Landfill Gas Freakometrics: Metrics-Based Management of Landfill Gas Systems across the U.S.

As landfill gas collection and control systems (GCCS) become more complicated and operating conditions more challenging, it is no longer sufficient for the landfill gas (LFG) industry to operate gas systems based solely on compliance thresholds associated with state and federal air regulations. With the volume and variety of data collected at a single point (e.g., gas concentration, pressures, temperature, flow rate, liquid levels, pump cycle counts, etc.), and dozens of possible data collection point types (blowers, laterals, wellheads, probes, leachate sumps, etc.), landfill owners/operators find themselves armed with a significant arsenal of information that can – and should – be leveraged for more than simply ensuring compliance with regulatory thresholds for pressure, temperature, and oxygen (PTO). Key stakeholders, including operations and maintenance (O&M) technicians operating the wellfields, engineers evaluating system performance and designing GCCS expansions, and regional and corporate managers responsible for the overall management of the facility focus on different aspects of landfills, yet all can benefit from utilization and optimization of the data at their disposal.

BACKGROUND

With an increase in available data, the challenge is in identifying and focusing on which data are most important from the standpoint of optimizing operational efficiency to maintain regulatory compliance, while maximizing LFG extraction in the most cost effective manner. Managers need to quickly identify trends, highlight areas of concern, and measure whether O&M and construction efforts are effective in improving GCCS operations and providing the appropriate value. Senior managers need to demonstrate that policies and procedures related to LFG management are driving corporate and municipal assets in the correct direction and limiting environmental and legal liabilities.

As the second largest solid waste management company in North America, Republic Services (Republic) operates an LFG program that relies heavily on accurate data collection and a robust technology platform to provide O&M and compliance metrics to site monitoring personnel, consultants, and managers who operate, maintain, and monitor GCCSs at more than 200 Republic landfills located throughout the U.S.

This metrics-based approach to LFG management marks an evolution from reactive to proactive, with processes ranging from simple evaluation of trends and counts of monthly threshold exceedances, to complex advanced statistical methods to identify key drivers such as methane to carbon dioxide ratio as a possible indicator that a site is experiencing precursor conditions that may require a modified or alternative management approach. Tangible benefits include:

- **Operational and Planning:** O&M teams can measure, quantify, and improve the "health" of wellfields by evaluating the effectiveness of system components currently installed and better understanding areas where improvements are needed. Managers and engineers can use this tool to help identify, forecast, and properly budget expansion needs rather than rushing to implement improvements when regulatory exceedances occur.

- **Predictive:** Owners and operators are able to make business decisions based on advanced predictive analytics to minimize risk in their operations.

- **Multi-Site Management:** Managers of multiple sites are able to use metrics as a "snapshot" to compare or rate GCCS performance between sites and against set performance goals or criteria. This enables them to identify sites with challenges and where additional resources may need to be deployed.

A number of potential metrics that can be beneficial when evaluating GCCS performance, and each landfill owner and GCCS operator employs different approaches. Common metrics include:

- Overall flow rate
- Flow/well
- Flow/waste in place
- Available pressure
- System pressure
- Liquid levels in wells
- Wellhead CH_4/CO_2 ratio
- Wellhead static pressure
- Wellhead temperature
- Wellhead oxygen concentration
- Wells with non-negative pressure
- Excessive system adjustments

Examples of how operational, predictive, and management benefits are gained by harnessing the power of robust database tools and properly applied metrics are provided below.

CASE STUDY #1 – OPERATIONAL AND PLANNING BENEFITS OF MULTIVARIATE DATA ANALYSIS

As illustrated by the following case study, when landfill GCCS operations are driven only by NSPS operating criteria (i.e., PTO), larger systemic issues can be missed altogether. At Landfill Site A, December 2013 LFG wellfield monitoring identified only a single well with an NSPS operating criteria exceedance. All wells had negative pressure, all wellhead temperatures were below 131 °F, and only one well (as depicted by the box around the circular well symbol in **Figure 1**) contained oxygen greater than 5 percent. It should also be noted that surface emissions (another NSPS monitoring requirement) are below regulatory thresholds.

Figure 1. LFG Extraction Well Oxygen Concentration Range Map, Site A

Based on compliance data, it would appear there is limited work required in order to maintain "good" operating conditions. However, by analyzing the GCCS from a broader perspective and using just two additional metrics, overall LFG flow rate and available pressure, it is possible to quickly identify conditions that may warrant additional investigation, or that directly identify problems. These conditions may be precursors to regulatory compliance issues, point to reduced system performance, or indicate other operational issues. The supplemental criteria used to provide better insight into GCCS performance are further described below.

- **Overall LFG flow rate** – This is defined as the rate of gas flow to the control component of the GCCS.

  What does not show up in the compliance-centric data evaluation approach is that over the previous several months, the site-wide LFG flow rate at this active landfill sharply declined from an average of approximately 1,480 standard cubic feet per minute (scfm) to an average of approximately 1,170 scfm (a 21% decline). This trend is shown in **Figure 2**.

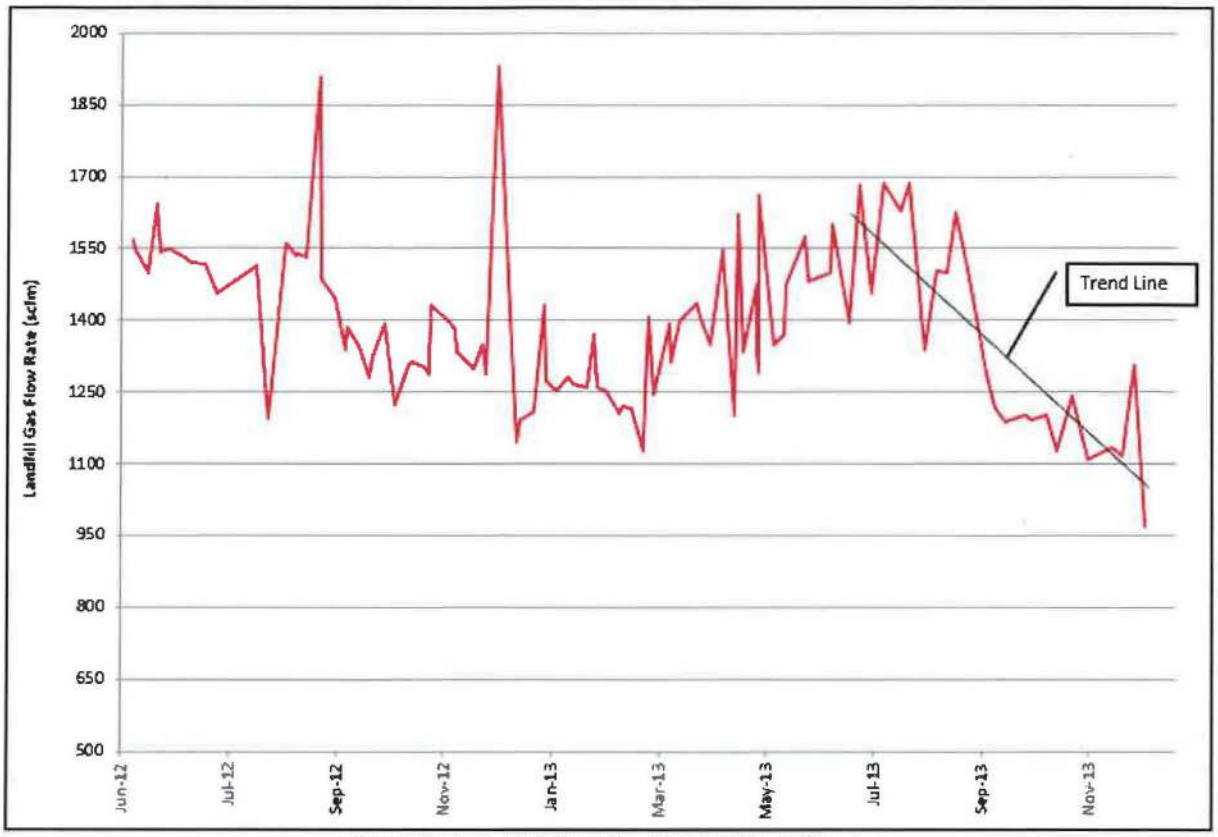

Figure 2. Landfill Gas Flow Rate Trend, Site A

- **Available pressure** – Available pressure is defined as the difference between the *system pressure* that is measured in the gas collection header/lateral pipe at the well and the *wellhead static pressure* measured inside the well. Informally, available pressure is known as the "room to run" for vacuum since it gives a measure of how much additional negative pressure (i.e., vacuum) can be applied to a well or collector. While design criteria vary, it is generally accepted that available pressure should be -10 in-w.c. or lower (i.e., 10 in-w.c. vacuum or more).

  Based on industry experience, negligible available pressure (i.e., between 0 and -5 in-w.c.), is typically an indication of one of the following:

  - A "deadhead" condition (i.e., little to no flow rate) caused either by:
    - Liquids that have submerged a significant portion of the perforated pipe in the well, or
    - Pinching or other obstructions in the well casing
  - Minimal vacuum in the header caused by:
    - Low blower vacuum set point
    - Insufficient blower (or flare) capacity
    - Blockage in the header or lateral gas collection pipe network
  - Undersized header or lateral pipes

By applying the metric of available pressure, **Figure 3** shows that the well with the NSPS exceedance had an abundance of available pressure, which is desirable, but the majority of the wellfield had minimal or negligible available pressure. While not directly evident from a compliance-driven evaluation perspective, this is an operational concern because it means there is reduced ability to increase LFG flow in the majority of the wells. If not addressed, this operational concern could lead to compliance issues in the future.

Looking at just these two metrics, it is apparent that wellfield performance has diminished during this period, even though regulatory compliance is being maintained. These metrics also quickly highlight where future O&M and construction efforts should be focused in order to ensure infrastructure is in place and functioning properly to avoid compliance problems, thus enabling the site compliance management to shift from a reactive to proactive management approach.

Figure 3. Wellhead Available Pressure Map, Site A

CASE STUDY #2 – PREDICTIVE BENEFITS

Moving beyond simple counts of exceedances of performance or compliance criteria, robust database tools provide the ability to identify trends in operating data and variances from what is considered the status quo for a well or group of wells. Going beyond looking at numerical thresholds and looking at trends in the data is especially important for early detection of subsurface reactions or other conditions that can have a profound effect on the installed infrastructure at a landfill and may require alternative approaches in management and operation of both the site and the GCCS.

As an example, at Site B, for years, gas capture was sufficient to meet compliance thresholds. But as shown in the series of graphs in **Figure 4**, changes occurred in the gas composition over time. The ratio of methane (CH_4) to carbon dioxide (CO_2) was originally greater than 1.0, then inverted such that a gradual, then rapid decline in CH_4 and a corresponding increase in CO_2 occurred, which was followed by an increase in wellhead gas temperature that approached, and

in some cases exceeded, 200 °F. The advanced analytical tools the landfill owner used allowed it to better understand the subsurface reaction that was occurring and the speed with which conditions were changing, particularly with respect to rising gas temperature. These trends, particularly those showing large changes from normal operating conditions were important for identifying that enhanced monitoring, O&M, and infrastructure improvements were necessary to properly manage the subsurface conditions.

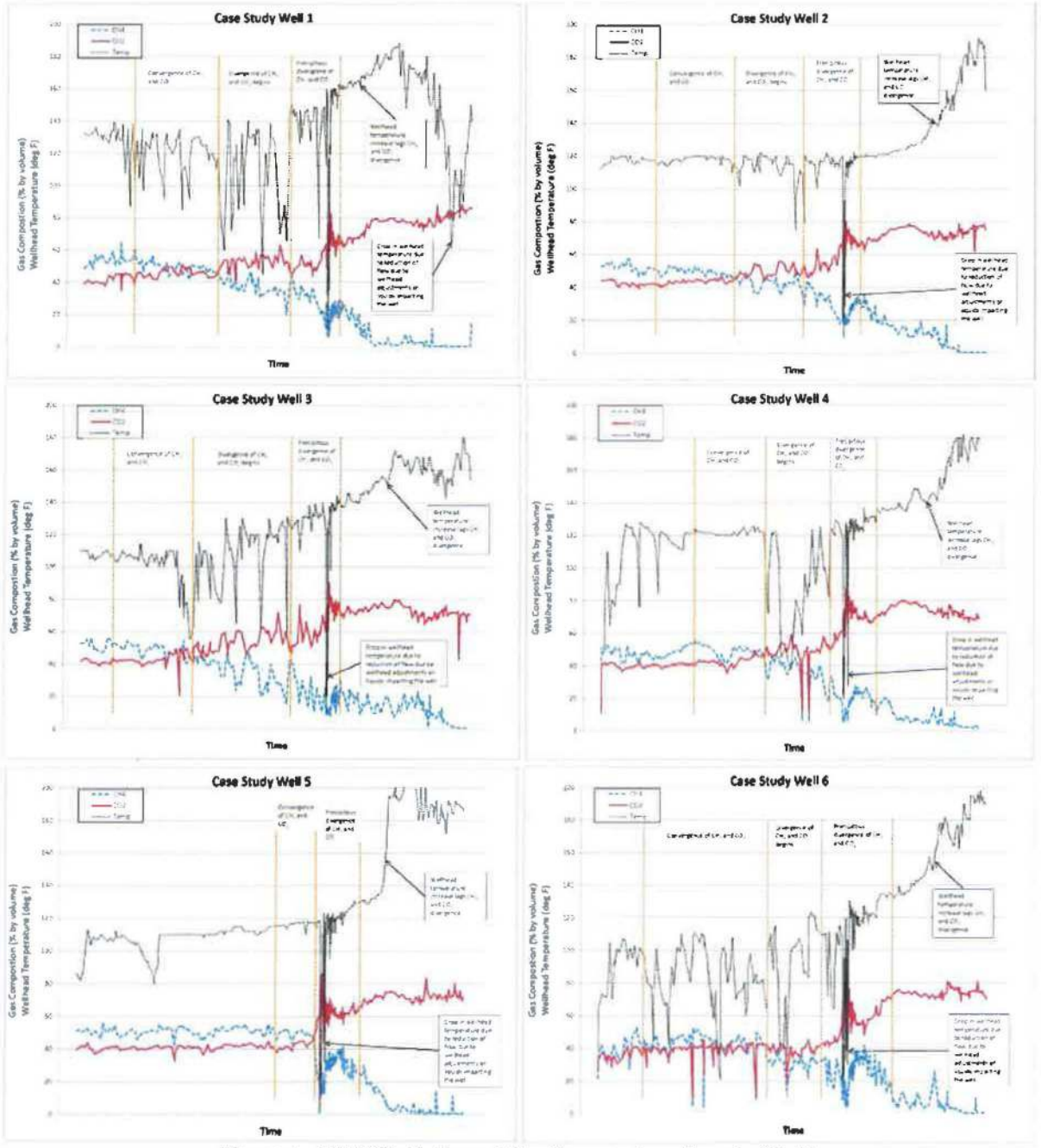

Figure 4. CH_4/CO_2 Ratio and Gas Temperature Trends, Site B

CASE STUDY # 3 – MANAGEMENT BENEFITS OF ENHANCED DATA ANALYSIS

Owners and managers (including managers of O&M providers) who oversee multiple sites need to be able to look at sites from both a macroscopic and microscopic scale to ensure that each GCCS is meeting performance and efficiency targets. From a macroscopic perspective, stake holders can evaluate possible site-wide issues identify if additional resources are needed, whether standard operating procedures are effective, and whether there are lessons that can be gleaned from particular sites and deployed elsewhere. From a microscopic perspective, multivariate analysis can help to determine the true nature of the genesis of a compliance issue and/or if there is more to an issue than simple wellhead adjustment alone can mitigate.

In addition, from a multi-site perspective, there is profound benefit in tracking performance relative to various and multiple metrics. An example of the improvements that have been witnessed by applying a metrics-based O&M approach is shown in **Figure 5**. In this graph, 30 landfills have been placed into 5 groups based on common site characteristics (e.g., geographic location, moisture, nature of refuse, etc.). These groups were evaluated based on a straight arithmetic average of their conformance to a confidential set of criteria. Thus, the percentage of wells in each group of sites meeting the evaluation criteria was tracked over a 19-month period. At the outset, there was a 6 month period (Jul-Dec) during which focus was gradually and increasingly brought on landfills of greatest priority. Modest overall progress was witnessed during this initial period. As a more regional and company-wide focus was applied in months 7 and 8 (Jan-Feb), O&M and construction efforts accelerated and focused, bringing a significant downward trend across the population.

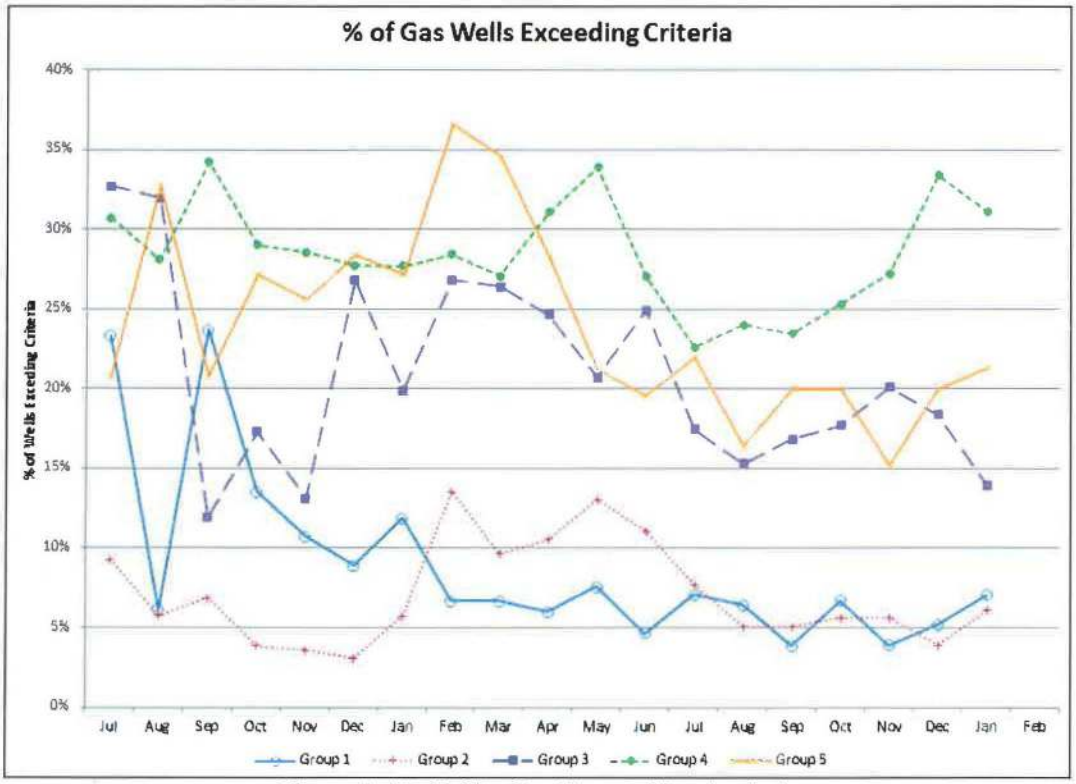

Figure 5. Multi-Site Gas Composition Analysis

By tracking data in this manner, O&M teams are incentivized to excel, and upper and mid-level management can identify the groups of sites where progress is lagging and deploy resources or training as necessary to meet the company's goals. It also enables decision makers to evaluate whether sufficient benefit is being gained from capital expenditures such as equipment upgrades, system expansions, etc.

CONCLUSION

The power and advantages afforded by sophisticated analytic tools cannot be understated. Robust technological platforms allow landfill owners and operators a new insight into GCCS operations by providing views of operating conditions and trends across a broad range of parameters, whether for individual wells, individual sites, or multiple sites. This approach focuses O&M teams and helps to ensure proper deployment of resources. Given the benefits of this metrics-based approach, the LFG O&M industry is, for what appears to be the first time, focusing in concert on site-wide analysis. It has been done in limited amounts in the past, but the current movement is larger and casting a wider net than ever before. The result is a greater focus on field practices, higher quality of data oversight, deeper insight to the causes for various conditions, proactive discovery and correction of GCCS issues, and ultimately more efficient operations.