CRITICAL ANALYSIS OF LITERATURE ON LANDFILL GAS COLLECTION EFFICIENCY

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EXECUTIVE SUMMARY

The ultimate end products of anaerobic biodegradation as it occurs in landfills are methane and carbon dioxide which together are referred to as landfill gas (LFG). Many landfills have gas collection and control systems (GCCS); however, not all the generated LFG is collected, as some is generated before the GCCS is installed and GGCSs are not 100% effective. Methanotrophic bacteria that reside in landfill cover soils can oxidize some of the uncollected methane to carbon dioxide, and the remainder is released to the atmosphere as “fugitive” emissions. The U.S. EPA estimates that landfills are the third largest source of anthropogenic methane emissions in the country. Thus, there is considerable interest in estimating and measuring methane emissions from landfills that receive biodegradable waste.

The objective of this study is to review the existing literature on LFG collection efficiency (CE) and to evaluate the literature for data that can be used to parameterize models to estimate LFG emissions for U.S. landfills. A desired outcome of this review was to recommend values or ranges of values that could be applied to emissions models. This report reviewed 22 studies that reported on emissions from landfills in Sweden, Denmark, France, Finland, Italy, Iceland, the UK, and the U.S. Ultimately 92 landfills were determined to be relevant to collection efficiencies at U.S. landfills based on design and operational characteristics, such as cover type and the age and amount of waste in place. The distribution of CE measurements included in this review can be seen in Figure ES-1.

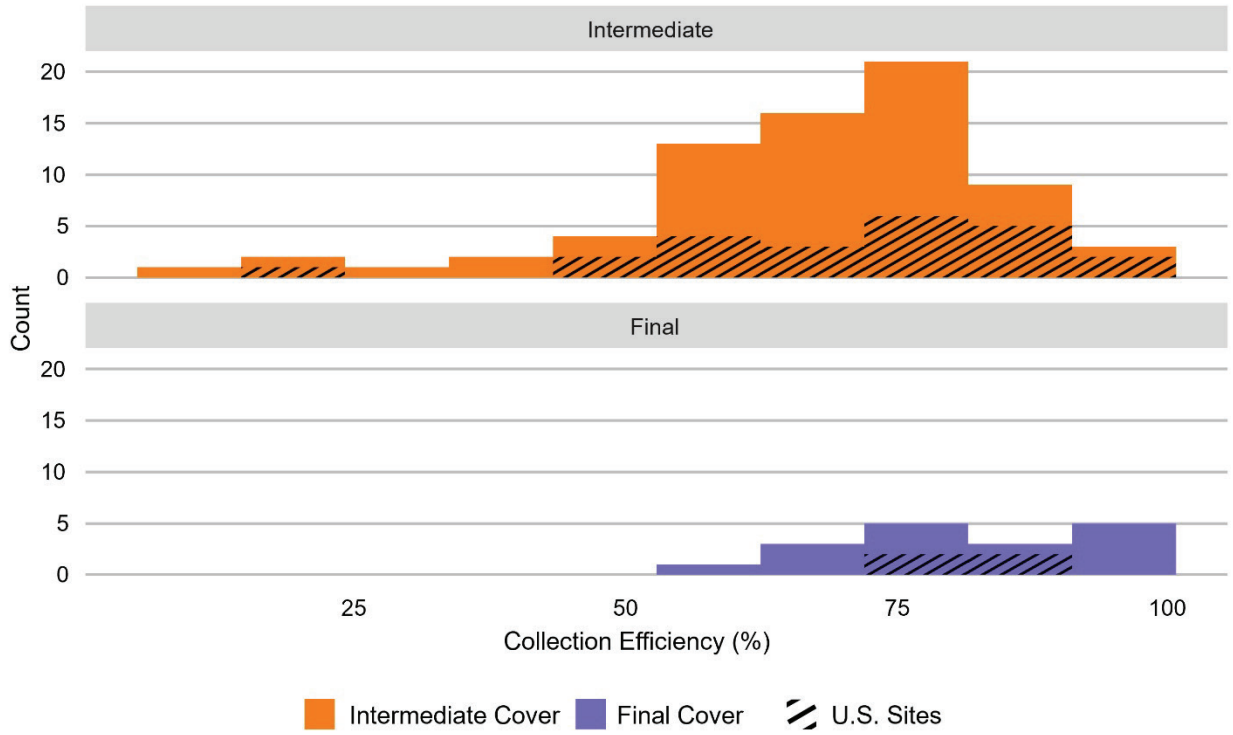

Figure ES-1. Histogram of included collection efficiencies by cover type. The black lines represent data from U.S. landfills.

Based on the results of this review, the authors are reluctant to recommend a point value for the CE for either an intermediate or final cover and rather think that it behooves the operator to select a CE in the context of considerations applicable to their site and the published dataset. With this caveat, a summary of the CE measurements that were judged useful to inform U.S. emissions modeling is presented in Table ES-1.

We observe the following ranges:

- The middle 50% of values, i.e. the interquartile range for for U.S. landfills with intermediate cover had a range of 59.5 – 85%. A long-term intermediate cover can be expected to be at the upper end of this range (or higher).
- The interquartile range of values for all landfills with final cover had a CEs between 71.7% and 92.6%; as there were only 4 final cover measurements reported for U.S. landfills, all locations are represented here. A well-maintained final cover with a geomembrane, clay, and vegetation will be at the upper end of this range or above, while a poorly maintained clay would be at the lower end of the range.
- Two studies of U.S. landfills documented negligible emissions from selected final covers which indicate that values above 92.6% are appropriate for final covers that include a geomembrane.

Table ES-1 Summary statistics for reported Collection Efficiencies

Intermediate Cover MCI (%)		
	All	**U.S. Only**
Mean	66.9	71.3
Median	70.0	81.0
Std. Dev.	16.4	17.0
Interquartile range	59.5 – 79.0	59.5 - 85
Number of data points	75	23

Final Cover MCI (%)		
	All	**U.S. Only** (including sites with negligible flux)^a
Mean	80.6	82.7(88)^a
Median	79.4	83.7(89)^a
Std. Dev.	14.0	8.0
Interquartile range	71.7 – 92.6	Not calculated
Number of data points	17	4

a. Two studies each reported a site with negligible flux through final cover, but no measured gas collection volume, so a collection efficiency could not be calculated. Two sites with an MCI of 98% have been added to the calculations in parenthesis to represent these sites.

Recommending values, or ranges of values, that could be applied to emissions models is difficult in consideration of the large ranges reported in the literature and the numerous site-specific factors that influence CE. The full range for intermediate cover reported in the literature spans from 14% to 95%. Ultimately, each of the reported measurements is valid, which means that there is precedent for a CE for an intermediate cover of 14 – 95%. The 14% could be attributable to a sandy cover that results in high infiltration and flooded gas collection wells, all of which lead to poor LFG collection. The 95% may be a long-term interim cover that uses clay and perhaps an exposed geomembrane, is vegetated to minimize erosion and cracking, and/or has good LFG collection well coverage.

Many factors contributed to large ranges of values for intermediate and final cover, some of these factors are listed below. Quantitative relationships between each operational variable and CE would be ideal, but given the complexities of landfills are beyond what can be expected from data collection, since landfill conditions change frequently and emissions measurements are expensive, complicated, and have uncertainty:

- All landfills with intermediate cover were combined into one category. This includes landfills with a mix of daily and intermediate cover, and daily, intermediate and final cover. The fraction of intermediate cover was rarely specified. In addition, the cover design was not uniform across studies.
- There are several variables in addition to cover type that can be expected to influence the CE, e.g., well coverage (wells/acre), well depth and the quality of well maintenance.
- The influence of climate is not well understood, but generally landfills in arid regions produce less gas than landfills in moderate and wet climates, which could lead to a decrease in the volume of emissions and perhaps a higher CE.
- There are other operational and design elements that can be expected to impact the CE including the placement of horizontal gas collection systems early after waste burial, connecting the leachate recovery system to the gas collection system, regular inspection and maintenance/replacement of seals at wellheads, and aggressive cover placement and maintenance.
- The mass of waste in place and its age influence methane generation and likely influence CE.
- Estimates of CE are dependent on field measurements of emissions. Emissions measurements based on a range of methods including static chambers, downwind measurements of a methane plume and aerial-based measurements were considered. Each of these methods has limitations and uncertainty, yet only a few studies quantified uncertainty. The impact of uncertainty on the calculated CE will vary depending on the relative magnitude of the volumes of collected and emitted gas.