MSW Management
The Journal for Municipal Solid Waste Professionals

Elements 2011

LFG Collection Efficiency: Debunking the Rhetoric

Recent research shows that EPA default values exaggerate landfill-gas fugitive emissions.

By Amy Van Kolken Banister, Patrick S. Sullivan

Landfill-gas (LFG) collection efficiency is the amount of LFG that is collected relative to the amount generated by the landfill. Landfill opponents often incorrectly cite an Intergovernmental Panel on Climate Change (IPCC) LFG collection efficiency value of 20%, which represents the low end of lifetime average collection efficiencies for international greenhouse gas (GHG) inventories for landfills (IPCC, 2006). They also suggest that some time after closure, LFG generation could increase if liquids are allowed to infiltrate into the refuse mass resulting in LFG generation rates that are equal to or greater than the peak rate. This assumption is far divorced from fact, and simply not supported by the available data.

Regulators often use assumed collection efficiencies to calculate landfill emissions for regulatory and other purposes. The EPA's AP-42 document (USEPA, 1997) provides a conservative default collection efficiency value of 75% (from a range of 60% to 85%). The EPA derived this default value from a literature review and compilation of engineering estimates made by various practitioners in the LFG industry, rather than from field test data (Leatherwood, 2002).

Landfill proponents believe that collection efficiencies greater than 75% are commonly achieved, and that the widespread use of a default value prevents sites from demonstrating enhanced collection using available site-specific information. Required use of default values also creates disincentives for owner/operators to achieve higher collection efficiencies.

While a variety of experts, including those involved with development of the IPCC methodologies, have proffered opinions about LFG collection efficiencies based on theoretical analyses, few quantitative estimates of LFG collection efficiency have been developed until quite recently.

Literature Review

The only way to rigorously quantify collection efficiency is to measure collected and fugitive methane emissions from the same landfill area at the same time. While collected methane data are readily available, measures of fugitive emissions are considerably more difficult to obtain and have only been reported for a few landfills. The Solid Waste Industry for Climate Solutions (SWICS, 2009) compiled data on field studies of methane flux where collection efficiency was or could be calculated and presented these in an industry guidance document. The numeric values for collection efficiency proposed by SWICS were adopted by the EPA in its Mandatory GHG Reporting Rule (40 CFR, Part 98, Subpart HH).

As detailed in SWICS (2009), Spokas et al. (2006) summarized intensive field studies of the methane mass balance for nine individual landfill cells at three French landfills with well-defined waste inputs. Collection efficiency was calculated as the ratio of recovered gas to empirically modeled gas generation. Specifically, Spokas et al. used the following equation:

CH4 generated = CH_4 emitted

+ CH_4 oxidized + CH_4 recovered

+ CH_4 migrated + ΔCH_4 storage

Methane generation was estimated from a gas production model. Emitted methane was measured either by static chambers or by an atmospheric tracer technique. Methane oxidation was measured by a stable isotope technique that provides a conservative estimate of oxidation. Recovered methane was based on direct measurements at each landfill, and methane migration was based on calculations of methane diffusion through liners. Maximum potential methane storage was calculated from an estimate of waste porosity and changes in methane concentration and used as an upper limit of the value required to close a mass balance. For this report, the data were recalculated where collection efficiency was defined as (Equation 1):

$$\frac{\text{methane collected}}{\text{methane collected + emissions + oxidation + migration}}$$

Results are summarized in Table 1. As presented, collection efficiencies for final clay covers were uniformly above 90% while the collection efficiency for the temporary cover was slightly above 50% in the summer but over 90% in the winter. Collection efficiencies were then recalculated to be consistent with other literature, which exclude the oxidation and migration terms that can introduce more uncertainty. The difference between equations 1 and 2 is minor in consideration of the uncertainty of these types of studies. Equation 2 is as follows:

$$\frac{\text{methane collected}}{\text{methane collected + emissions}}$$

Borjesson, et al. (2007) reported on methane oxidation and gas collection at six Swedish landfills using Fourier-transformed infrared (FTIR) in combination with a tracer. While the emphasis of their study was on methane oxidation, sufficient data were published to calculate collection efficiency as in Equation 2. Data from two of the landfills (Hagby and Visby) were excluded from this review because it was reported that the gas collection system was not working during the test period. Landfill test results are presented in Table 2. All landfills reported were active and only minimal information was reported on the cover type.

Mosher et al., (1999) reported a summary of methane emissions from nine landfills in the Northeastern US. Emissions were measured by both static chambers and a tracer flux technique. Two of the landfills collected LFG, making it possible to compare emissions to collected gas. One of the two landfills was closed and had a geomembrane plus soil cover. A collection efficiency of 90.5% was calculated as in Equation 2. The authors indicate that the gas collected was not measured accurately, which casts some doubt on this value. This collection efficiency is nonetheless likely to be reasonable from two perspectives. First, this landfill had the lowest emissions of the sites studied, and, second, the collection efficiency is consistent with other values in this review. A collection efficiency of 70% was calculated for an active landfill in which part of the landfill was covered with a geomembrane but other parts had daily cover only.

Huitric and Kong (2006) reported collection efficiencies for the Palos Verdes Landfill (PVLF) in Los Angeles County. The PVLF was closed in 1980, has a 5-foot-thick clay cap and an active gas-collection system. LFG emissions were measured using an SEM-500 flame ionization detector (FID) monitor. An "integrated surface methane" (ISM) concentration was measured by surface scans at 3 inches above the surface after dividing the landfill into approximately 1-acre grids. The measured ISM was compared to the ISM that was calculated using the EPA's Industrial Source Complex (ISC) air dispersion model. The calculated ISM assumes no gas collection, and the source term was based on the volume of collected gas at the PVLF. Collection efficiency was calculated by Equation 3, as follows:

$$\frac{ISM_r}{(ISM_r + ISM_e)}$$

Where: ISMr is the modeled reduction in surface emission due to collection and ISMe is the measured surface methane concentration due to emissions.

In this method, emissions from methane oxidation are incorporated into the measured ISM. This calculation assumes that methane concentration is correlated to flux. Calculated collection efficiency of the PVLF system was 94% to 96%. In Huitric et al. (2007), the collection efficiency determined using Equation 3 was supported by the results of a static-flux-chamber study completed at the PVLF under the direction and approval of the California Department of Toxic Substances Control (DTSC). In fact, even higher collection efficiencies were reported for the PVLF when using flux-chamber results, approaching 100%.

Lohila, et al. (2007) reported methane fluxes for a section of a Finnish landfill that included an active disposal area and a sloped area. The active area was covered daily with soil and construction-and-demolition waste rejects, and the sloped area had a cover that included 0.2 to 0.5 meters of compost over 0.5 to 2 meters of diamicton and clay. Three estimates of collection efficiency were reported. First, it was reported that the mean methane flux over seven days was reduced by 79% when the gas collection system was turned on. This measurement was made by using methane concentration data coupled to an eddy covariance method. Another estimate was made by comparing the mean methane emission to the volume of gas collected and assuming that methane production was the sum of emissions and collection. This resulted in an estimate of 69% collection efficiency.

Numeric Collection Efficiency Values

Based upon literature review, LFG collection efficiencies for landfills with different types of cover and active LFG collection systems are presented in the bullets below (SWICS, 2009):

- 50%–70% (mid-range default = 60%) for a landfill or portions of a landfill that are under daily soil cover with an active LFG collection system installed;
- 54%–95% (mid-range default = 75%) for a landfill or portions of a landfill that contain an intermediate soil cover with an active LFG collection system;
- 90%–99% (mid-range default = 95%) for landfills that contain a final soil and/or geomembrane cover systems with an active LFG collection system.

Note that the mid-range default values for the three cover types identified above were adopted by the EPA as part of its Mandatory GHG Reporting Rule (40 CFR, Part 98, Subpart HH). This gives strong credence that these values are representative of landfills in the United States.

Numeric Collection Efficiency

The most recent IPCC guidance on landfills (IPCC, 2006) states that "Some sites may have less efficient or only partial gas extraction systems, and there are fugitive emissions from landfilled waste prior to and after the implementation of active gas extraction; therefore estimates of lifetime recovery efficiencies may be as low as 20%." Landfill opponents commonly use this statement to support a position that the lifetime collection efficiency for US landfills is only 20%. To clarify, the 20% value quoted by the IPCC represents a global average, not a US average. There are numerous inaccuracies associated with this position, which clearly demonstrate that the 20% value has no relevance for landfills in the US.

The 20% capture rate is not representative of landfills in US for the following reasons. The lifetime capture rate of 20%, is representative of all landfills around the world, where many landfills are not designed or operated consistent with US standards for sanitary landfills. Also, the value is clearly defined as the low end ("may be as low as"), and the United States is clearly not on the low end of LFG collection worldwide. As reported by Themelis (2008), the US collects approximately 60% of all LFG currently recovered worldwide, far more than any other country, even though the US generates only 24% of the worldwide methane. Themelis (2008) also notes that US landfills emit only approximately 15% of the fugitive methane emissions worldwide. By this measure, clearly US landfills are not on the low end of the global gas-capture scale.

In addition, the same IPCC report also says that "greater than 90% recovery can be achieved at cells with final cover and an efficient gas extraction system," which, of course, landfill opponents never cite. This higher estimate is based on intensive field studies of the methane mass balance at landfills, as detailed above, while the 20% value is only an estimate.

Further, the US has the most comprehensive requirements for LFG collection and control in the world, as accomplished through the landfill New Source Performance Standards (NSPS) under 40 CFR, Part 60, Subpart WWW, as well as more stringent state regulations such as California Assembly Bill 32's landfill methane rule. These regulations prevent excessive fugitive emissions by requiring LFG collection and control as well as extensive monitoring for surface emissions of methane to maximize LFG capture. They also dictate specific requirements for how comprehensive LFG systems must be designed and operated.

In addition to air-quality regulations, US landfills install LFG collection systems to comply with Resource Conservation and Recovery Act (RCRA) Subtitle D requirements. Sites also operate collection systems for LFG migration control and to prevent offsite odor and groundwater impacts, as required by regulations and to support LFG recovery and beneficial use projects. Finally, the US has an active carbon credit trading market with landfill methane reduction projects representing the largest percentage of projects where verified carbon credits have been issued (Climate Action Reserve [CAR], 2010).

To summarize: There are numerous drivers leading to the installation and operation of LFG collection and control systems in the US, thus achieving the highest degree of LFG collection worldwide. As such, the 20% value suggested by IPCC, and misquoted by the landfill opponents, is neither representative of nor reasonable to ascribe to US landfills.

LFG Emissions after Closure

Landfill opponents suggest that some time after closure, LFG generation could increase if liquids are allowed to infiltrate into the refuse mass, resulting in LFG generation rates that are equal to or greater than the peak rate. This assumption is far divorced from fact, and not supported by the available landfill data. It is well known and recognized that LFG generation rates will decrease over time to insignificant levels and that the maximum LFG generation rate occurs at or within two years of closure.

According to LandGEM the EPA's LFG emissions model (USEPA, 1997), gas generation resembles a bell curve, as shown in Figure 1.

LandGEM is based on a first-order decomposition rate equation for quantifying municipal solid waste (MSW) landfill emissions. The first-order decay model is also used by the IPCC and is the standard and accepted technique for estimating LFG generation. During the early and late phases of a landfills lifetime, LFG generation is at its lowest, as shown in Figure 1. The majority of LFG produced occurs during the active phase of the landfills lifetime—during the time when LFG collection is required per regulation. LFG generation decreases after the landfill is closed, as shown at the peak of the graph, which occurs the year after closure.

The NSPS requires landfills to install LFG collection within the first two to five years of the initial placement of the first ton of waste in the landfill after the NMOC emissions reach 50 mg per year. The system may be removed at a closed landfill when the NMOC emissions decrease below the 50 mg threshold. During these uncontrolled time periods (shown in red in the area under the curve), the assumption is that limited methane emissions will occur. Also, much of the fugitive emissions is oxidized by the cover materials, since oxidation is at its greatest when gas production and resulting methane flux are at their lowest (Bogner, et al., 2007).

Bogner, et al., (2007) reported that "under circumstances of high oxidation potential and low flux of landfill methane from the landfill, it has been demonstrated that atmospheric methane may be oxidized at the landfill surface. In such cases, the landfill cover soils function as a sink rather than a source of atmospheric methane." Schuetz, et al. (2003) also reported that "...landfill soil covers show a significant potential for methane oxidation and co-oxidation of NMOCs. Under certain conditions, landfills may even function as sinks of both methane and selected NMOCs including aromatic hydrocarbons and lower chlorinated compounds." This research demonstrates that methane oxidized in landfill cover can actually result in no net emissions.

The thought that additional moisture will infiltrate into the waste far into the post closure period, resulting in substantive gas production, is flawed. There is no evidence of landfill covers failing in United States in post-closure to any substantial degree. These barriers are generally clay/soil caps, mostly with vegetation. The vegetation prevents erosion of the cap, and there is no evidence that these caps degrade substantially over time to the degree necessary to allow massive infiltration of liquids. Even synthetic caps have additional soil layer that would remain intact even under the highly unlikely scenario that there was failure of the primary cap. Further, at and throughout closure, landfill surfaces are graded to drain rainwater away from the landfill, which would further prevent water infiltration.

A final landfill cap is also unlikely to fail, because RCRA regulations require the landfill owner/operator to maintain the final cover during the lengthy post-closure maintenance period. RCRA requirements dictate when the landfill operator may be released from post-closure maintenance responsibilities and are designed to ensure the landfill's potential to affect the groundwater and to generate LFG is no longer significant.

US landfills that have been closed and capped for over 50 years have not experienced even a small increase in gas production well into post-closure. For example, the LFG rule applicable to Los Angeles area requires LFG systems remain in operation at many smaller and older landfills. Some of these sites have been redeveloped into golf courses and parks where the surface is actually irrigated well after closure. Even with this irrigation, there have been no increases in gas generation/recovery after closure. The landfill opponents stating this opinion have absolutely no real-world evidence of the phenomenon they suggest will occur.

LFG Emissions Prior to LFG Collection

Landfill opponents believe substantial methane emissions occur before LFG collection systems are commissioned. This position is predicated on two theories. First, certain highly degradable organic wastes produce methane before LFG collection and cover practices are used. Second, LFG systems are not installed in new waste disposal areas until five years after disposal, the regulatory deadline per NSPS.

Again, these opinions are unfounded. Although the NSPS rule does not require LFG collection for up to five years in an active area, many landfills install controls early to prevent migration and odor and to support renewable energy projects. Sites also install systems early to meet RCRA and other applicable regulations (i.e., local nuisance rules). As such, most of the waste is subject to a much shorter deadline to install the LFG system.

According to Themelis (2008), the majority (66%) of the waste that is placed in the US is disposed in landfills with active gas collection systems in place. Many of the "new" disposal areas overlay and/or are adjacent to areas that already have LFG collection. As such, LFG generated is

immediately under the vacuum influence of existing LFG systems upon deposition. Second, US cover practices require refuse be covered with daily cover at the end of a working day; therefore, waste is covered within 24 hours per federal and state regulations.

Surface emissions monitoring data from the South Coast Air Quality Management District Rule 1150.1, which requires monitoring of all landfill surfaces regardless of waste age, shows no appreciable difference in emissions for the active face of the landfill where recent disposal has occurred versus other areas under intermediate cover with active collection. Therefore, field data do not support the hypothesis that methane emissions are not controlled because of LFG collection delays. The concept that such delays occur for five years is incorrect and misleading.

Finally, the research on methane oxidation, as summarized by SWICS (2009) and Chanton (2009), demonstrates that daily cover soils oxidize methane to a greater degree than many low-permeability final-cover soils. Biocovers used as alternative daily cover (ADC) have been shown by Abichou (2004) and others to have even greater methane oxidation potential than soil covers, thus creating an excellent use in emissions reductions for the same organic materials that the landfill opponents claim will cause excess methane to be released. This serves as an additional control measure for methane not controlled in the active disposal areas.

Topics: LFG,LFGTE,Outreach