June 8, 2022

RE: Comments on CAR's draft U.S. Landfill Protocol v6.0, baselines adjustments

Dear Climate Action Reserve Staff,

Thank you for the chance to comment on CAR's draft U.S. Landfill Protocol Version 6.0.

We are researchers with expertise in landfill engineering and carbon offsets collaborating on a study of landfill gas offset protocols and the quality of the offset credits generated under them from US-based projects.

We offer the following suggestions, two of which focus on refining the baseline methods used by the protocol:

1. A higher oxidation rate is likely to be more accurate for the pool of participating projects. The 10% rate estimated by the IPCC used by the protocol is an averaged rate for all landfills. The landfills with lower methane emission rates that are not required to implement capture systems in the United States and are therefore eligible for offsets likely have on average higher baseline methane oxidation rates.

2. The baseline should be amended for some landfills that implement leachate recirculation. Leachate recirculation can both accelerate decomposition that produces methane, and also increase total methane produced over the life of a landfill. If a new gas capture system precipitates the implementation of leachate recirculation and thereby increases total lifecycle methane production, the baseline should be amended to the original without-project levels. Since leachate recirculation is broadly beneficial for landfills, in part because it can decrease the production of toxic pollutants, any amendment to the protocol to modify the baseline should also avoid creating a disincentive for landfills to recirculate leachate. This can be done by accurately assessing the additional methane production that results from leachate recirculation.

3. CAR might consider allowing landfills that pursue activities that enhance methane oxidation to generate offset credits as a new activity type.

These recommendations are described in more detail below.

<u>Baseline Oxidation Assumptions</u>

Methane oxidation occurring in landfill covers depends on multiple parameters including methane influx, soil temperature, soil moisture, and physical soil properties. The Intergovernmental Panel on Climate Change (IPCC) recommends using a default value of 0% for the oxidation efficiency at landfills with final covers, and otherwise recommends a value of 10% at covered, well-managed landfills to account for the methane diffusing through the cap and escaping via cracks and fissures (IPCC, 2019). However, since the 10% IPCC value is an average for all landfills without a final cover, it is likely to be too low for the set of landfills participate in the offset program. This is because those landfills with the most methane production are both more likely to have lower oxidation levels and more likely to be required to capture methane making them ineligible to generate offsets. Landfills that are eligible for offsets are more likely to have higher-than-average rates of oxidation.

The United States Environmental Protection Agency (USEPA) uses graduated default values of 0 to 35% for methane oxidation, depending on the total flow of methane per unit area and the depth of the soil cover layer (USEPA, 2013, Table HH-4, p 71971).

The 10% default value might be appropriate for landfills that are covered with low-permeable soils (such as clayey soils) (e.g. Aghdam et al., 2018; Scheutz et al., 2011b, 2011a). Higher oxidation efficiencies have been reported by numerous studies based on field measurements. Rates documented in the literature include 17-37% (Aghdam et al., 2018), 12-92% (Fjelsted et al., 2020), 26-57% (De la Cruz et al., 2015). Borjesson et al. (2007) conducted field measurements at six Swedish landfills (cold weather) to estimate methane oxidation rates and recommended that the IPCC default values for methane oxidation in managed landfills in similar weather conditions could be set to 10% for active sites and 20% for closed sites. Chanton et al. (2009) reviewed literature results from around 42 determinations of the fraction of methane oxidized in a variety of soil types and landfill covers. The overall mean fraction oxidized across all studies was 36% with a standard error of 6%. Nine of these studies were conducted in Florida and had a fraction oxidized of 27 ±4%; five studies in northern Europe (~50–55°N) exhibited an average of 54 ± 14%; one study in New Hampshire had a value of 10%. Of the 42 determinations of methane oxidation reported, only four report values of 10% or less. The results indicate that the fraction of methane oxidized in participating landfills is likely to be greater than the default value of 10%.

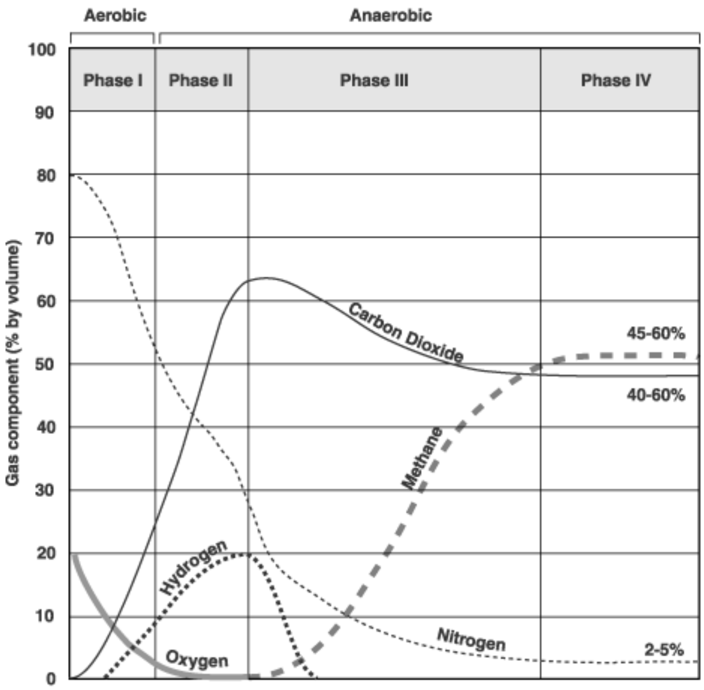
We are aware that increasing oxidation with better soil covers or biowindows can reduce methane emissions at low cost. Biowindows have been shown to increase oxidation rates up to 76% (Berenjkar et al., 2022). These techniques are used in other parts of the world, and are rare in the United States. Has CAR considered allowing activities focused on increasing oxidation rates as an eligible project activity?

Leachate Recirculation

Organic waste disposed in landfills experience four degradation phases (Figure 1). During the first phase, oxygen is consumed and the waste is aerobically degraded. As the second phase starts, acidogenic microorganisms increase biological oxygen demand (BOD) and chemical oxygen demand (COD) and decrease the pH in the leachate. With the onset of the third phase, the generated acid species are consumed. Methane is the primary product at this phase. To completely proceed toward the third phase, sufficient moisture, nutrients, and substrate (organic waste) are needed.

Introducing leachate to waste facilitates the shift from phase two to phase three, accelerating waste decomposition, and increasing methane production. This effect has been well documented in field studies. Methane production increased up to 350% in a one-year lab experiment (Karimi and Bareither, 2021) and 220% in a three-year field study comparing two side-by-side cells one with and one without leachate recirculation (Mehta et al., 2002). In another study, methane concentrations increased from 45% (before recirculation) to 55% (after recirculation) in vertical wells in a landfill (Morrisa et al., 2003). Chung et al. (2015) injected leachate monthly for more than half a year, finding that the methane concentration in vertical wells increased from 30% (before recirculation) to 70% when leachate was injected back into the aged landfill (Table 1).

Figure 1: Production phases of typical landfill gas



Source: ATSDR, 2001

Table 1: Increased methane production from leachate recirculation documented in field studies

Reference	Area (m2)	During time (year)	Injection volume (m3)	Original waste moisture	New waste moisture	Increasing amplitude (%)
Velez (1999)	230	0.15	13			50
Mehta et al. (2002)	930	3	3,000	14%-19%	31%-38%	250
Morrisa et al. (2003)	4,000	6	1,920	20%	40%	700
Benson et al. (2007)	121,000	1	19,771/yr	15%	45%	69
Manzur et al. (2012)	178,000	4	17,035/yr	-	-	150
Chung et al. (2015)	3,000	0.5	116	-	-	230

Adapted from Liu et al. (2018)

It is well known that leachate recirculation expedites the waste degradation process. It can be inferred that it also increases total methane production over the life of the landfill. Lack of leachate recirculation can keep the waste degradation process in the second phase, maintaining high BOD and COD and low pH levels in the leachate. These intermediate products (acidic species) can have public health risks. Enhancing waste moisture converts organic carbon to methane, reducing these potentially harmful species, while also increasing methane production.

Further, because gas collection systems are active in landfills when high rates of methane are generated, postponing organic waste degradation (lack of a leachate recirculation system) might lead to higher methane emissions in the future when gas collection systems are not active.

Preventing bioreactors from participating in the protocol does not fully avoid this baseline complication. Adding any liquid, whether leachate or other, can enhance methane generation. Further, methane production is a continuum that increases with increased moisture but which still happens at moisture levels below 40%. Applying a continuous correction factor for waste moisture instead of excluding any landfill with waste moisture above 40% can help resolve this baseline issue.

We recommend that CAR consider applying an equation for estimating true baselines for landfills that circulate leachate because of the landfill gas capture system. This function would adjust baseline methane generation rates according to the amount of leachate recirculated and the volume of the disposed waste. This approach could potentially be applied to some bioreactors, recognizing that the distinction between leachate recirculate and bioreactors is somewhat artificial. These methods should both avoid over-crediting but also avoid creating a disincentive for landfills to implement leachate recirculation given its potential to reduce toxic pollutants.

We are both happy to discuss the issues raised.

Sincerely,

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