Odor and Corrosion Problems in Wastewater Collection Systems and Treatment Plants:

Two Related Issues Requiring Separate Control Strategies

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Odor control systems are critical to handling and treating foul air in wastewater collection systems and treatment plants. However, odor control systems do not stop corrosion related to biogenic sulfide formation of sulfuric acid, as some engineers would have you believe. Conversely, if you have an odor problem, you also typically have a corrosion problem, and each problem requires separate control strategies.

This article explains why odor control ventilation does not mitigate biogenic sulfide corrosion in wastewater treatment plants or pump stations and why corrosion protection is also required. In fact, as the article will illustrate, odor control ventilation merely reduces the severity of corrosion related to the biogenic sulfide formation of sulfuric acid that damages wastewater system infrastructure. Research by others has shown this to be true and is discussed later in this article.

Odor Control Ventilation: Reducing the Severity of Headspace Corrosion

Odor control systems generally extract the air from the enclosed headspaces of tanks and other structures and collect it in one of the many types of odor treatment systems. These treatment types include activated carbon adsorbers, biofilters,
fine-mist wet scrubbers, packed-tower wet scrubbers, and thermal oxidizers. There is no doubt that collecting this foul air for treatment is an essential control strategy. Extracting and collecting the foul air can reduce the concentration of \( \text{H}_2\text{S} \) gas in the headspace atmosphere. Fresh air is brought into the headspace with multiple air changes per hour, so that a negative pressure environment is maintained within the headspace. And while this air movement does lower the hydrogen sulfide gas levels within the headspaces of tanks, wet wells, and channels, the \( \text{H}_2\text{S} \) gas can still contact the concrete and metal surfaces upon which condensation of water is generally constant. As such, the gas is dissolved or absorbed into the layers or sheets of moisture where sulfur-oxidizing bacteria reside. Therefore, sulfuric acid formation can still occur, and corrosion continues, although to a lesser degree.

The design of airflow patterns for odor control systems is quite involved. Care is taken to sweep the air over all of the water surfaces with greater flow over areas where wastewater turbulence occurs. Also, the design process is focused on preventing dead spots within the headspaces where air changes could be obstructed or slowed due to the geometry of the structure. In doing this, an ample supply of oxygen passes over the surfaces where the sulfur oxidizing bacteria have colonized. Remember that these bacteria, mostly of the _Thiobacillus_ genus, are aerobic and thrive in an oxygen-rich environment. If the number of air changes provided does not remove the gaseous hydrogen sulfide as quickly as it comes out of solution, the amount of \( \text{H}_2\text{S} \) gas dissolved into the wetted surfaces will increase, as will the formation of the sulfuric acid responsible for corrosion. If dead spaces are allowed to exist, more rapid corrosion rates will occur at the locations where the higher \( \text{H}_2\text{S} \) gas levels remain for longer periods of time.

Further important points about corrosion must be considered in relation to odor control systems. The construction materials for these systems are also subjected to biogenic sulfide corrosion. Ductwork, fans, damper valves, and treatment equipment routinely degrade due to acidic exposure and associated corrosion, and as such, are typically constructed using FRP, stainless steel, or other corrosion-resistant materials. These odor control components are not constructed from unprotected concrete or carbon steel because the corrosion rates would be too high. Therefore, would it not be prudent also to continue to protect the concrete and metallic substrates found in the headspaces of the wetwells, tanks, and channels at treatment plants or pump stations? These surfaces can be considered as an extension of the air collection and conveyance components (the ductwork if you will) of the odor control system. Thus, they must still be properly coated or lined to prevent rapid deterioration.

**Hydrogen Sulfide Gas and the Dynamic Chemical Equilibrium**

Hydrogen sulfide generation in wastewater is mostly controlled by a chemical equilibrium in which the sulfide ion \( \text{S}^{2-} \) is first produced and introduced into the liquid wastewater from the anaerobic slime layer. The sulfide ion reacts with hydrogen in the wastewater to form bisulfide or hydrosulfide (\( \text{HS}^- \)). It, \( \text{HS}^- \) in turn, further reacts with hydrogen to form dissolved \( \text{H}_2\text{S} \) [or \( \text{H}_2\text{S} \) (aq)]. At areas of turbulence, the dissolved \( \text{H}_2\text{S} \) is released as gas into the headspaces of tanks or structures. As this occurs, more bisulfide ions are transformed into more dissolved \( \text{H}_2\text{S} \) to...
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nation of chemical equilibrium reactions is given in sidebar below), the quantitative relationship between the four species of sulfides is mainly controlled by the pH of the wastewater.

The sulfide ion does not exist at a pH much below 12.0. So we know that once released into the wastewater at near neutral pH, the dominant species will be bisulfide. At the normal pH of municipal wastewater (6.8 to 7.2), this means that in a 50/50 proportional relationship, nearly half of the sulfide present will be bisulfide ions, while the other half will exist as dissolved hydrogen sulfide (H$_2$S(aq)). And because the concentration of dissolved gases tends to be directly proportional to the partial pressure of the same gas above the liquid surface, the H$_2$S(aq) can be released to exist in its free gas form. The concentration of dissolved H$_2$S gas in solution is controlled by the specific Henry’s Law coefficient for H$_2$S. When subjected to turbulence, the wastewater releases the dissolved H$_2$S as free H$_2$S(g), and more bisulfide ions are transformed into the dissolved gas form to replace the H$_2$S lost to the headspace environment. The main thrust here is to replace the molecules that are lost to the headspace. More sulfide ions then react with hydrogen in the wastewater to form more bisulfide ions to replace those lost to form aqueous H$_2$S. Through this dynamic equilibrium (Fig. 5 on p. 28; also, an expla-
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point out that, despite odor control ventilation, H₂S gas will continue to be released into the headspace atmosphere unless chemical treatment is applied upstream to reduce sulfides in the wastewater.¹

\[
\begin{align*}
\text{pH} &< 12 \\
2 \text{S}^2^- & \rightarrow 2 \text{HS}^- + \text{H}_2 \rightarrow 2 \text{H}_2\text{S(aq)} \rightarrow 2 \text{H}_2\text{S (g)} \\
\text{pH} &< 12
\end{align*}
\]

**Fig 5: Dynamic Chemical Equilibrium of H₂S**

**Ideal Conditions for Mitigating Biogenic Sulfide Corrosion**

Studies based on laboratory work by the County Sanitation Districts of Los Angeles and others have shown that biogenic sulfide corrosion does not occur when H₂S gas concentrations are less than 2 parts per million volume (ppmv) because the growth of sulfur oxidizing bacteria (SOB) is not possible.² It would also be nearly impossible for biogenic sulfide corrosion to occur if headspace surfaces were completely dry. If no moisture from condensation was present, then H₂S has could not be dissolved and be made available to the bacteria.

So for corrosion to be mitigated by odor control ventilation, the H₂S gas concentrations would have to be kept below 2 ppmv and/or the headspace surfaces would have to be kept dry. Such ideal conditions cannot possibly be sustained in wastewater treatment plant or collection system tanks or structures. Just the difference in temperature between the concrete structures and the liquid wastewater will generally produce moisture condensation in the headspaces of these environments. Additionally, odor control ventilation exacerbates this situation by introducing air that is either warmer or cooler than the wastewater or the concrete surfaces, depending on the time of year. Keeping such headspaces completely dry using dehumidification equipment is simply not an economical alternative. Creating conditions in the wastewater collection system to ensure that H₂S gas concentrations remain below 2 ppmv is also both impractical and uneconomical. The National Fire Protection Association (NFPA) recommends that a minimum of 12 air changes per hour be provided at a minimum negative pressure of 0.1 inch of water column to maintain H₂S gas concentrations below 10 ppm.³ This is a typical air change rate used for odor control systems in wastewater treatment plants. Typically, even air change rates up to 20 per hour are not able to reduce H₂S concentrations much below 10 ppm. Much larger motors, fans, and ductwork would be necessary to achieve such high volume air flow requirements. And such equipment costs would be much higher.
higher than the costs for proven linings for corrosion protection of the headspaces.

**Real World Experience**

Inspections of wastewater treatment plant covered tanks that have odor control systems consistently show corrosion losses and active (ongoing) corrosion of concrete and metallic substrates. See Figs. 1, 2, and 3 (p. 24-26), which show headspace concrete corrosion problems in treatment plant and pump station tanks and structures where odor control ventilation has operated routinely for several years. By contrast, Fig. 4 shows corrosion damage that has developed in a structure's headspace where an odor control air flow system did not operate properly for several years.

**Summary**

Odor control systems do not magically make H₂S gas disappear from the headspaces of wastewater tanks and structures. Rather, odor control ventilation systems pull foul air over headspace surfaces, which are wet and inhabited by sulfur oxidizing bacteria. Additionally, fresh air supply to these headspaces brings an ample supply of oxygen to the aerobic bacteria, ensuring their health and the proliferation of corrosion. Dead spaces in the airflow patterns have been shown to create zones of higher corrosion in headspaces with operating odor control systems, as well.

The ductwork and the other air handling and treatment equipment used for odor control systems suffer from biogenic sulfide corrosion when not constructed from corrosion resistant materials. The headspaces of the covered tanks and other wastewater treatment structures are an extension of the odor control air collection system. Hence, concrete and many metal surfaces in these headspaces must also be protected from corrosion.

Because the sulfide species are in chemical equilibrium in wastewater environments, the free H₂S gas removed by ventilation will invariably be replaced by...
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