Understanding landfill gas monitoring techniques

There are a number of technologies that can measure landfill gas. The key for operators is finding one that is cost-effective and reliable.

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Landfill gas (LFG) is typically about 50 percent methane, making it the chief component present in emissions. This gas can be monitored and used to determine how much LFG a site is emitting, both directly as methane and as a surrogate for total emissions.

Methane can be monitored above the surface of the landfill as a gauge of potential emissions or can be directly measured using techniques that test for the rate or flux of emissions.

The above-surface monitoring techniques for gauging potential emissions include surface emission monitoring, ground-based or low-altitude imaging and satellite and aerial imaging.

SURFACE EMISSION MONITORING

Surface emission monitoring (SEM) is a technique that involves using a portable methane meter near the landfill's surface to measure concentrations while traversing the site.

SEM is a requirement under the federal New Source Performance Standards (NSPS) for landfills generating more than 50 megagrams per year of non-methane organic compound (NMOC) emissions; however, the U.S. Environmental Protection Agency (EPA) (https://www.epa.gov/)recently changed the NSPS regulation to require monitoring for facilities generating 34 megagrams per year. California also has SEM requirements for landfills, which are more stringent than the EPA's. The California regulation requires more extensive monitoring and a lower methane concentration limit.

The EPA and California regulations set standards for how the monitoring must be performed. Critical factors in determining the requirements are the spacing of the pathway used in the monitoring, the inclusion of integrated (average concentration across a grid) monitoring in addition to instantaneous monitoring, the action level for emission reductions, the monitoring of cover penetrations (e.g., gas well locations) and the frequency of monitoring.

The EPA requires monitoring using a serpentine pathway with 30-meter intervals. California requires much tighter spacing of 7.6 meters (25 feet).

Instantaneous monitoring is monitoring of the methane concentration at the landfill surface at a single point and time. Instantaneous monitoring provides a picture of localized methane emission locations. Integrated monitoring, on the other hand, is the aggregation of the methane readings for a specific area of the landfill. Instantaneous and integrated monitoring can be performed simultaneously, though it requires additional data processing.

The new NSPS and the California regulation both require monitoring cover penetrations such as wellheads, vents and posts that pass through the cover of the landfill (the older NSPS rule does not require this). These penetrations are potential points where LFG can flow to the surface with less resistance than passing through other areas of the cover.

Finally, both the EPA and California regulations require monitoring on a quarterly basis. The California regulation allows less frequent monitoring if several conditions are met, but the NSPS does not allow less frequent monitoring except for closed landfills that meet certain criteria.

The cost of implementing the California requirements is roughly three times higher than implementing EPA requirements due to the tighter path spacing, additional equipment and processing requirements and the need to monitor cover penetrations. The costs for large sites scale roughly proportionately with the site's area, and costs for small sites (smaller than 50 acres) are driven by fixed costs such as mobilization, equipment and reporting rather than the size of the site. Costs can range from several thousand dollars to more than $10,000 per event.

GROUND-BASED OR LOW-ALTITUDE IMAGING

Infrared (IR) cameras let you see frequencies that the human eye cannot, including frequencies where methane is visible. IR cameras are already used by the oil and gas industry to look for leaks along pipelines and at facilities, but they are not commonly used in the solid waste industry where there may be application-specific challenges. Other imaging technologies, including hyperspectral imaging and thermal imaging, are also available, but IR imaging is the most prevalent.

Methane can be emitted by a landfill both from the landfill surface and from the LFG collection and control system (GCCS) components. Methane leaks from oil and gas facilities tend to be localized hot spots, like seams and holes in equipment, and leaks from the landfill GCCS would be comparable. Methane from the landfill surface would be emitted from a larger area and would not necessarily have the same contrast with the surrounding methane concentration as a pipeline leak.

IR cameras could be used by landfill personnel to look for large methane sources. Adapting the technology and techniques used in the oil and gas industry to landfill GCCS systems seems straightforward, but it remains unclear whether the technology can be adapted to look for surface emissions in a way that is less expensive or more effective than SEM.

IR cameras can be mounted, handheld or drone-mounted, which allows for versatility and widespread use. Drone-mounted IR cameras have the potential to monitor areas where personnel are not available or that cannot be safely accessed; however, IR cameras may not be good at pinpointing methane emission sources, and personnel will be required to have access to the location to remediate emissions in question.

Equipment and monitoring costs can range from the high thousands of dollars range to tens of thousands of dollars per event. As technology improves, IR technologies may be able to see and accurately quantify low concentration leaks as these tools become more cost-effective.

SATELLITE AND AERIAL IMAGING

Satellite and aerial imaging require using imaging technology similar to IR cameras or spectrometry to detect methane from a much higher elevation than commercial drones can. Satellite or aerial imaging can provide a measurement of methane emissions from very large sites or for entire regions.

In 2016, satellites were able to detect emissions of the methane gas leak from the SoCalGas Aliso Canyon facility, which is a large natural gas facility in Los Angeles County. Those images were gathered by both aircraft and satellites. Similar high-altitude imaging could be used to get a picture of the methane emissions at landfills. Some studies in Southern California have detected large landfills via emissions with this high-altitude imaging. However, due to the distance and scale of the imaging, it is not suitable for finding point emission sources at landfills at this point. This remote imaging does not currently provide a reliable quantitative estimation of methane emissions or concentrations, but research and methodologies are being developed to establish quantitative measurements.

Additionally, high-altitude imaging is too expensive to be used for regular monitoring of individual sites, with costs ranging from the high tens of thousands to mid hundreds of thousands of dollars per event. This technology is primarily useful as a research tool to determine methane emissions from a region with a number of methane sources. It is not as practical as and is much more expensive than using a handheld or drone-mounted IR camera for the monitoring of individual sites.

RECOMMENDED APPROACH FOR LANDFILL MONITORING

With the number of monitoring technologies out there, it can be difficult for operators to distinguish which is best.

SEM is a well-demonstrated and proven monitoring strategy for assessing landfill emissions. SEM requirements can be balanced to achieve cost-effective monitoring by adjusting the monitoring path spacing and the action level for required remedial action.

IR imaging is a promising technology. Although it is not as robustly demonstrated for landfill application, it should be considered an alternative or complement to SEM. IR imaging has the potential to quickly identify high-methane emission points on landfills that could potentially be missed by SEM, while SEM has the ability to quantify the concentration of methane accurately at such hot spots. These technologies work well in concert, but the combined costs may make them prohibitive for individual sites.

Although satellite and aerial imaging offer promising data, they aren't comprehensive enough yet for practical use. These limitations, in addition to cost, disqualify satellite and aerial imaging methods in favor of more traditional LFG monitoring technologies.

Direct methane measurement

Landfill methane measurement is the direct measurement of methane emissions from landfills. Direct measurement of methane is much more expensive than SEM. Four ways to measure landfill methane directly are flux chamber testing, plume measurement, micrometeorological methods and dispersion modeling

FLUX CHAMBER TESTING

Flux chamber testing measures methane flux (mass emissions per area) at points on the landfill surface using flux chambers. Flux chambers are small (typically around 1 square meter or less) half-open chambers that are placed on the surface being sampled. The total area sampled by flux chambers is only a small fraction of the overall landfill area, so flux chamber testing must include a method to extrapolate isolated flux measurements to site-wide emission rates. Flux sampling methods are generally standardized, but there are no industry-accepted standardized methods for the extrapolation of site-wide emissions.

The EPA published a method for determining the number of required samples and sample locations (Radian 1986), but the number of samples required for even a small landfill is impractical.

PLUME MEASUREMENT

Plume measurement methods use ground-based optical sensors to measure the methane plume coming from the landfill. Those plume measurements are then used to calculate the landfill's methane emission rate. There is currently no widely used standardized optical sensor method. The EPA has published Other Test Method 10 (OTM 10), but the method has been found to be unreliable, with poor accuracy and poor repeatability. Over the last several years, the EPA has moved away from the use of OTM 10 for determining methane emissions from landfills.

Due to the high cost ranging from the high tens of thousands of dollars to mid hundreds of thousands of dollars per event, specialized requirements, poor accuracy, poor consistency and poor repeatability of results in studies done to date, plume measurement methods like OTM 10 are not recommended for quantification of methane emissions from landfills at this time.

MICROMETEOROLOGY METHODS

Eddy covariance and similar methods are emerging as the current practice for measuring methane plumes. While eddy covariance appears to be the most common practice, similar methods, such as eddy accumulation and the Bowen ratio, may find similar application.

In eddy covariance, the concentration of methane is measured using an infrared laser at multiple elevations above the landfill surface while collocated meteorology data are collected. The measurements are used to calculate the methane emission rate from the source. Micrometeorological methods are generally superior to plume measurements because some equipment packages can remain in place and provide regular monitoring over extended periods with more consistent results. Commercial sensor and software packages are available for turnkey micrometeorological monitoring installations.

Eddy covariance is well demonstrated in applications outside the landfill industry, but costs for this method are in the low to mid-hundreds of thousands of dollars per site, which make it impractical for most sites. However, this may be practical for research purposes or other special cases.

AIR DISPERSION MODELING

Air dispersion modeling can be used to determine emission rates from landfills. This method monitors on-site and/or downwind methane concentrations using a dispersion model to calculate methane emissions from the landfill.

The methane monitoring must be contemporaneous with the collection of modeling-quality meteorology data. The methane monitoring is typically more expensive than a typical SEM event due to the collection of meteorology and location data during the monitoring event. Ongoing, near-real-time monitoring requires advanced monitors for methane and meteorology, significant automated data management and sophisticated data processing to quickly process meteorology.

Calculation of methane emissions using dispersion modeling is not required by regulation, though it has been used to demonstrate regulatory compliance in California. No standard method for reverse modeling has been developed, but methods have been proposed (Huitric and Kong, 2006). Air dispersion models generally provide conservative downwind concentrations, which are necessary when using the models to demonstrate compliance with air quality standards; however, the conservative results could lead to an underestimation of methane emission rates.

Dispersion models, and AERMOD in particular, can be inaccurate when modeling impacts very close to area sources, such as landfills. Air dispersion modeling costs will be in the high tens of thousands of dollars to low hundreds of thousands of dollars per event.

RECOMMENDED APPROACH FOR LANDFILL MEASUREMENTS

The cost of directly measuring methane emissions from landfills does not justify widespread adoption of any of the methods discussed for regular use. The direct measurement methods cost two to three orders of magnitude more than typical SEM events. However, the methane measurement methods are useful in research applications or on a case-by-case basis to demonstrate site-specific emissions.

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