Category		Title
NFR:	5.A	Solid waste disposal on land (including mineral waste handling)
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Coordinator (including to earlier versions of this chapter)

Carlo Trozzi, Céline Guéguen

Contributing authors (including to earlier versions of this chapter)

Jeroen Kuenen, Katja Hjelgaard, Céline Guéguen, Adriana Gomez Sanabria, Richard Claxton,

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1 Overview

This chapter treats emissions from solid waste disposal on land, especially NMVOC emissions from organic waste degradation in landfills. Particulate (as TSP, PM10, PM2.5) emissions from mineral waste handling during disposal in landfills and reuse as backfilling and construction material are also considered. These sources, however, are typically only minor sources of air pollutant emissions. They are of greater importance regarding emissions of greenhouse gases (CH_4, CO_{2bio}).

Mineral waste backfilling and reuse are considered as recycling practices and not strictly regarded as mineral (solid) waste disposal practices. However, in the current version of the Guidebook the method is presented in the current chapter and the emissions from mineral waste handling can be reported in 5A.

Other air pollutants may be emitted from solid waste disposal, such as NH3 from waste degradation in landfills or NOx, CO, SOx, PM, and POPs from landfill gas flaring, but emissions are expected to be negligible and no EFs are proposed in the current version of the chapter.

Landfill fires may be a substantive source of air pollutants, depending on the frequency and size of such events, but no methodology is proposed yet to estimate these emissions. Air pollutant emissions from energy recovery and traffic also result from landfilling practices, and estimation methodologies are presented in the Energy chapters. .

2 Description of sources

2.1 Process description

Municipal, industrial and other solid waste may be disposed of in landfills where the organic fraction of waste degrades into landfill gas over decades. Some organics may also dissolve or be leached from the landfill over time. As stated in detail in Volume 5, Chapter 3 of the 2006 IPCC Guidelines, the degradation rate of disposed waste into landfill gas largely depends on waste composition. The composition of the landfill gas, especially the proportion between the major pollutants CH_4 and CO_2, mainly depends on the anaerobic conditions of the landfill. The amount of landfill gas emitted depends on climatic variables, waste disposal practices and management of the site e.g. landfill gas recovery and flaring, compaction of waste, use of daily cover, and capping of completed parts of the site.

Mineral waste may be disposed of in landfills, recycled or recovered as backfilling material, depending on its composition and origin. Landfilling of mineral waste is more likely for inert materials, or for disposal of waste after primary e.g. chemical treatment. In all cases, mineral waste treatment implies multiple handling activities such as loading/loading out activities. Piles and storage areas may also be sensitive to wind erosion.

2.2 Techniques

No techniques are identified.

2.3 Emissions

As highlighted, the current chapter relates to two distinct sources: NMVOC emissions from organic waste degradation in solid waste disposal on land and particulate emissions from mineral waste handling and site operations.

NMVOC emissions occur during the degradation of the organic part of municipal, industrial and other solid waste disposed of in landfills, as a small fraction of the emitted landfill gas (mainly composed of CH_4 and CO_2).

Particulate emissions occur at several points in the storage in landfill and in the recovery cycle of mineral waste as backfilling material, such as from handling activities (loading of wastes onto storage piles, vehicle traffic and loading equipment in storage areas), and from wind erosion of piles and ground areas during storage. The quantity of particulate emissions depends mainly on particle size, wind speed and the material moisture content.

2.4 Controls

In many industrialised countries, waste management has changed much over the last decade. Waste minimisation strategies have been introduced to reduce the amount of waste generated, and increasingly, alternative waste management practices to solid waste disposal in landfills (recycling/reuse) have been implemented to reduce the environmental impacts of waste disposal. Also, landfill gas recovery has become more common as a measure to reduce CH_4 emissions from solid waste disposal sites (SWDS). More information with regard to this source can be found in the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

Regarding mineral waste, dust suppression techniques such as watering waste storage areas during loading/loading out activities can reduce particulate emissions.

3 Methods

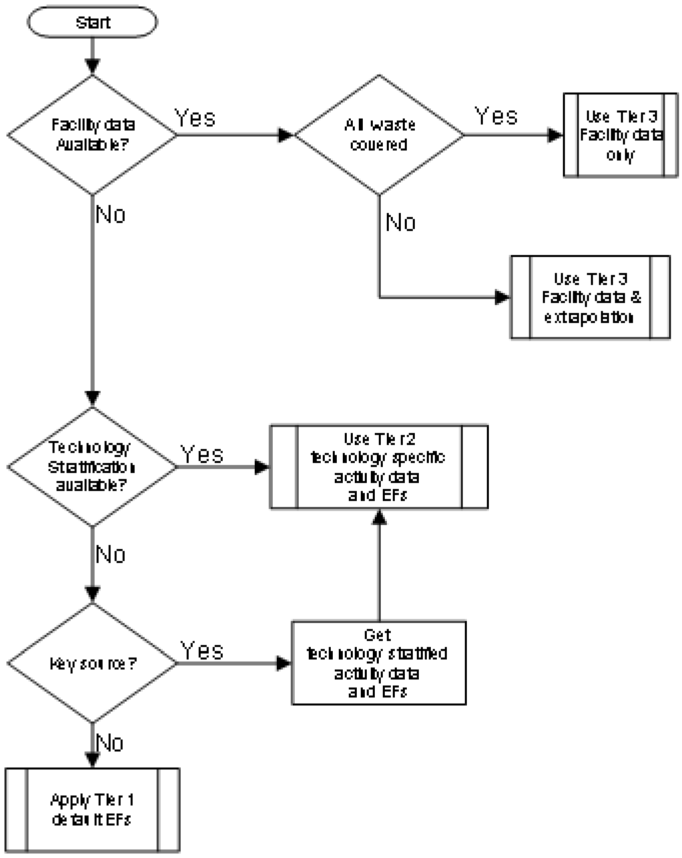
3.1 Choice of method

Figure 3-1 presents the standard recommended procedure to select the methods for estimating emissions from solid waste disposal on land. The basic concept is:

- if detailed information is available, use it;
- if the source category is a key category, a Tier 2 or better method must be applied, and more detailed input data must be collected.

Tier 1 emission factors are available for NMVOC and particulates (as TSP, PM10 and PM2.5). A Tier 2 methodology is provided for NMVOC and a Tier 3 methodology is proposed for particulates according to US EPA (2006).

Figure 3-1 Decision tree for source category 5.A Solid waste disposal on land



3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach for TSP, PM10 and PM2.5 emissions from handling and storage of mineral waste uses the general equation:

$$E_{pollutant} = AD_{Min\_hand} \times EF_{pollutant} \qquad (1)$$

This equation is applied at the national level, using the national amount of mineral waste handled annually (AD_{Min_hand}) and EFs presented in Table 3-1.

The Tier 1 approach for NMVOC emissions from solid waste disposal on land uses the general equation:

$$E_{NMVOC} = V_{LG} \times EF_{NMVOC} \qquad (2)$$

This equation is applied at the national level, using the volume of landfill gas emitted (V_{LG}) and the EF presented in **Table 3-2**.

Please note: The Tier 1 emission factors assume typical technology and abatement implementation is in place.

3.2.2 *Default emission factors*

Table 3-1 presents the Tier 1 default particulate emission factors for mineral waste handling and storage activities. These emission factors are calculated using equation 2 and default data described in subsection 3.3 of this present chapter (US EPA, 2006).

Table 3-1 Tier 1 emission factors for source category 5.A Solid waste disposal on land – Mineral waste handling and storage

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	5.A	Solid waste disposal on land - Mineral waste handling and storage			
Fuel	NA				
Not applicable	NO_x, CO, SO_2, NMVOC, NH_3, Hg, Pb, Cd, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, BC, HCH				
Not estimated	-				
			95% confidence interval		
Pollutant	**Value**	**Unit**	**Lower**	**Upper**	**Reference**
TSP	0 463	g/Mg	0.006	2.21	US EPA (2006)
PM_{10}	0 219	g/Mg	0.003	1.05	US EPA (2006)
$PM_{2.5}$	0 033	g/Mg	0.0004	0.16	US EPA (2006)

Particulate uncertainty estimates are calculated as 'worst case' examples. The lower boundaries are calculated as wet fly ash (27 % moisture content (M)) at a wind speed of only 0.6 m/s (U). The upper boundaries are calculated as dry slag (3.6 % moisture content) at a wind speed of 6.7 m/s.

Table 3-2 presents the Tier 1 default NMVOC emission factor for waste degradation. This EF corresponds to the NMVOC concentration in emitted landfill gas.

Table 3-2 Tier 1 emission factors for source category 5.A Solid waste disposal on land – Waste degradation

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	5.A	Solid waste disposal on land – Waste degradation			
Fuel	NA				
Not applicable	NO_x, CO, SO_2, Hg, Pb, Cd, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, BC, HCH				
Not estimated	NH_3				
			95% confidence interval		
Pollutant	**Value**	**Unit**	**Lower**	**Upper**	**Reference**
NMVOC	3.6	kg/ Mg CH_4	0.4	4.2	UK Inventory (2023) Ricardo-AEA (2014)

This NMVOC EF extracted from the UK inventory published in the 2023 Informative Inventory report (IIR) and is based on Broomfield & al. (2014).

3.2.3 *Activity data*

Regarding particulate emissions, AD is the annual amount of mineral waste handled (AD_{Min_hand}). As a first approach, and because of the minor contribution of this source to national emissions, it can be approximated by the amount of mineral waste generated or treated, whatever the treatment is

This information is available from the national statistics agencies, environmental agencies or Eurostat.

When the Eurostat database is used, a request regarding treatment of waste by waste category, waste management operations can be done, selecting the waste following categories : Mineral waste from construction and demolition, Other mineral wastes (W122+W123+W125), soils, Dredging spoils and Mineral wastes from waste treatment and stabilised wastes. A more refined AD (e.g. exclusion of stabilized hazardous mineral waste) can be used, if justified transparently. For countries not documented in the Eurostat Database, a per capita ratio of mineral waste treated could be derived of from data reported by a comparable country and used to estimate national AD.

3.3 Tier 2 technology-specific approach

No Tier 2 is proposed for particulate emissions from handling and storage of mineral waste.

Regarding NMVOC emissions from waste degradation, a Tier 2 method can be applied, using a country specific EF.

3.3.1 Default emission factors

The country specific NMVOC EF can be derived from measurements of NMVOC concentration in landfill gas in a representative sample of national landfills or be obtained through direct contact with the landfill site operators.

3.3.2 Activity data

The activity data consistent with the EF is the volume of landfill gas emitted (V_{LG}).

This value can be obtained through direct contact with the landfill site operators or can be estimated on the basis of CH4 emissions reported to UNFCCC in kilotons, using equation 3.

$$V_{LG} = E_{CH4} \times 2.8 \times 10^6 \qquad (3)$$

V_{LG} : Volume of landfill gas, in m^3

E_{CH4}: CH_4 emissions, in ktons

2.8: assuming Normal Conditions of Temperature and Pressure (molar volume of 22.4 l/mol), a CH4 ratio in landfill gas of 0.5 and a CH_4 molar mass of 16 g/mol.

Information on estimation methods for greenhouse gas emissions, including CH4, is given in the 2006 IPCC Guidelines (IPCC, 2006).

3.4 Tier 3 emission modelling and use of facility data

Regarding particulate emissions from waste handling and storage a Tier 3 methodology is proposed. This methodology corresponds to the application of equation 4 (US EPA, 2006, chapter 13.2.4). This formula estimates emissions from any handling related operation:

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \qquad (4)$$

E: emission factor (kg/Mg)
k: particle size multiplier; k (PM_{TSP}) = 0.74, k (PM_{10}) = 0.35 and k ($PM_{2.5}$) = 0.053

U: mean wind speed (m/s)
M: material moisture content (%)

If specific parameters are available, countries should use these to apply with the Tier 3 method. The following factors are standard assumptions and standard values; if no country specific information is available for U and/or M the Tier 1 emission factors should be used instead.

According to US EPA (2006) the wind speed varies from 0.6-6.7 m/s, the default average wind speed is set to:
U = 6.7 m/s
This upper range for equation 2 will be too high for many areas. If a country specific mean wind speed is available this should be applied.

According to US EPA (2006) table 13.2.4-1, the moisture content for municipal solid waste landfills can vary from 2.3 % (low end range for slag) to 29 % (high end range for fly ash). The average moisture content for miscellaneous fill materials is set to:
M = 11 %
If a country specific average moisture content is available this should be applied.

No Tier 3 is proposed for NMVOC emissions from waste degradation in landfills.

4 Data quality

No specific issues.

5 References

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan, (https://www.ipcc-nggip.iges.or.jp/public/2006gl/ (accessed 5 June 2019).

Ricardo-AEA on behalf of UK Department for Environment, Food and Rural Affairs, "Ongoing review of landfill gas recovery and emissions: NAEI Improvements FY 2013-14 Task 6," Ref. ED59429014, 31 March 201,.

UK Inventory (2023). United Kingdom Air Pollutant Emission Inventory.

US EPA (1990). Air Emissions Species Manual, Volume 1: Volatile Organic Compounds Species profiles, second edition, EPA-4502-90-001a, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, January 1990.

US EPA (2006). AP42 Fifth Edition, Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources, (https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors), accessed 19 July 2019.

6 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.