Measuring Emissions of Organic Waste

Appendix

Appendix A

2006: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf
2019: https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_2_Ch02_Waste_Data.pdf

TABLE 2.4
DEFAULT DRY MATTER CONTENT, DOC CONTENT, TOTAL CARBON CONTENT AND FOSSIL CARBON FRACTION OF DIFFERENT MSW COMPONENTS

MSW component	Dry matter content in % of wet weight [1]	DOC content in % of wet waste		DOC content in % of dry waste		Total carbon content in % of dry weight		Fossil carbon fraction in % of total carbon	
	Default	Default	Range	Default	Range [2]	Default	Range	Default	Range
Paper/cardboard	90	40	36 - 45	44	40 - 50	46	42 - 50	1	0 - 5
Textiles [3]	80	24	20 - 40	30	25 - 50	50	25 - 50	20	0 - 50
Food waste	40	15	8 - 20	38	20 - 50	38	20 - 50	-	-
Wood	85 [4]	43	39 - 46	50	46 - 54	50	46 - 54	-	-
Garden and Park waste	40	20	18 - 22	49	45 - 55	49	45 - 55	0	0
Nappies	40	24	18 - 32	60	44 - 80	70	54 - 90	10	10
Rubber and Leather	84	(39) [5]	(39) [5]	(47) [5]	(47) [5]	67	67	20	20
Plastics	100	-	-	-	-	75	67 - 85	100	95 - 100
Metal [6]	100	-	-	-	-	NA	NA	NA	NA
Glass [6]	100	-	-	-	-	NA	NA	NA	NA
Other, inert waste	90	-	-	-	-	3	0 - 5	100	50 - 100

[1] The moisture content given here applies to the specific waste types before they enter the collection and treatment. In samples taken from collected waste or from e.g., SWDS the moisture content of each waste type will vary by moisture of co-existing waste and weather during handling.

[2] The range refers to the minimum and maximum data reported by Dehoust *et al.*, 2002; Gangdonggu, 1997; Guendehou, 2004; JESC, 2001; Jager and Blok, 1993; Würdinger *et al.*, 1997; and Zeschmar-Lahl, 2002.

[3] 40 percent of textile are assumed to be synthetic (default). Expert judgement by the authors.

[4] This value is for wood products at the end of life. Typical dry matter content of wood at the time of harvest (that is for garden and park waste) is 40 percent. Expert judgement by the authors.

[5] Natural rubbers would likely not degrade under anaerobic condition at SWDS (Tsuchii et al., 1985; Rose and Steinbüchel, 2005).

[6] Metal and glass contain some carbon of fossil origin. Combustion of significant amounts of glass or metal is not common.

[DOC]
0.38

DOC values for different waste types, which are derived from analyses based on sampling during waste collection at SWDS or at incineration facilities, may include impurities, e.g., traces of food in glass and plastic waste. Carbon contents of paper, textiles, nappies, rubber and plastic may also be different between countries and at different time periods. These analyses may therefore result in DOC estimates different from those given in Table 2.4. It is *good practice* to use DOC values consistently with the way the waste composition data are derived.

The best composition data can be obtained by routine monitoring at the gate of SWDS or incineration and other treatment facilities. If these data are not available, composition data obtained at generation and/or transportation, treatment and recycling facilities can be used for disposed DOC estimations using waste stream analysis (see Box 2.1).

Waste can be sampled at pits in waste treatment facilities, at loading yards in transportation stations and SWDS. Composition data of disposed waste can be obtained from field sampling at SWDS. The amount of waste (typically more than 1 m^3 for a representative sample) should be separated manually into each item and weighed by item in order to obtain wet weight composition. A certain amount of each item should be reduced and sampled by quartering and used for chemical analysis including moisture and DOC. Samples should be taken on different days of the week.

MSW composition will vary by city in a same country. It will also vary by the day of the week, season and year in the same city. National representative (or average) composition data should be obtained from sampling at several typical cities on same days of the week in each season. Sampling at SWDS on rainy days will change moisture content (i.e., wet weight composition) significantly, and needs attention in interpretation of that in annual data.

Appendix B

https://www.ipcc.ch/site/assets/uploads/2018/03/5_Waste-1.pdf
https://www.atsdr.cdc.gov/hac/landfill/html/ch2.html

Fraction of degradable organic carbon dissimilated (DOC_F)

DOC_F is an estimate of the fraction of carbon that is ultimately degraded and released from SWDS, and reflects the fact that some organic carbon does not degrade, or degrades very slowly, when deposited in SWDS. The *IPCC Guidelines* provide a default value of 0.77 for DOC_F. Based on a review of recent literature, it appears that this default value may be an overestimate. It should only be used if lignin C is excluded from the DOC value. For example, experimental values in the order of 0.5-0.6 (including lignin C) have been used in the Netherlands (Oonk and Boom, 1995) and demonstrated to give reliable estimates of landfill gas generated and recovered in the Netherlands. It is also *good practice* to use a value of 0.5-0.6 (including lignin C) as the default. National values for DOC_F or values from similar countries can be used for DOC_F, but they should be based on well-documented research.

[DOC_F]
0.55

Fraction of CH_4 in landfill gas (F)

Landfill gas consists mainly of CH_4 and carbon dioxide (CO_2). The CH_4 fraction F is usually taken to be 0.5, but can vary between 0.4 and 0.6, depending on several factors including waste composition (e.g. carbohydrate and cellulose). The concentration of CH_4 in recovered landfill gas may be lower than the actual value because of potential dilution by air, so F values estimated in this way will not necessarily be representative.

Methane recovery (R)

Methane recovery is the amount of CH_4 generated at SWDS that is recovered and burned in a flare or energy recovery device. CH_4 recovered and subsequently vented should not be subtracted from gross emissions. The default value for methane recovery is zero. This default should only be changed when references documenting the amount of methane recovery are available. Recovered gas volumes should be reported as CH_4 not as landfill gas, as landfill gas contains only a fraction of CH_4[4]. Reporting based on metering of all gas recovered for energy utilisation and flaring is consistent with *good practice*. The use of undocumented estimates of landfill gas recovery potential is not appropriate, as such estimates tend to overestimate the amount of recovery.

Degradable organic carbon (DOC)

Degradable organic carbon is the organic carbon that is accessible to biochemical decomposition, and should be expressed as Gg C per Gg waste. It is based on the composition of waste and can be calculated from a weighted average of the carbon content of various components of the waste stream. The following equation, as presented in the *IPCC Guidelines*, estimates DOC using default carbon content values:

EQUATION 5.4

$$DOC = (0.4 \bullet A) + (0.17 \bullet B) + (0.15 \bullet C) + (0.3 \bullet D)$$

Where:

A = Fraction of MSW that is paper and textiles

B = Fraction of MSW that is garden waste, park waste or other non-food organic putrescibles

C = Fraction of MSW that is food waste

D = Fraction of MSW that is wood or straw

The default carbon content values for these fractions can be found in the *IPCC Guidelines* (Table 6-3, Reference Manual).[3] The use of national values is encouraged if data are available. National values can be obtained by performing waste generation studies and sampling of different SWDS within a country. If national values are used, survey data and sampling results should be reported. In addition, it is important that inventory agencies exclude lignin from their DOC calculations if the default value (0.77) for DOC_F is used, as discussed below.

Appendix C

https://www.atsdr.cdc.gov/hac/landfill/html/ch2.html

Table 2-1: Typical Landfill Gas Components

Component	Percent by Volume	Characteristics
methane	45–60	Methane is a naturally occurring gas. It is colorless andodorless. Landfills are the single largest source of U.S. man-made methane emissions
carbon dioxide	40–60	Carbon dioxide is naturally found at small concentrations in the atmosphere (0.03%). It is colorless, odorless, and slightly acidic.
nitrogen	2–5	Nitrogen comprises approximately 79% of the atmosphere. It is odorless, tasteless, and colorless.
oxygen	0.1–1	Oxygen comprises approximately 21% of the atmosphere. It is odorless, tasteless, and colorless.
ammonia	0.1–1	Ammonia is a colorless gas with a pungent odor.
NMOCs (non-methane organic compounds)	0.01–0.6	NMOCs are organic compounds (i.e., compounds that contain carbon). (Methane is an organic compound but is not considered an NMOC.) NMOCs may occur naturally or be formed by synthetic chemical processes. NMOCs most commonly found in landfills include acrylonitrile, benzene, 1,1-dichloroethane, 1,2-cis dichloroethylene, dichloromethane, carbonyl sulfide, ethyl-benzene, hexane, methyl ethyl ketone, tetrachloroethylene, toluene, trichloroethylene, vinyl chloride, and xylenes.
sulfides	0–1	Sulfides (e.g., hydrogen sulfide, dimethyl sulfide, mercaptans) are naturally occurring gases that give the landfill gas mixture its rotten-egg smell. Sulfides can cause unpleasant odors even at very low concentrations.
hydrogen	0–0.2	Hydrogen is an odorless, colorless gas.
carbon monoxide	0–0.2	Carbon monoxide is an odorless, colorless gas.

Source: Tchobanoglous, Theisen, and Vigil 1993; EPA 1995

[F_C]
[F_L]

Appendix D

https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_2_Ch02_Waste_Data.pdf

Default data

Region-specific default data on per capita MSW generation and management practices are provided in Table 2.1. These data are estimated based on country-specific data from a limited number of countries in the regions (see Annex 2A.1). These data are based on weight of wet waste[3] and can be assumed to be applicable for the year 2000. Waste generation per capita for subsequent or earlier years can be estimated using the guidance on how to estimate historical emissions from SWDS in Chapter 3, Section 3.2.2, and the methods for extrapolation and interpolation using drivers in Chapter 6, Time Series Consistency, in Volume 1, General Guidance and Reporting.

TABLE 2.1
MSW GENERATION AND TREATMENT DATA - REGIONAL DEFAULTS

Region	MSW Generation Rate[1, 2, 3] (tonnes/cap/yr)	Fraction of MSW disposed to SWDS	Fraction of MSW incinerated	Fraction of MSW composted	Fraction of other MSW management, unspecified[4]
Asia					
Eastern Asia	0.37	0.55	0.26	0.01	0.18
South-Central Asia	0.21	0.74	-	0.05	0.21
South-East Asia	0.27	0.59	0.09	0.05	0.27
Africa[5]	0.29	0.69	-	-	0.31
Europe					
Eastern Europe	0.38	0.90	0.04	0.01	0.02
Northern Europe	0.64	0.47	0.24	0.08	0.20
Southern Europe	0.52	0.85	0.05	0.05	0.05
Western Europe	0.56	0.47	0.22	0.15	0.15
America					
Caribbean	0.49	0.83	0.02	-	0.15
Central America	0.21	0.50	-	-	0.50
South America	0.26	0.54	0.01	0.003	0.46
North America	0.65	0.58	0.06	0.06	0.29
Oceania[6]	0.69	0.85	-	-	0.15

[1] Data are based on weight of wet waste.

[2] To obtain the total waste generation in the country, the per-capita values should be multiplied with the population whose waste is collected. In many countries, especially developing countries, this encompasses only urban population.

[3] The data are default data for the year 2000, although for some countries the year for which the data are applicable was not given in the reference, or data for the year 2000 were not available. The year for which the data are collected, where available, is given in the Annex 2A.1.

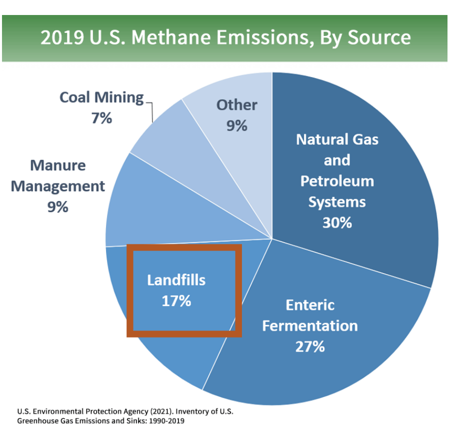
[4] Other, unspecified, includes data on recycling for some countries.

[5] A regional average is given for the whole of Africa as data are not available for more detailed regions within Africa.

[6] Data for Oceania are based only on data from Australia and New Zealand.

Appendix E

https://www.epa.gov/ghgemissions/overview-greenhouse-gases



U.S. Environmental Protection Agency (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019

Appendix F

https://www.epa.gov/system/files/documents/2021-07/pdh_chapter1.pdf

1.2 LFG Collection and Flaring

LFG collection typically begins after a portion of the landfill (known as a "cell") is closed to additional waste placement. A gas collection system (GCS) can be configured with vertical wells, horizontal trenches or both, and its design can vary based on factors such as location, operational goals and waste filling practices. Most landfills with energy recovery systems include a flare for the combustion of excess gas and for use during equipment downtimes. Each of these components is described below, followed by a brief discussion of GCS and flare costs.

Gas Collection Wells and Horizontal Trenches. The most common method of LFG collection involves drilling vertical wells in the waste and connecting those wellheads to lateral piping that transports the gas to a collection header using a blower or vacuum induction system. Another type of GCS uses horizontal piping laid in trenches in the waste. Horizontal trench systems are useful in deeper landfills and in areas of active filling. Some systems involve a combination of vertical wells and horizontal collectors. Well-designed systems of either type are effective in collecting LFG. The design chosen depends on site-specific conditions and the timing of the GCS installation. Figure 1-2 illustrates the design of a typical vertical LFG extraction well, and Figure 1-3 shows a typical horizontal extraction well.

Figure 1-2. Vertical Extraction Well

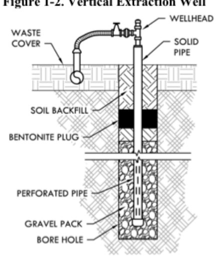


Figure 1-3. Horizontal Extraction Well

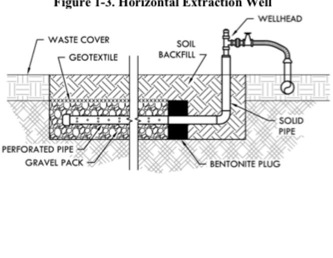
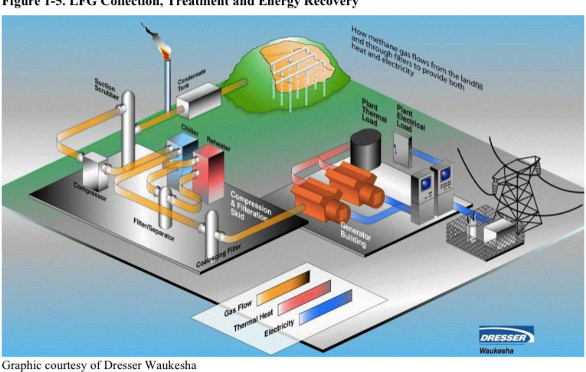


Figure 1-5. LFG Collection, Treatment and Energy Recovery



Graphic courtesy of Dresser Waukesha

Appendix G

Measuring emissions of organic waste (See Table 1 + Table 2 on poster for variable values)

Decomposition	
Compost	**CARBON (TONS)** ([Initial mass of organic waste] * [DOC] * [DOC_F] * [K_C]) ([1.00 tons] * [38%] * [55%] * [100%]) (0.209 tons) **GLOBAL WARMING POTENTIAL** (CO_2 segment w/ GWP factored in) **+** (CH_4 segment w/ GWP factored in) ([Tons] * [$F_{C\text{-}CO2}$] * [GWP]) **+** ([Tons] * [$F_{C\text{-}CH4}$] * [GWP]) ([0.209 tons] * [100%] * [1]) **+** ([0.209 tons] * [0%] * [36]) (0.209 tons) **+** (0.000 tons) (0.209)
Landfill	**CARBON (TONS)** ([Initial mass of organic waste] * [DOC] * [DOC_F] * [K_L]) ([1.00 tons] * [38%] * [55%] * [100%]) (0.209 tons) **GLOBAL WARMING POTENTIAL** (CO_2 segment w/ GWP factored in) **+** (CH_4 segment w/ GWP factored in) ([Tons] * [$F_{L\text{-}CO2}$] * [GWP]) **+** ([Tons] * [$F_{L\text{-}CH4}$] * [GWP]) ([0.209 tons] * [40%] * [1]) **+** ([0.209 tons] * [60%] * [36]) (0.0836 tons) **+** (4.5144 tons) (4.598)
Vertical well CH_4 capture	
Compost	**CARBON (TONS)** (Carbon tons via decomposition) * (Gas recovery rate via vertical wells) * (-1) (0.209 tons) * (R_C) * (-1) (0.209 tons) * (0%) * (-1) (0.000 tons) **GLOBAL WARMING POTENTIAL** (GWP Compost Decomposition) * (Gas recovery rate via vertical wells) * (-1) (GWP Compost Decomposition) * (R_C) * (-1) (0.209) * (0%) * (-1) (0.000)
Landfill	**CARBON (TONS)** (Carbon tons via decomposition) * (Gas recovery rate via vertical wells) * (-1) (0.209 tons) * (R_L) * (-1) (0.209 tons) * (35%) * (-1) (-0.073 tons) **GLOBAL WARMING POTENTIAL** (GWP Landfill Decomposition) * (Gas recovery rate via vertical wells) * (-1) (GWP Landfill Decomposition) * (R_L) * (-1) (4.598) * (35%) * (-1) (-1.609)
CH_4 instead of coal	
Compost	**CARBON (TONS)** (Carbon tons via vertical well CH_4 capture) * (emissions differences b/w CH_4 & coal) (0.000 tons) * (C) (0.000 tons) * (50%) (0.000 tons) **GLOBAL WARMING POTENTIAL** (GWP Vertical well CH_4 capture) * (emissions differences b/w CH4 & coal) (0.000) * (C) (0.000) * (50%) (0.000)
Landfill	**CARBON (TONS)** (Carbon tons via vertical well CH_4 capture) * (emissions differences b/w CH_4 & coal) (-0.073 tons) * (C) (-0.073 tons) * (50%) (-0.037 tons) **GLOBAL WARMING POTENTIAL** (GWP Vertical well CH_4 capture) * (emissions differences b/w CH4 & coal) (-1.609) * (C) (-1.609) * (50%) (-0.805)