MICROBIAL DISCOVERY GROUP

Reducing Hydrogen Sulfide Production Within Municipal Collection Systems Using Bioaugmentation

Authors: Jennifer Cray, Megan Duersteler, Josiah Menako, Dan Romanek, Sona Son & Mike King

Abstract

Hydrogen sulfide (H_2S) poses significant problems to municipal collections systems due to its malodorous smell, danger to human health and corrosive effect on infrastructure. Application of various chemical treatments such as precipitants, oxidizers, and nitrates can be used to mitigate H_2S, however, these options require significant annual costs and often do not address the root of the problem. Sulfate reducing bacteria (SRB) utilize sulfate to generate energy and expel H_2S as a byproduct of respiration. SRB live primarily in biofilms and within anaerobic environments which can be intensified by the buildup of fats, oils, and grease (FOG). Bioaugmentation is an effective treatment option that prevents H_2S from forming by removing sources of sulfate, food, and habitat that SRB need to thrive. Twenty municipal systems were treated with Biotifx®, a *Bacillus*-based bioaugmentation product, for H_2S issues ranging from nuisance odor to extensive corrosive damage and extreme health hazards. Treatment resulted in H_2S reduction in 90% of systems with an average H_2S reduction of 68% amongst successful applications. Results show that bioaugmentation products reliably and significantly lower H_2S levels in collection systems.

Introduction

Hydrogen sulfide (H_2S) is a highly toxic colorless gas with a pungent unpleasant odor that is a common occurrence in municipal collection systems. Humans can detect H_2S odor in the air at concentrations as small as 0.01-1.5 ppm, but exposure to higher concentrations can have serious health effects. At 100 ppm eye and respiratory irritation can occur within less than an hour of exposure, and at 700 ppm or greater the gas is deadly within minutes (1). In addition to the health hazards for workers, H_2S production in collection systems has other costly side effects. Costs range from fines due to odor regulations, to frequent repairs or total replacement of concrete and metal infrastructure due to extensive corrosion (2).

There are multiple methods for controlling H_2S in wastewater systems. Scrubbers and filters can be installed to physically remove H_2S gas before it is released from the system. In addition to being a large capital expense, scrubbers and filters do not stop the H_2S from being generated in the system. Chemical treatments such as precipitants, oxidizers, and nitrates are also common in the industry. Precipitants and oxidizers work to chemically convert existing H_2S into less harmful compounds (6). Nitrates replace sulfate in bacterial respiration which prevents H_2S from forming (6). These options can work to minimize the problems associated with H_2S, but all require large capital expenditures and/or high volumes of chemicals and few are actually addressing the source of the problem.

Lift stations and force mains suffer from high levels of H_2S because of sulfate reducing bacteria (SRB) that thrive in those environments. Municipal wastewater treatment systems have abundant food for SRB in form of volatile fatty acids (VFA), high amounts of sulfate which SRB utilize in anaerobic bacterial respiration, and built-up fats, oils, and grease (FOG) which provides the anaerobic or anoxic biofilms where SRB prefer to live (4). SRB use sulfate, which originates from cleaning product residue and breakdown of amino acids, to facilitate cellular respiration and produce energy, and this process creates a byproduct of H_2S (3,4). This H_2S exists in a dissolved form in the water until physical agitation or chemical conditions cause it to be released into the air (5). Sulfur oxidizing bacteria (SOB) can then use H_2S to create sulfuric acid, which is what causes corrosion in areas with high H_2S concentrations (4). The problems associated with high H_2S are most effectively mitigated by treatments that prevent SRB from thriving in collection systems.

Bioaugmentation is the process of enhancing the microbial community that naturally exists in an environment through the addition of bacterial species and/or nutrients that support microbial growth. *Bacillus*-based bioaugmentation products work to reduce H_2S in wastewater systems by removing SRB's food sources and habitats. VFA are one of the primary food sources for SRB, but *Bacillus* are able to consume them as well (7). *Bacillus* can grow rapidly in wastewater systems and therefore need to consume a lot of food, including VFA, which limits the amount available for SRB (Figure 1). *Bacillus* also breakdown FOG to obtain nutrients thus disrupting SRB's preferred anaerobic habitat (Figure 2). As they grow, *Bacillus* utilize sulfate to build amino acids and proteins to incorporate into new cells which reduces the sulfate available for SRB (Figure 3). Through the utilization of VFA and sulfates, and the consumption of FOG, *Bacillus* can reduce SRB activity in collection systems, thus reducing H_2S production, and therefore alleviating the associated problems.

Biotifx®, a *Bacillus*-based bioaugmentation product, was used to treat 20 different municipal collection systems and was able to effectively reduce H_2S in 90% of these systems. H_2S reduction resulting from bioaugmentation creates a safer work environment, saves costs by decreasing the frequency of equipment repair due to corrosion, and reduces or eliminates the need for costly chemical and mechanical treatments.

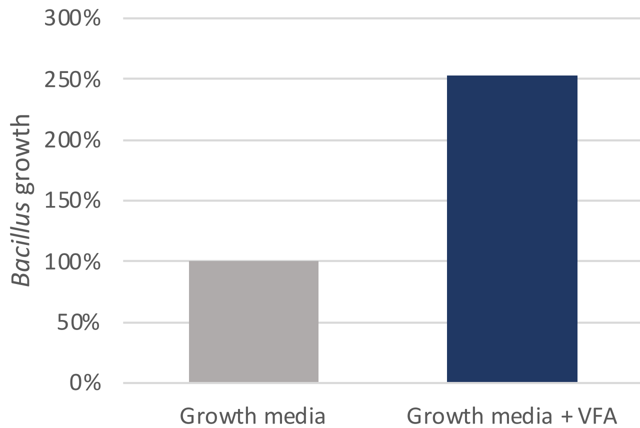


Figure 1. In a laboratory study, a minimal growth media was spiked with 100 ppm of volatile fatty acids (VFA). When *Bacillus* was grown in media with and without VFA, there was a 2.5-fold increase in *Bacillus* growth within 24 hours when additional VFA were available. This data shows that *Bacillus* consume VFA as a carbon source to support growth.

Figure 2. A municipal lift station with fats, oils, and grease (FOG) coverage over most of the surface of the water (left) was treated with Biotifx®. After treatment most of the surface of the water was cleared of FOG (right).

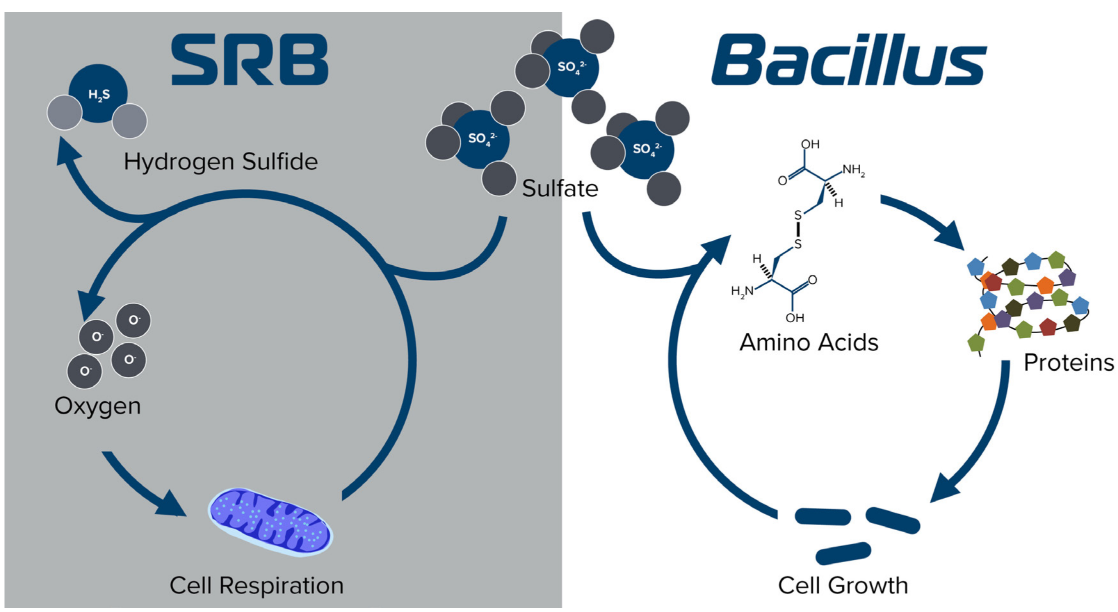


Figure 3. *Bacillus* utilize sulfate in wastewater to synthesize amino acids which are incorporated into proteins and used to facilitate growth of new bacterial cells. As the population thrives more sulfate is used. This limits the amount of sulfate available in the environment for use by SRB in cellular respiration which produces H_2S as a byproduct.

Methods

The goal of this study was to analyze the efficacy of Biotifx® on H_2S reduction in municipal wastewater collection systems. Twenty applications were included in this study with average pre-treatment H_2S levels ranging from less than 10 ppm to greater than 600 ppm. Locations of systems were spread across the US covering 11 different states. The size of the systems varied with an average daily flow of 628,000 gallons per day, and a range of 10,000 – 3,000,000 gallons per day.

Each location treated underwent an initial survey. The layout of the system was investigated to fully understand the flow and choose appropriate H_2S monitoring and product dosing locations. Ideally monitoring was conducted at the site with the most severe level of H_2S within the system and dosing was set up upstream of the monitoring location. In all systems, H_2S data was obtained through constant gas monitoring. Portable AcruLog or Odalog monitors were deployed into lift stations to continuously collect data. Baseline data was collected in each system in order to assess the severity of the problem prior to treatment. Biotifx® was applied via a peristaltic pump which was set to dispense multiple times per day during periods of lowest flow. Product dosages and frequency of dosing varied in each application based on flow and severity of H_2S. The duration of each treatment monitoring period was between 2 to 12 weeks.

Results

Bioaugmentation with Biotifx® resulted in a significant (p-value <0.05) decrease in average H_2S levels of the twenty systems analyzed. Treatment successfully lowered H_2S levels in 90% of the systems (Figure 4). In the 18 systems where bioaugmentation was able to reduce H_2S levels, there was an average of 68% (SD = 18%) reduction in H_2S after treatment. Measurable H_2S reductions can be seen as early as the first week of treatment with Biotifx® (Figure 5).

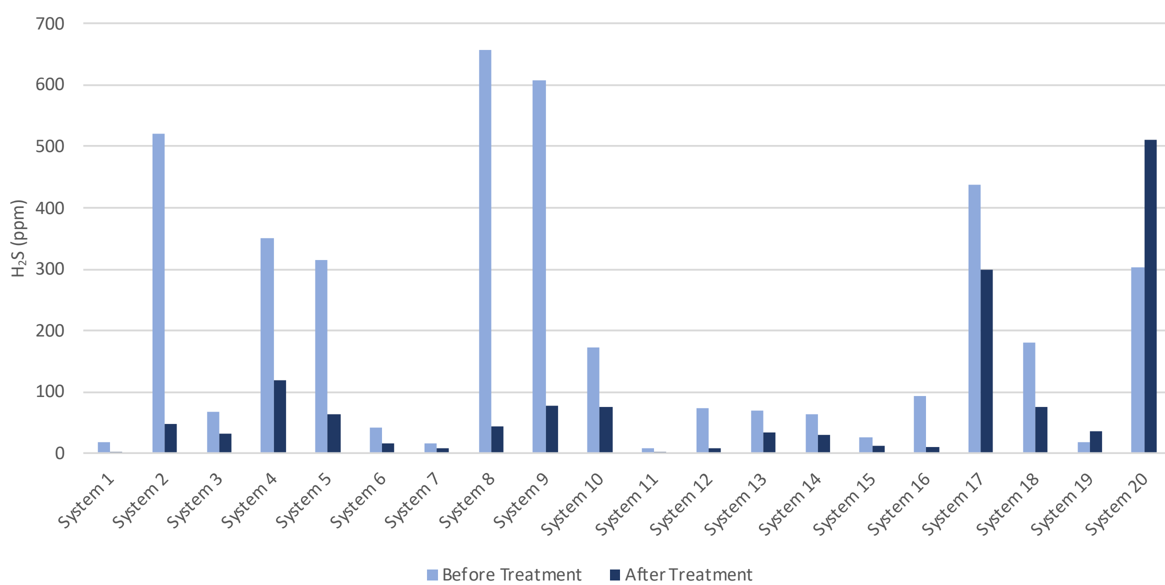
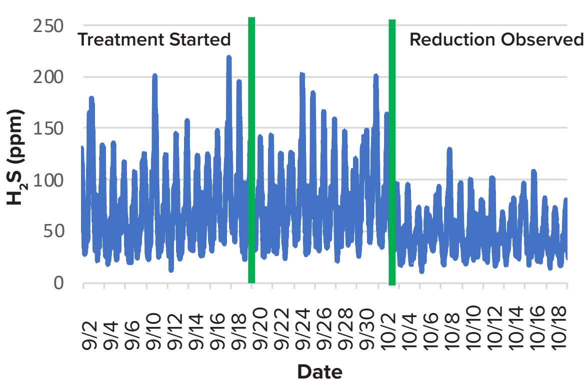


Figure 4. H_2S levels before and after treatment with Biotifx® in 20 municipal wastewater systems. Length of treatment varied from 2-12 weeks. A reduction in H_2S was observed in 18 of 20 applications.



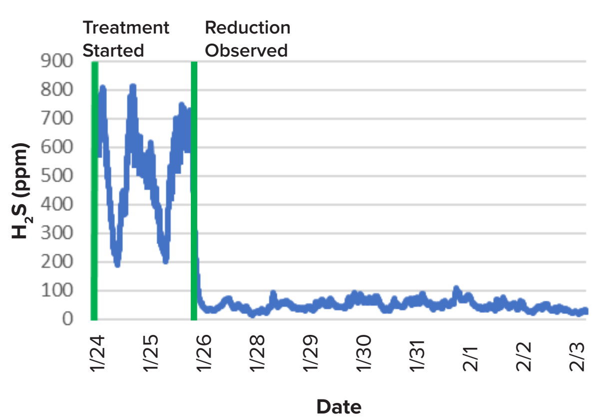


Figure 5. Example of H_2S OdaLog data from two municipal systems treated with Biotifx®. The start of treatment and when H_2S reduction was first observed is represented by the green lines on each graph. The graph on the left shows that H_2S levels decrease 10 days after treatment begins. The graph on the right shows that H_2S levels decrease 3 days after treatment begins.

Conclusions

Bioaugmentation is an effective strategy to treat wastewater systems with H_2S challenges. Each of the problems that H_2S can cause, including unsafe working conditions, equipment corrosion, and odor complaints can be improved by tackling H_2S at its source. Many chemical and mechanical treatments only work to remove H_2S post-production or stop its release from a system instead of preventing its formation.

Our study demonstrated that bioaugmentation worked in most applications to treat H_2S, but for treatment to be effective it is important to understand the system and dose correctly. Dosing needs to occur in an appropriate location so that the bacteria can reach the problem areas. Bioaugmentation products should be dosed at periods of low flow and upstream of the locations with high H_2S levels so the bacteria have the time and opportunity to be effective. It is also important to know the daily flow so that dosage can be calculated correctly. Missing the critical information described here prior to treatment contributed to the lack of response in Systems 19 and 20 in this study where treatment was unsuccessful.

Bioaugmentation can treat and prevent future H_2S problems in wastewater systems. With the right treatment plan and product, bioaugmentation can reduce or eliminate odor complaints, equipment replacement due to corrosion, and the need for other chemical or mechanical H_2S treatments, which will result in ROI for a wastewater treatment facility.

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