduces the risk of unscheduled maintenance.

HDPE pipes and Relining

Using high-density polyethylene (HDPE) pipes or relining existing pipes with HDPE liners provides superior resistance to H_2S-induced corrosion. This extends the longevity of the affected sewer line but may also help move a problem further downstream in the network.



	Design & construction	Operational control
Limit H_2S formation	Pipe sizing Pipe pigging	Nitrate dosing Aeration Pump optimizations
Eliminate formed H_2S	Filters Ventilation Stripping Sacrificial piping HDPE pipes and Relining	Iron salts dosing

Figure 6 - Framework for H_2S mitigation activities depending on type and purpose.

3) Limiting H_2S formation through operational control

Nitrate dosing

Dosing nitrate promotes the growth of nitrate-reducing bacteria. These bacteria outcompete H_2S-producing bacteria, thereby reducing H_2S production. Nitrate dosing is a commonly used method to prevent H_2S formation.

Aeration

Injecting oxygen inhibits the growth of SRB. Aeration can be achieved through mechanical means or by natural aeration processes.

Pump optimizations

Optimized pump operation can prevent conditions favorable to H_2S formation.

4) Eliminating formed H_2S through operational control

Iron salts dosing

Dosing iron salts is a widely employed method to eliminate formed H_2S due to its effective chemical reaction with H_2S compounds.
Iron salts undergo a series of reactions that precipitate H_2S as iron sulfide, thereby removing the hydrogen sulfide from the wastewater.

In the next and final section of this whitepaper, we present a general framework for smart H_2S control as well as specific control strategies.

Why reliable insights matter

Reliable data empower utilities to identify and solve H_2S problems at the optimal location, to prioritize activities across the network, and to cost-optimize operational control strategies.

4. Smart H_2S control strategies

Implementing smart H_2S control strategies requires a systematic and iterative approach based on reliable data. This section introduces both a general framework and 3 specific control strategies for how to make smarter H_2S control decisions.

Tying everything together

We've now arrived at the essential section of this whitepaper.

In the previous sections, we've addressed how and why H_2S is formed, seen how to reliably keep track of changes in H_2S levels, and discussed various techniques for solving the issues of odor, corrosion, and worker safety. Now it is time to tie everything together by implementing a framework of smart H_2S control strategies.

First, a basic 5-step iterative framework is presented for how to use data to make better decisions in general.

And on the following pages, 3 specific strategies show how it is possible to adopt smart strategies for different goals - for optimizing chemical dosing stations, locating the root source of H_2S challenges, and for adopting a city-wide overview to prioritize mitigation activities on a fully informed basis.

General H_2S control framework

Step 1: Define an objective

The first step in setting up a smart H_2S control strategy is to clearly define an objective.

Determine the specific goal(s) you want to achieve. This could include identifying the root source of a H_2S challenge or optimizing the cost-effectiveness of a chemical dosing station. Defining a clear objective will help focus your efforts throughout the process.

Step 2: Select the right data

Once the objective is established, it is crucial to select an appropriate H_2S data setup. This involves identifying new data acquisition sources, such as real-time sensor monitoring systems, but could also include historical data, residential odor complaints, inspections, and other data types such as flow and pump data.

Choose the most suitable data setup to ensure you have sufficient data to select and optimize the mitigation strategy.

Step 3: Collect Data

With the data setup in place, the next step is to collect data. Depending on the objective and selected setup, this may involve installing sensors in the sewer network.

Implement data collection procedures that align with industry best practices and safety guidelines. Pay attention to data integrity, ensuring proper calibration of sensors to get accurate measurements.

Step 4: Select, implement, or optimize a mitigation strategy

Once sufficient data has been collected, it is time to analyze the data, and select and implement an appropriate mitigation strategy or optimize an existing strategy. Analyze the data to identify patterns, trends, sources, and potential risks. Consider various mitigation techniques as described earlier in this whitepaper when selecting new strategies.

An iterative process

H_2S control is an ongoing process. Repeat it periodically to ensure continuous improvement and adaptability as circumstances change.

Choose the strategy that aligns with your objectives and implement it effectively, considering factors including cost, feasibility, and long-term sustainability.

Step 5: Analyze the effectiveness of the system

After implementing the selected mitigation strategy, it is essential to analyze the effectiveness on an ongoing basis. Continuously monitor H_2S levels and evaluate the impact of the implemented controls.

Specific H_2S control strategies

In the following pages, we present ideas on how you can use reliable sensor data for 3 specific H_2S mitigation scenarios:

- **Optimizing chemical dosing stations**
- **Finding the cause of H_2S challenges**
- **Getting a city-wide overview**

Optimizing chemical dosing stations

Many utilities dose chemicals in a steady stream to mitigate H_2S challenges. This is however an inefficient approach, because H_2S concentrations fluctuate, and these utilities will thus either dose an insufficient or excessive dosage.

Basic optimizations

Optimizing chemical dosing stations does not have to be complicated. For dosing stations where the dosing occurs before the pumping - i.e., for nitrate dosing - there is a time-delay caused by the retention time, which makes real-time dosing control challenging. A basic yet effective approach to start-of-pipe dosing control includes adjusting a fixed dosing rate up or down based on effect measurements, while more advanced applications include continual adjustments of time-determined patterns based on diurnal H_2S variations.

Fully automated dosing

The holy grail in dosing control is fully automated dosing control, where the dosing rate is dynamically set in real-time for full efficiency. This setup is possible in an end-of-pipe setup, where the dosing system and sensor are located at the same physical place as shown in Figure 6.

Making ROI calculations for optimizing dosing systems is not trivial, and it is critical to not focus on chemical costs alone but to also factor in the value of an increase in sewer asset lifespan.

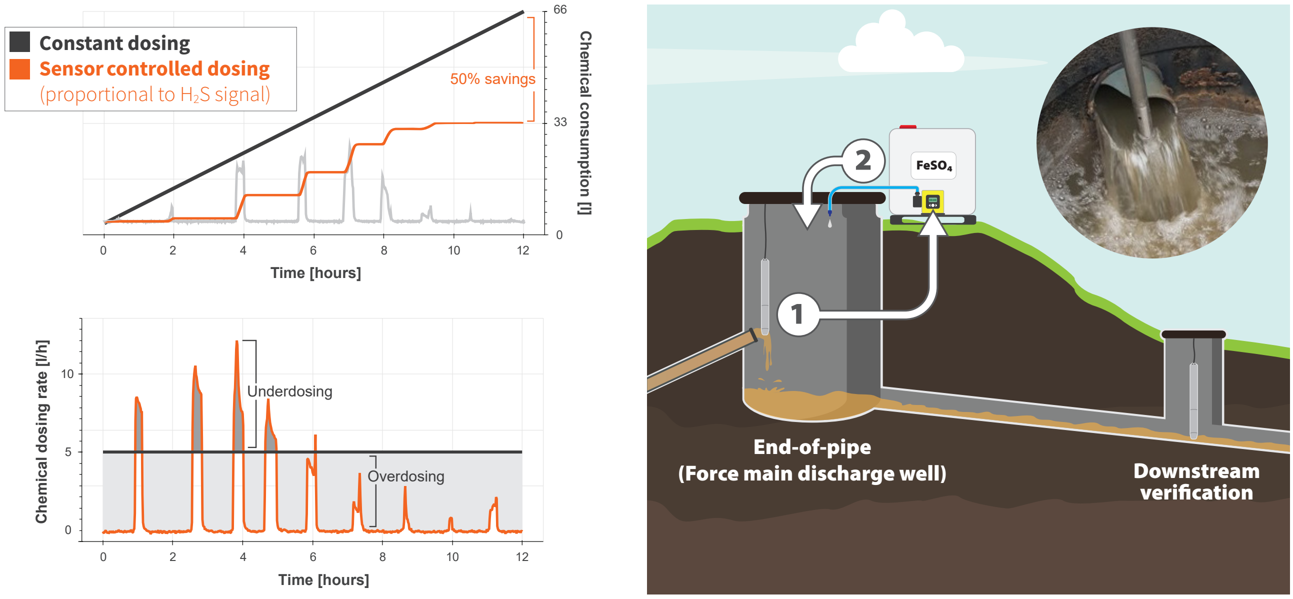


Figure 7 - Example of a fully automated dosing system. The $FeSO_4$ dosing rate is dynamically adjusted in real-time in proportion to the continuous measurements of a liquid-phase H_2S sensor. Using this approach, a utility managed to cut dosing costs by 50% when compared with a constant dosing strategy, while also improving mitigation effectiveness.

Finding the cause of H_2S challenges

Locating the origins of H_2S challenges is a complex but critical process. Depending on the situation and the resources available, utilities may aim to get a general understanding of the source area - or aim to identify a specific culprit.

Finding the general source

To get a general idea of the source, liquid phase H_2S sensors can be positioned in two or more closely related areas in a short-term measurement campaign.

Pinpointing the culprit

Identifying the specific cause of an H_2S challenge may require a more systematic and iterative approach. The process could begin with a broad investigation that subsequently narrows down the focus to one or more additional sensor mapping campaigns until the culprit is discovered. This approach may be suitable for identifying the cause of H_2S challenges in areas with clusters of industrial factories with varying discharge patterns.

Account for other factors

H_2S challenges are complex, and it is important to not limit the investigation to a comparison of sensor data but to also consider factors such as diurnal variations, irregular discharge patterns, and flow rates. Factoring in multiple variables ensures an accurate evaluation and facilitates the implementation of optimal next steps.

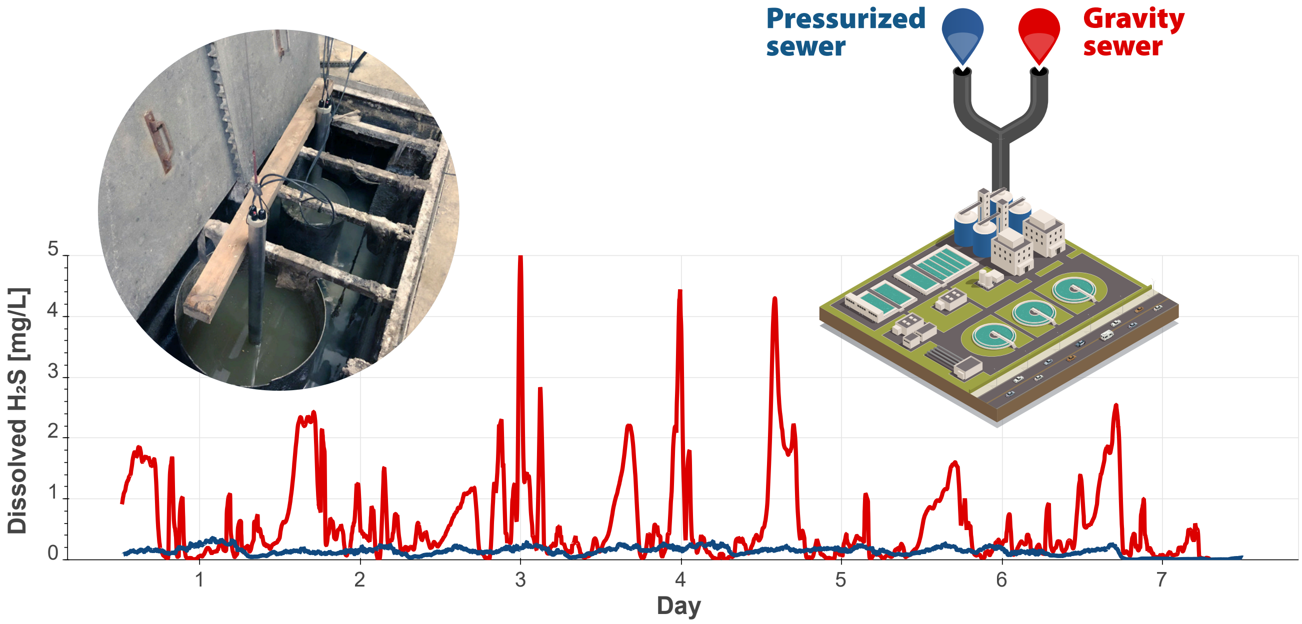


Figure 8 - Example of a basic root cause investigation. A wastewater utility wanted a better understanding of the source of a H_2S challenge at a wastewater treatment plant and used two liquid-phase H_2S sensors to compare two inlet sources; a pressurized sewer line (blue) and a gravity sewer line (red).

Getting a city-wide overview

H_2S is not an isolated issue, but a persistent challenge that may be as complex as the sewer network itself. With a city-wide overview, utilities can get an in-depth understanding of this challenge and compare and prioritize areas in need of targeted mitigation initiatives. These insights can be achieved using reliable sensors.

5-step process

Step 1: Plan the sensor mapping campaign

Choose between a short-term or permanent sensor mapping approach. Short-term campaigns require fewer sensors but more time as sensors are moved around in the network, while permanent monitoring provides a dynamic overview with a higher initial investment.

Step 2: Identify hotspots

Identify which areas to set up sensors. Locate H_2S hotspots such as force main discharge wells, areas with stagnant water, and sites with irregular or industrial discharge.

Step 3: Prioritize the hotspots

Prioritize the hotspots based on factors such as retention time, flow data, historical odor complaints, material type/age, and critical infrastructure or residential housing.

Step 4: Collect data

Set up sensors and continuously measure H_2S levels at the chosen hotspots. For short-term campaigns, measure at each location for at least a week to account for diurnal variations.

Step 5: Analyze the data

Compare average H_2S loads, peak loads, incidents above thresholds, and time above thresholds to identify problem areas. Visualize the data with color-coded maps or other techniques to identify and prioritize areas in need of targeted mitigation activities.

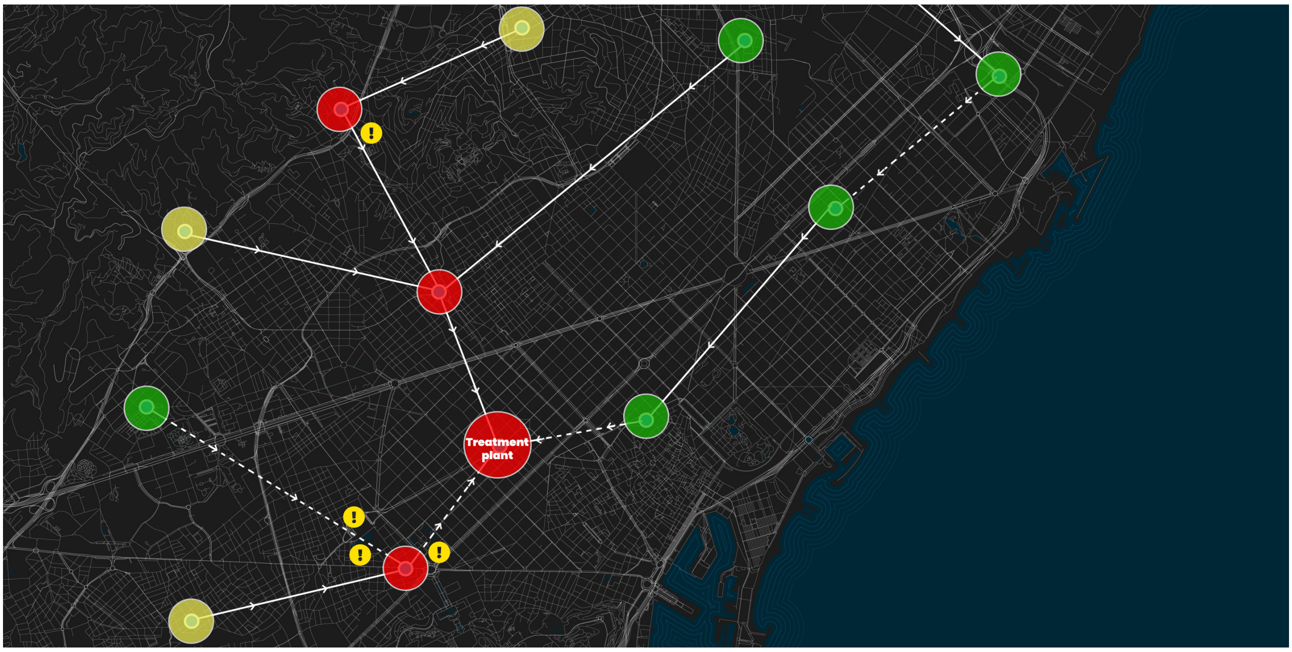


Figure 9 - Conceptualized map for presenting city-wide sensor data with "traffic light" colors. Consider basing the visualization on GIS charts or similar available maps, where pressurized lines and gravity lines are distinguished from each other. Consider visualizing historical data (such as odor complaints) and critical infrastructure.

Final remarks

We hope you found the whitepaper inspirational, and that you can use some of the tips and ideas in your fight against H_2S.

H_2S is a complex challenge, and intelligent mitigation is difficult without the right insights. With this whitepaper, it was our aim to highlight the critical role of reliable data as the key to effectively solving this challenge.

Data empowers us to take better decisions. It provides the insights needed to identify problem areas, prioritize mitigation efforts, and optimize resource allocation.

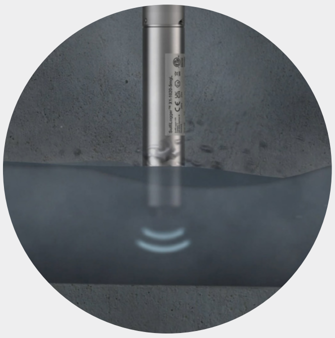
With data as our guide, we can navigate the complexities of H_2S control more effectively and achieve a better and more sustainable management of sewer infrastructure assets.

It all starts with knowing

While this whitepaper offers valuable tips, it does not hold all the answers. Each situation is unique, but the path toward smart H_2S control always starts with knowing.

Our sensor experts at SulfiLogger are ready to discuss your H_2S challenge and help you get on the right path - by knowing.

BOOK A MEETING



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