REVIEWING AND INTERPRETING LANDFILL GAS MONITORING DATA

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ABSTRACT

Landfill gas (LFG) data is typically collected from a number of locations on and around a landfill. These include: 1) LFG header ports, 2) LFG extraction wells, 3) soil monitoring probes, 4) bar hole probes, 5) surface emission monitoring including integrated surface sampling, point source and flux chamber.

Correct interpretation of data is needed to make well field adjustments and to know if a problem or potential problem exists. This paper discusses how to interpret data from a landfill gas collection and monitoring system and from the landfill's surface.

INTRODUCTION

Proper data interpretation can be a tremendous asset to aid in the operation of LFG systems. Good data can help an operator determine if there is a problem or potential problem with a LFG extraction system. It can help identify the source of a problem. It can be used to quantify LFG surface emissions or to estimate how much air is being drawn into a landfill. It can also help to determine if a problem is transient (follows barometric pressure changes) or continuous. Some of the questions an operator typically wants answered are:

1. Are the data valid (does the data make sense)?
2. Is the landfill at risk of a fire?
3. How much LFG is escaping through the surface and subsurface?
4. Is the landfill complying with the perimeter and surface control requirements?
5. Are structures on or adjacent to the landfill at risk?
6. Is LFG likely to cause groundwater contamination?
7. Is there more gas available for collection?

There are no absolute rules to use when interpreting data, but there is a general sequence that we like to use. These are:

1. Validate the data
2. Look for outliers in the data, indicators of problems
3. Compare the current data with past data looking for trends

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4. Based on the objectives of the LFG system, make recommendations for adjustments and/or system improvements
5. If trying to correct a specific problem, form a hypothesis of the cause of the problem and test it against the data to see if it is valid

Landfill gas measurements are normally taken using portable instruments. This paper focuses on interpreting data using these instruments.

DISCUSSION

Evaluating Data Validity

The first step in interpreting the data is to evaluate the data to see if it is reasonable. Often times there are errors or anomalies in the data rendering it unsuitable for interpretation. Several sources of problem data include: 1) instrument limitations, 2) poor calibration, 3) leaks in the sample train, 4) poor or improper sampling procedures, and 5) sample point construction deficiencies. Examples of some of these limitations include:

1. Zero methane readings in a catalytic type combustible gas indicator.

   Normally one would look at a zero methane reading in monitoring probes as being good; however, this is only valid if there is sufficient oxygen in the sample to catalytically combust the hydrocarbons present in the sample. If O_2 is not measured or if O_2 content is less than 10%, and if a percent methane measurement is not taken using a non-catalytic type of instrument (an instrument that does not require oxygen to function properly). The actual methane reading is indeterminate.

2. The results of probe monitoring show low methane and low carbon dioxide with high oxygen and nitrogen.

   There are two tests we like to use with these results to determine if air is short circuiting into the gas sample, or if air travels through the soil or refuse first. This test assumes that air migrating through soil or refuse will have some or most of the infiltrating oxygen consumed by aerobic bacteria. The first test looks at the CH_4/CO_2 ratio. For raw undiluted LFG, this ratio is typically 1.3 - 1.5. Ratios less than this typically indicate some aerobic activity. The second test is to compare the percent nitrogen (balance gas) to the percent oxygen. A nitrogen to oxygen ratio close to 3.76 indicates that the sample is probably diluted with pure air. Subtracting the air and normalizing the results will give the probable raw LFG concentrations. This test is useful when doing probe monitoring to verify that a fitting in the probe or gas sample train is not loose.

3. Modern hand-held field instruments can sometimes complicate data interpretation. This is because algorithms in the instrument sometimes recalculate the percentage of measured concentrations so that the sum does not exceed 100%. This takes away from the technician's ability to observe drift or possible instrument problems.

This problem was encountered at a landfill using three separate calibrated instruments. The gas concentrations measured by the instruments consistently looked valid and were within the expected range. However, subsequent measurements using a gas chromatograph showed that the instruments consistently measured methane 10 to 17% higher than the actual concentration. Instead of being above 50% methane as the instruments read, the actual concentration was less than 40%.

A few of the commonly used field instruments and problems they can have are listed below:

- Flame Ionization Detector (FID) - without a gas chromatography column attached, this instrument does not distinguish between various molecular weight hydrocarbons. One volume of benzene, for instance, has similar results as six volumes of methane.
- Infrared (IR) - These instruments are typically multi-function with built in normalizing algorithm. Some contaminants can cause substantial error in the readings.
- Combustible Gas Indicator (CGI) - This instrument is most commonly used to monitor probes. Because the instrument catalytically combusts the sample, if insufficient oxygen is present, the results will be low. A negative (down scale) reading in a CGI normally indicates high methane and low oxygen.
- Photo Ionization Detector (PID) - PIDs are normally used for safety monitoring. High methane in the sample or moisture can both effect the results. At one site, a PID was used to measure chlorinated hydrocarbons in processed landfill gas. Because of the elevated methane in the sample, vinyl chloride at 15 to 20 ppm was not detected.

This list is not meant to be exhaustive, rather it is provided to help understand the need to know the limitations of field instruments.

<u>Outliers</u>

Once you are satisfied that the data is valid, look for outliers that may indicate an operational problem with the LFG collection system. Things to look for and their meaning are presented in Table 1 below.

TABLE 1
IMPACT OF SUSPECTED OUTLIERS

Outlier	Impact
1. Elevated temperature	Potential fire risk
2. Unusually high methane	probably a bad measurement
3. Unusually high CO2	High aerobic activity
4. Oxygen in the LFG greater than 2% (Note: Most oxygen is consumed by aerobic bacteria in landfills)	Increased fire risk or leak in the sample train
5. Residual Nitrogen* greater than 20%	Increased fire risk

*Residual nitrogen is caused by air infiltrating the landfill. It is the nitrogen that is measured in the LFG that no longer has the corresponding amount of oxygen. For instance, the following measurements for oxygen and nitrogen are made: Oxygen = 2%, Nitrogen = 30%. The residual nitrogen $RN_2 = 30 - 2 \times 3.76 = 22\ ½\%$. The 3.76 value is the ratio of nitrogen to oxygen in air.

When dealing with outliers, it is always worth the effort to repeat the monitoring to validate the suspect data. Outliers may be valid. Examples of confirmed outliers include unusually high or low methane in samples. For instance, it is possible to have confirmed monitoring results showing methane in wells exceeding 80%. Conversely, there was one landfill that had a confirmed concentration of more than 80% carbon dioxide in a well. As a result there are no absolute answers.

Trending

Trending data using graphs is one of the most powerful tools to determine the performance of a gas system. At one site, GCE was reviewing monthly data provided by the owner. Some of the data started to show subtle increases in residual nitrogen and gas temperature. Each data point taken by itself did not indicate a problem, however, when looking at the trend it became obvious that something was happening. We notified the client that there was a potential problem and within a week a fire broke out in the landfill.

Trending has a second significant benefit when evaluating probe data. The time of day monitoring is performed can have a substantial impact on the results. For instance, probes at a desert landfill were getting occasional methane measurements greater than 5%. The methane data alone did not show a consistency pattern. However, comparing the methane measurements with the time of day they were made indicated that they had increasing methane concentrations in the afternoon. To test the hypothesis that barometric pressure was causing the offsite emissions, monitoring was performed over a six hour time period. It was discovered that as the barometric pressure decreased, the probe methane concentration increased. This problem was caused by a decrease in the barometric pressure.

Recommendations for Adjustment

Determining the objectives of the gas system is necessary to make well field adjustments. Some of the objectives that are used include:

1. Protection of groundwater
2. Subsurface LFG migration control
3. Surface emission control
4. Odor control
5. Beneficial use (energy recovery)

Each of these can have slightly different well field design and operations criteria. Typically, the first four objectives require more aggressive LFG collection than the fifth. Beneficial use may require a higher BTU value gas, hence LFG emissions can be higher.

There are two common methods of making well adjustments. Methane targeting is normally used to adjust interior LFG extraction wells and residual nitrogen targeting is used to adjust perimeter wells. A Table showing normal adjusting ranges and complete procedures on making well adjustments based on targeting is included in the "Landfill Gas Operation and Maintenance Manual of Practice", Solid Waste Association of North America, 1997.

Several excerpts from this manual are given to clarify how these procedures are used and how ranges of residual nitrogen and methane are used for targeting.

The methane targeting equations is:

$$\text{Adjusted LFG Flow} = \text{Measured LFG Flow} \times \frac{\text{Measured CH}_4\%}{\text{CH}_4\%\text{ Target}}$$

and the methane target values are:

Example Methane Target Values

Target	Application
50-55%	Interior gas wells used for energy recovery
45-50%	Interior gas wells where environmental control is important
40-45%	Aggressively trying to control LFG migration
30-40%	Interior gas wells where acute LFG emission problems are occurring (There may be an increased risk of landfill fires at some sites when operating in this range.)
less than 30%	Perimeter gas wells outside of refuse

The residual nitrogen equation is:

$$\text{Adjusted LFG} = \text{Measured LFG Flow} \times \left(\frac{(100 - RN_2\%\text{Actual})}{(100 - RN_2\%\ \text{Target})} \right)$$

and the RN2 target values are:

Interpretation of Nitrogen Residual in LFG

Residual Nitrogen %	Interpretation
0 to 6	Normal to understressed; typical for high BTU facility where low nitrogen is desirable
6 to 12	Normal desirable operating range without compromises for problem landfills
13 to 20	Excessive nitrogen; may be necessary for aggressive perimeter migration control, or side slope emission control
Greater than 20 percent	Over-stressed, this level of nitrogen should be avoided if at all possible except for aggressive emission control

SURFACE EMISSIONS

Surface emission monitoring is another area that can be helpful in determining how well a gas system is operating. Integrated surface sampling (ISS) or instantaneous surface monitoring (ISM) procedures can be used to quantify emissions and determine locations of excess emissions. It should be pointed out that emissions are generally greatest on the slopes of a landfill and less on the flat surfaces. (This is probably because the horizontal permeability of refuse is greater than the vertical permeability.)

One of the questions that is commonly asked is, "How much gas is escaping from the landfill?" Air modeling procedures may be used to estimate surface flux based on surface concentrations. Methane is the gas of greatest interest because it gives a direct correlation of raw LFG emissions. Carbon dioxide is also useful because it can be used to estimate the amount of aerobic attenuation in the landfill surface.

In a properly designed LFG system, it is not uncommon for the calculated LFG collection system efficiency to be 90% or greater. Collection efficiency (CE) is calculated as follows:

$$CE = 1 - \left[\frac{\text{Surface Methane scfm}}{\text{Collected Methane scfm} + \text{Surface Methane scfm}} \right]$$

This calculation assumes zero subsurface emissions

The primary difficulties in obtaining good surface emission data (Instantaneous Surface Monitoring (ISM) and Integrated Surface Sampling (ISS)) is maintaining the sample collection at a constant height above the landfill surface and variable wind speed.

An approximate estimate of LFG emissions from a landfill surface can be made by summing the total carbon (methane and carbon dioxide) leaving. This measurement has some error because of carbon dioxide generated by the aerobic decomposition of vegetation in the landfill surface.

CONCLUSION

The best way to interpret and understand data is to establish a site hypothesis and test field measurements against it. It is important to collect sufficient data and then invest time in data analysis. The ideas listed in this paper are only the starting point. Landfills often have ways of giving unexpected results.