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Determination of as-discarded methane potential in residential and commercial municipal solid waste

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ABSTRACT

Methane generation potential, L_0, is a primary parameter of the first-order decay (FOD) model used for prediction and regulation of landfill gas (LFG) generation in municipal solid waste (MSW) landfills. The current US EPA AP-42 default value for L_0, which has been in place for almost 20 years, is 100 m^3 CH_4/Mg MSW as-discarded. Recent research suggests the yield of landfilled waste could be less than 60 m^3 CH_4/Mg MSW. This study aimed to measure the L_0 of present-day residential and commercial as-discarded MSW. In doing so, 39 waste collection vehicles were sorted for composition before samples of each biodegradable fraction were analyzed for methane generation potential. Methane yields were determined for over 450 samples of 14 different biodegradable MSW fractions, later to be combined with moisture content and volatile solids data to calculate L_0 values for each waste load. An average value of 80 m^3 CH_4/Mg MSW was determined for all samples with 95% of values in the interval 74–86 m^3 CH_4/Mg MSW as-discarded. While no statistically significant difference was observed, commercial MSW yields (mean 85, median 88 m^3 CH_4/Mg MSW) showed a higher average L_0 than residential MSW (mean 75, median 71 m^3 CH_4/Mg MSW). Many methane potential values for individual fractions described in previous work were found within the range of values determined by BMP in this study.

1. Introduction

As concerns about greenhouse gas (GHG) emissions and the necessity for improved waste management continue to rise, the need to accurately predict methane generation in municipal solid waste (MSW) landfills becomes increasingly important. Methane generation potential, L_0, is a primary parameter of the first-order decay (FOD) model used for the prediction and regulation of landfill gas (LFG) generation (Krause et al., 2016). In the United States (US) two default regulatory values are attributed to L_0. The first is the Clean Air Act (CAA) default, $L_0 = 170$ m^3 CH_4/Mg MSW. This value was promulgated under the New Source Performance Standards (NSPS) of the CAA and is used by MSW containment facilities (landfills) to determine if a site requires a gas collection and control system (GCCS) (US Congress, 1996). The second default value is that found in AP-42, with $L_0 = 100$ m^3 CH_4/Mg MSW. This value was determined by the Environmental Protection Agency (US EPA) for use in air emission inventories (US EPA, 1998).

In addition to the importance of FOD and L_0 in GCCS design and regulatory compliance, the ability to accurately estimate methane yields is critical in assessing GHG emissions, both in regional and national inventories. Accurate yield predictions are also vital for lifecycle assessments and the comparison of various methods of waste management and treatment technologies. Estimates of L_0 have been used to compare waste management methods with each other, including landfilling, composting, anaerobic digestion, and potential GHG emissions in scenarios with and without GCCS (Zhao et al., 2009) and prior to disposal (Zhou et al., 2017). The broad set of applications and potential influence on waste management practices calls for a well-tested and appropriate value for L_0 (Aguilar-Virgen et al., 2014; Staley and Barlaz, 2009; Clavreul et al., 2012).

With published estimates of the ultimate yield of MSW ranging from 20 to 223 m^3 CH_4/Mg MSW, properly assessing the value of L_0 is vital (Krause et al., 2016). The US EPA has suggested 100 m^3 CH_4/Mg MSW to be appropriate for most landfills since the 1998 amendment to AP-42: Compilation of Air Emission Factors (US EPA, 1998). This value was derived by incorporating data from laboratories, landfill sites, material balance studies, and engineering estimates generated by numerous contributing investigators (Krause et al., 2016). This is lower than the default value (170 m^3 CH_4/Mg MSW) stated in the Clean Air Act, a number used by landfill operators in determining necessity for compliance with NSPS (US Congress, 1996).

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The 100 m^3 CH_4/Mg MSW value described in the CAA falls above values determined in some studies (Eleazer et al., 1997, Staley and Barlaz, 2009). The Intergovernmental Panel on Climate Change (IPCC) maintains a series of models and estimates for landfill gas emissions. The IPCC FOD model incorporates the fraction of degradable organic carbon (DOC) and anaerobically decomposable degradable organic carbon (DOC_f) in the material decomposing, along with a methane correction factor (MCF) to determine methane generation potential (L_0) (Krause et al., 2016). Proposed values of DOC_f and MCF, along with influence from regional weather and composition, translate to L_0 estimates of 50–130 worldwide with a global average of 82 m^3 CH_4/Mg MSW and a US average of 93 m^3 CH_4/Mg MSW using IPCC models (Krause et al., 2016). In the Dutch FOD model, Afvalzorg (version January 2015), household waste is expected to generate 89 m^3 CH_4/Mg (Krause et al., 2016).

Estimates of L_0 are typically based on waste stream composition and methane generation assays, though some estimates have been inferred from collected gas volumes at landfill sites (Wang et al., 2013). The most prevalent method for determining methane generation potential of a substrate is the biochemical methane potential (BMP) assay, first described by Owen et al. (1979). Results from BMP assays on MSW, both similar to the Owen et al. methodology and from modified experimental configurations, have been reported for individual MSW components (Eleazer et al., 1997; Machado et al., 2009), mixed MSW (Eleazer et al., 1997), and samples excavated from landfills (Kim and Townsend, 2012; Caldas et al., 2014). Differences in sample set sizes, sources of materials studied, and the array of differing protocols contribute to the wide range of published L_0 values in these BMP studies (Krause et al., 2016).

One of the most prevalent challenges with measuring L_0 of mixed MSW in a landfill is collecting a representative sample. A more common approach is to determine a weighted average MSW L_0 using specific L_0 values for individual MSW components and their mass fraction based on waste composition studies (Krause et al., 2016). This allows analysis of wide geographic areas with multiple sites of disposal. One study used waste composition data from 11 different states and reported average L_0 to be 59 m^3 CH_4/Mg MSW (Staley and Barlaz, 2009). The waste composition data in the 2009 study was paired with methane yield data from previously published literature (Eleazer et al., 1997), meaning a single yield value for each category was applied to the composition studies from all 11 states. The resulting prediction of methane generation was less than 60% of the current AP-42 standard.

The goal of this work was to assay the L_0 of current residential and commercial MSW in the Southeast US by completing waste composition studies at the point of disposal, assess the moisture and volatile solids content of each sample, and measure the same sorted samples with a uniform BMP analysis. In an effort to include the full range of methane-generating materials, small materials (referred to as *fines* in this study) that often go unsorted and uncharacterized, were specifically included and analyzed as a separate fraction (Lebersorger and Schneider, 2011; Dahlén and Lagerkvist, 2008). The combination of these analyses provides a L_0 value to each of 39 waste collection vehicle loads at four different waste collection host facilities.

2. Materials and methods

2.1. Waste sorting and sampling

Waste composition studies were performed over a 15-month period in sites located in Florida, Georgia, and North Carolina. Relevant details for each facility are listed in Table 1. MSW was sorted into 42 sub-components for this study with 14 biodegradable fractions targeted for methane generation potential assays. After sorting 39 loads of waste at four different facilities, 450 individual samples of the biodegradable MSW fractions were transported to the laboratory and analyzed. BMP assays were performed in triplicate; over 1400 individual assays of samples and controls were constructed and measured throughout this project. Objectives of conducting BMP assays on individual fractions as opposed to the bulk waste itself were to minimize the inherent difficulty of creating a homogenous sample from a mixture of materials with very different properties and to allow an examination of the relative contribution of different components (including fines) to methane yield.

An abbreviated 3–4 day execution of the ASTM D5231-92 protocol for solid waste composition studies was implemented at each of the four locations to gather samples (ASTM International, 2003). Because both residential and commercial loads were targeted, researchers worked with facility operators to select representative incoming loads of both types for sorting. Residential waste streams originated mostly from single-family households and were found in rear-loading or side-loading compactor trucks. Commercial loads were transported mostly by front-loading compactor trucks and enclosed compaction boxes. Only vehicles utilizing a compacting mechanism were selected to avoid bulky wastes typically found in roll-off bins. Drivers were also used as a reference in the selection process to avoid sorting loads with unusual composition (McCauley-Bell et al., 1997).

Targeted waste loads were tipped on a designated area before facility operators mixed and quartered the MSW with heavy equipment until a subsample weighing between 91 and 136 kg was obtained as specified in the ASTM (ASTM International, 2003). Subsamples were hand-sorted into specific material categories by eight sorters with the aid of a sorting table constructed on-site. The sorting table stood 1 m high, 1 m wide, and 2.5 m long and featured a top with metal screen mesh (5 cm square) that allowed smaller particles to drop through to a lower secondary metal screen (2.5 cm square). This allowed separation of the fine materials into two fractions; 2.5–5 cm *fines* and less than 2.5 cm *fines*.

Table 1
Locations and details of waste composition studies.

Sampling location	Facility description	Regional waste description	Waste trucks characterized	Date of study
Lee County, Florida	Municipal waste-to-energy facility	Facility accepts 1800 tons MSW daily from 618,000 residents. 46% overall recycling rate (Florida Department of Environmental Protection, 2014)	6 Commercial 6 Residential	January 2014
Alachua County, Florida	Municipal waste transfer station	Facility transfers about 530 tons MSW per day from 250,000 residents. 58% overall recycling rate (Florida Department of Environmental Protection, 2014)	4 Commercial 0 Residential	March 2014
Athens-Clarke County, Georgia	Municipal waste landfill	Facility landfills about 150 tons MSW from 115,000 residents daily. 44% diversion rate (Athens-Clarke County, 2014)	6 Commercial 6 Residential	March 2015
Durham County North, Carolina	Municipal waste transfer station	Facility transfers estimated 600 tons waste from 223,000 residents daily. 16% overall recycling rate (Durham County, 2009)	6 Commercial 5 Residential	March 2015

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