Sludge Gas Leaks

A Novel Approach for Preventing Explosions

By Peter Erndwein

In April 2009, a gas explosion occurred at a municipal-owned wastewater treatment plant (WWTP) in southeastern Pennsylvania. The explosion occurred in one of two active anaerobic sludge digesters at a 4-million-gallon-per-day domestic WWTP. The process building was equipped with general dilution ventilation and a fixed explosive gas monitoring system. The building's electrical systems were of ordinary construction (i.e., not explosion proof).

The resulting shock wave and fire caused life-altering injuries to an employee and extensive physical damage to the process building. A third-party investigation conducted by the municipality's workers' compensation and property insurers traced the cause of the explosion to a leak in the sludge gas conveyance system piping. The explosion's ignition source could not be determined because the building contained several potential ignition sources ranging from electric motors to light switches.

IN BRIEF
- **Methane is a potentially explosive by-product of the anaerobic digestion of wastewater solids.**
- **Following a methane explosion at a wastewater treatment plant (WWTP), a municipal risk sharing pool implemented a novel approach to preventing recurrence. Collection system piping and associated equipment at several WWTPs were monitored for methane leaks using a portable flame ionization detector (FID).**
- **Methane leaks were identified in five of the six studied plants. These leaks were most commonly associated with the condensation drip trap gas piping component.**
- **Results of this six-plant analysis suggest FID monitoring may be a cost-effective screening tool to verify the integrity of methane collection system piping and components at WWTPs, landfills and other biogas-producing facilities.**

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Anaerobic Sludge Digestion

Anaerobic sludge digestion is a process whereby organic solids generated during the treatment of municipal wastewater are further degraded by means of anaerobic bacteria. As a by-product of metabolism, the bacteria generate a sludge gas that is 60% to 70% methane, 30% to 40% carbon dioxide, and 0% to 3% trace substances (Erftverband, 2006). Gas generation rates for typical municipal digestion processes have been described to range from 0.8 to 1 m^3/kg volatile solids destroyed (Vesilind, 2003).

Sludge gas is not odorized through the addition of sulfide or mercaptan compounds as is common practice for commercial fuel gas. Consequently, plant personnel receive no olfactory warning of leaks. Instead, they must rely on fixed and portable flammable gas monitoring systems as well as soap bubble testing of equipment to identify system leaks.

Sludge gas is managed in several ways depending on the quantity generated and its methane content. The gas may be vented directly to the atmosphere if generated in small quantities (e.g., typically concentrations below 10% lower explosive limit), or the gas may be thermally oxidized via an automatic flare system. Most commonly, however, methane-rich sludge gas is thermally oxidized in an industrial furnace for energy recovery purposes. Less common is thermal oxidation in a gas turbine to produce electric power (Erftverband, 2006). Photo 1 shows a typical anaerobic sludge digester building at a municipal WWTP.

Incidence of Methane Explosions in Anaerobic Sludge Digester Operations

Although the potential presence of methane at municipal WWTPs and in the collection infrastructure is well described in the literature, little evidence suggests that methane explosions are anything more than infrequent events. The 2009

Photo 1: Typical anaerobic sludge digester building.

explosion was the first for the workers' compensation insurer, which has been underwriting municipal WWTPs since 1992.

A literature search for similar explosions occurring in Pennsylvania located a 1987 NIOSH report that described a fatal digester explosion at a different borough-owned WWTP. In this case, NIOSH concluded that the explosion was triggered when a non-explosion-proof light employed by operators draining a sludge digester shattered, igniting residual methane inside the tank. In addition, the author knows of only one other methane explosion occurring at a different insured's WWTP in the 1960s.

The relative low incidence rate of methane explosions at WWTPs in Pennsylvania may be due to rigorous permitting requirements by the state's Department of Environmental Protection (DEP). These requirements include agency design guidelines that specify process explosion controls and agency approval of plant designs before operating permits are issued (Pennsylvania DEP, 1997). It also has been the author's experience that municipal-owned WWTPs built in the 1980s and more recently often have more sophisticated ventilation and explosive gas monitoring systems compared to WWTPs built in the 1960s and 1970s.

Initial Insurer Response to Explosion

The methane gas explosion had a significant adverse effect on the injured employee, the injured employee's family, plant staff, the municipality and its insurers. In response to this large loss, the municipality's workers' compensation insurer, through its risk control department, initiated a safety review of all insured WWTP operations.

Six facilities, including the plant involved in the explosion, were identified as performing anaerobic sludge digestion. The insurer initiated a literature review and issued an advisory to its members summarizing best engineering practices for preventing methane explosions in anaerobic sludge digester processes. These best engineering practices were developed based on current editions of the following standards and guidelines:

•Pennsylvania DEP *Domestic Wastewater Facilities Manual* (1997);

•NFPA 820, Standard for Fire Protection in Wastewater Treatment and Collection Facilities (2008);

•NFPA 54, National Fuel Gas Code (2009);

•NFPA 85, Boilers and Combustion Systems (2011);

•NFPA 86, Standards for Ovens and Furnaces (2011);

•American Society of Mechanical Engineers (ASME) CSD-1, Controls and Safety Devices for Boilers (2009);

•OSHA 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals (2011).

Before distributing the advisory, the document was peer reviewed by the risk pool's boiler and machinery insurance provider. (To request a copy of the advisory, send an e-mail to **perndwein @dvit.com**.)

In addition to the advisory, risk control personnel implemented two other interventions. First, the group performed focused inspections of the six facilities with anaerobic sludge digestion processes to verify compliance with best engineering practices. Second, a program was implemented to provide funding support to members with the expectation that they would initiate an independent mechanical integrity evaluation of their processes using internal contract engineering resources.

While the initial focused audits were completed by the insurer's risk control staff, to date only one of the six plants has used the financial incentive program. Subsequent discussions with risk pool members indicate appreciation for the grants; however, due to the recession and subsequent discretionary

Table 1
Results of Methane Fugitive Emissions Monitoring

Plant	Location of leak	Concentration (ppm)
A	Sludge trap	3,500 to 4,000
	Drip trap	> 4,000
	Steel pipe flange	1,200 to 1,600
	Steel pipe flange	800 to 1,200
B	Drip trap	1,076 to 1,308
	Accumulator	1,800 to 2,200
C	Drip trap	704 to > 4,000
D	Drip trap	1,284 to 3,000
E	None. Sludge gas not being collected	
F	Pressure gauge	> 4,000

spending cuts, expenditures for all nonessential projects have been temporarily halted.

Fugitive Methane Emissions Monitoring Project

Due to the limited success of the technical assistance grant initiative, risk control staff decided to pursue an alternate strategy at the six WWTPs of concern. Nondestructive testing such as ultrasonic and industrial radiography was ruled out due to high project cost. Instead, the group decided to perform a mechanical integrity study using air pollution control methodology, EPA Method 21 (2011). Method 21 was originally developed to enable select fixed facilities to verify compliance with their air permit provisions. The method employs a direct-reading monitoring instrument to locate and classify volatile organic compound (VOC) leaks from process components such as valves, flanges, seals and pumps.

Since the risk control group lacked the personnel and instrumentation to complete the study internally, it retained a local industrial hygiene consulting firm to perform the field work. In consultation with the firm's CIHs, the team decided to utilize a portable flame ionization detector (FID) for monitoring. This instrument measures concentrations of airborne organic, combustible gases and vapors, and it is commonly employed for EPA Method 21 monitoring. Based on the manufacturer's literature, the instrument has a lower detection limit for methane of 0.5 ppm with a detection range of 0.5 to 50,000 ppm (PerkinElmer Inc., 2000). Photo 2 shows how an FID might be used in a field survey mode.

Given the nature of treatment operations and the potential for interference from trace VOCs, an action limit of 1,000 ppm was established as indicating a significant methane leak. This level was approximately an order of magnitude below the lower detection limit of the fixed and handheld explosive gas monitoring equipment available to employees at the WWTP where the explosion occurred. The consulting firm then visited each target WWTP and conducted an FID scan of all accessible methane collection piping and system components.

Portable FIDs

Flame ionization detectors (FIDs) are portable, direct-reading monitoring instruments capable of detecting a wide variety of volatile organic compounds including methane at low ppm concentrations. The instruments are commonly used in emergency response and environmental remediation operations. The FID is also the instrument of choice when performing fugitive emission monitoring, according to U.S. EPA Method 21 (PerkinElmer Inc., 2000).

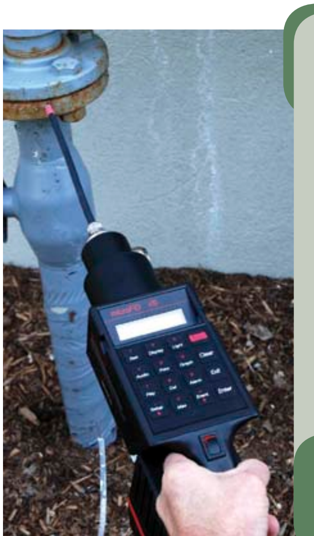

Photo 2: MicroFID portable flame ionization detector (*Image Courtesy of Photovac, an INFICON Brand*).

Monitoring Results

The monitoring study was performed over the course of 6 days in March 2011. Significant leaks were identified in five of the six plant. On the day of the study, Plant E, where the explosion had occurred, was venting sludge gas directly to the atmosphere and, thus, was not collecting methane in its collection system. Table 1 summarizes the results that exceeded the established action level of 1,000 ppm.

Discussion

Monitoring results were supplied to each WWTP superintendent along with photos of the process component where leaks were detected. Superintendents were asked to perform corrective maintenance and notify risk control staff when the leaks had been addressed.

Of considerable interest was the observation that four of the five facilities actively collecting methane had significant leaks associated with the condensate drip trap process component. Because water vapor is a normal component of sludge gas production, drip traps are standard process components designed to remove potentially corrosive moisture from piping systems (ASME, 2001). Drip traps allow the piping to be periodically drained while preventing sludge gas from escaping. Pennsylvania DEP's (1997) permitting guidance directs permittees to install drip traps at low points in the process piping where moisture tends to accumulate. Photos 3 and 4 show examples of typical condensation drip traps encountered during the study.

This unexpected finding suggests that the drip trap seals may degrade over time and, consequently, should be targeted for periodic preventive maintenance checks. A web search did not indicate that this concern has been previously described in

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the literature. This finding also suggests that the area near a drip trap is a good location for a fixed gas monitoring system sensor. The sensor could provide an early warning of seal degradation.

Subsequent to this discovery, risk control staff performed an Internet search to locate manufacturer guidance for drip trap inspection and maintenance. Most manufacturer literature found did not specify maintenance and testing intervals or procedures. One manufacturer provided a comprehensive installation, operation and maintenance guide for its line of manual drip traps. This guide stated, "It is important to regularly inspect and clean drip traps, especially their seating surfaces." No inspection interval was specified, however. Detailed maintenance procedures were then described (Groth Corp., 2003).

Conclusion

Through the use of an EPA air pollution control methodology and a direct reading instrument, significant leaks in the methane collection system can be pinpointed for corrective action. The method is a cost-efficient screening tool for use by risk management personnel in the absence of resources for more thorough nondestructive piping integrity testing.

This analysis suggests that WWTPs, landfills and other biogas producers should follow manufacturer recommendations on preventive maintenance of drip traps to ensure the seal integrity of this equipment. Absent a manufacturer's recommendation on inspection interval, the author recommends checking the proper function of drip traps annually using a monitoring instrument that can detect methane in the 1,000 ppm range.

Based on the success of this project and the potential for conditions to deteriorate over time, risk control staff plans to repeat the methane fugitive emission monitoring every 5 years for existing insureds. In addition, new members are subject to a baseline leak check upon joining the risk pool.

By publishing these findings, the author hopes owners and operators of WWTPs, landfills and other biogas-generating facilities will undertake similar studies and, thereby, avoid catastrophic methane explosions. **PS**

Photos 3 and 4: Typical condensation drip traps.

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Developing Best Engineering Work Practices

The risk control department has a fundamental mission to inform risk pool members of practical interventions for preventing personnel and property losses. In the aftermath of the sludge digester explosion, the department initiated a process to identify applicable regulations, standards and guidelines to serve as the basis for an advisory to its members. Drawing on the expertise of its in-house staff and external vendor partners, the risk control staff first compiled a list of potential governmental agencies and standards-setting organizations applicable to the wastewater treatment industry.

The websites for each entity were searched for applicable engineering and work practices. Search results were evaluated, and the specified safe work practices combined into a single guidance document. This work product was subsequently reviewed by the risk pool's boiler and machinery insurer for technical content and consistency. The final guidance document was ultimately distributed to each site risk control contact for implementation.

From this effort, the risk control group concluded that acquiring the myriad of safety standards and guidelines presents a significant challenge to municipal employers tasked with ensuring compliance.