Emission Calculation Fact Sheet

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MUNICIPAL SOLID WASTE LANDFILLS

Landfill gas (LFG) is generated via microbial decomposition of municipal solid waste (MSW) in a landfill under aerobic or anaerobic conditions. MSW initially undergoes aerobic microbial activity that produces predominately nitrogen gas and carbon dioxide. As oxygen levels decline, gas composition changes to a mixture of methane and carbon dioxide. LFG typically contains a small percentage of non-methane organic compounds (NMOC). The NMOC fraction consists of various organic hazardous air pollutants (HAP), greenhouse gases, and volatile organic compounds (VOC). Other emissions from MSW landfills include combustion products (e.g. CO, NOX, SOX, HCl, HAP, etc.) from flares, internal combustion engines, and other LFG control equipment; particulate matter from paved and unpaved haul roads and excavations; and VOC and HAP emissions from soil and groundwater remediation systems and parts washers.

For the Michigan Air Emissions Reporting System (MAERS), MSW landfills must report NMOC emissions in addition to emissions of the criteria pollutants (i.e. CO, Lead, NOx, PM10, SO2, and VOC). For annual Air Quality fee purposes, the NMOC from fugitive landfill gas sources (see EULANDFILL) is subject to fees. Since the fugitive landfill NMOC emissions already include VOC, no separate fee is assessed for the VOC that is reported under EULANDFILL. However, if an activity has VOC emissions but not NMOC emissions, the VOC emissions from that activity will be billed.

New Source Performance Standards (NSPS) and Emission Guidelines for air emissions from new and existing MSW landfills were promulgated on March 12, 1996. The regulation requires the use of Best Demonstrated Technology (BDT) to reduce landfill emissions from affected new and existing MSW landfills that emit $\geq$ 50 megagrams (Mg)/year (55 tons/year) of NMOC. Affected facilities with a design capacity of 2.5 million Mg or greater and a NMOC emission rate $\geq$ 50 Mg/year are required to construct and maintain a well-designed and operated gas collection system with a control system capable of reducing NMOC in the collected gas by 98 percent by weight.

LFG collection systems are either active or passive. LFG control systems include open flares or enclosed combustors. Enclosed combustors are defined as a firebox that maintains a relatively constant limited peak temperature generally using a limited supply of combustion air. The following are examples of enclosed combustors: enclosed flares (EUENCLOSEDFLARE), turbines (EUTURBINE), internal combustion engines (EUICENGINE), boilers (EUBOILER), and process heaters (EUPROCESSHEATER).

This document lists Source Classification Codes (SCC) and contains information on calculating emissions from MSW landfills. **It is not required that facilities use the listed emission factors or methods to estimate their emissions**. If a facility disagrees with any emission factor or calculation method in this document, it may use other emission factors or methods of calculating emissions if the emission factor or method correctly identifies the processes at the facility and the resulting emissions. A facility doing so must provide information and documentation showing the source of the factors or method used and justification for their use. The emission factors in this document were obtained from the U.S. Environmental Protection Agency's (EPA) Factor Information Retrieval Data System (FIRE) version 6.23 or 6.24 and the *Compilation of Air Pollutant Emission Factors (AP-42)*. Both are available on the Internet at **www.epa.gov/ttn/chief/index.html**.

Emission units

This document provides guidance for calculating emissions from emission units. An emission unit is a process device or a group of devices that operate together with a dependency between devices. Using the emissions units as presented in this document is recommended for maintaining consistency between Air Quality Division (AQD) programs. In MAERS, all emission units begin with an "EU" prefix.

Control factors

The listed emission factors are for uncontrolled emissions. If a facility has control equipment, such as a flare, the emissions can be multiplied by the control factor. Calculate the control factor by subtracting the percent control efficiency from 100 and then divide that number by 100. For example, if the control efficiency is 87%, the control factor would be (100 - 87)/100 = 0.13. Control efficiencies may be listed on the equipment or in the equipment documentation. Alternatively, equipment suppliers can provide control efficiency values.

Scientific notation

The emission factors are expressed in scientific notation, which means that the decimal point has been moved. If the exponent is negative, move the decimal point to the left. If the exponent is positive, move the decimal point to the right. If the exponent is zero, the decimal point does not move. For example, if a number is expressed as 2.0E-1, move the decimal point one place to the left to get 0.20. If a number is expressed as 2.0E2, move the decimal point 2 places to the right to get 200. If a number is expressed as 2.0E0, the decimal point does not move – the number is 2.0. A number expressed as E3 is 1,000.

EULANDFILL – Fugitive emissions from MSW landfills

Fugitive emissions from MSW landfills consist of NMOC, VOC, and particulate. At MSW landfills, landfill gas is required to be collected via a network of extraction wells and piping within the limits of the waste mass. A portion of the gas generated by the landfill is emitted as uncollected landfill gas fugitives, via the landfill liner, soil fill or vents, or pipe fittings of the collection system. These uncontrolled landfill gases are emitted in the form of fugitive NMOC and VOCs. Additionally, fugitive particulate emissions are generated by vehicle travel on both paved and unpaved surfaces.

SCC	DESCRIPTION	CALCULATION METHOD
5-04-002-01	General Processes: Fugitive NMOC emissions – Tons processed Material Code: WASTE,SOLID Material Throughput Unit Code: TON waste accepted/received/processed at the landfill during the year	Use the Landfill Air Emissions Estimation Model (LAEEM) or one of the two equations listed below to estimate fugitive NMOC, VOC and HAP emissions. The LAEEM program may be downloaded from the U.S. EPA's Clearinghouse for Inventories and Emission Factors Internet site at: **www.epa.gov/ttn/chief/software/index.html**.
3-05-025-04	Hauling fugitive emissions: Calculate fugitive dust emissions from **all** vehicle traffic (e.g. trucks, compactors, excavators, etc.) on unpaved or paved landfill haul roads. Material Code: DEVICE (device = hauling equipment) Material Throughput Unit Code: MILE (mile = vehicle miles traveled)	Emission factor: PM10,FLTRBLE 6.2E0 LB/MILE DEVICE The emission factor is based on uncontrolled emissions. If a facility has an AQD-approved fugitive dust control program or a method of controlling fugitive dust that is well documented, then a control efficiency of up to 80% may be used. Instead of using the emission factor, Sections 13.2.1 and 13.2.2 of EPA's AP-42 can be used for estimating fugitive dust emissions from paved or unpaved roads.

CALCULATIONS:

- **If the actual year-to-year solid waste acceptance rate is known, use Equation 1:**

  Equation 1: $M_{NMOC} = \sum_{i=1}^{2} 2\,k\,L_o\,M_i\,(e^{-kt_i})\,(C_{NMOC})\,(3.6 \times 10^{-9})$

- **If the actual year-to-year solid waste acceptance rate is unknown, use Equation 2:**

  Equation 2: $M_{NMOC} = 2L_o\,R\,(e^{-kc} - e^{-kt})\,(C_{NMOC})(3.6 \times 10^{-9})$

Where: M_{NMOC} = NMOC emission rate from the landfill (megagrams per year)

k = methane generation rate constant (year^{-1})

L_o = methane generation potential (cubic meters per megagram solid waste)

M_i = mass of solid waste in the i^{th} section (megagrams)

R = average annual acceptance rate (megagrams per year)

t = age of landfill (years)

t_i = age of the i^{th} section (years)

C_{NMOC} = concentration of NMOC (parts per million by volume (ppmv) as hexane)

c = time since closure (years). For active landfills, c = O and $e^{-kc} = 1$

Default values:

k = 0.04/year

L_o = 100 m^3/Mg (3,530 ft^3/ton)

C_{NMOC} = Tier II testing results, or one of the following:

1. Testing of header pipes to determine the C_{NMOC} of gas, if using an AQD-approved test plan. This data is intended for use in MAERS only and is not a substitute for Tier II testing as defined in New Source Performance Standard, 40 CFR Part 60 Subpart WWW.
2. 595 ppmv as hexane.

EUOPENFLARE – Emissions from open flares (an open combustor without enclosure or shroud). If the flare has an enclosure or a shroud, use EUENCLOSEDFLARES (described later in this document). Emission factors for industrial flares should not be used; however, site specific test data from the flares may be used.

SCC	DESCRIPTION	POLLUTANT	EMISSION FACTORS
5-01-004-10	Open Flare – passive gas collection system	CO NOX PM10,PRIMARY PM2.5,PRIMARY SOX VOC	7.5E2 LB/MMCF WASTE GAS BURNED* 4.0E1 LB/MMCF WASTE GAS BURNED* 1.7E1 LB/MMCF WASTE GAS BURNED* 1.7E1 LB/MMCF WASTE GAS BURNED* 7.8E0 LB/MMCF LANDFILL GAS BURNED** 5.6E0 LB/MMCF WASTE GAS BURNED*
5-03-006-01	Open Flare – active gas collection system	CO NOX PM10,PRIMARY PM2.5,PRIMARY SOX VOC	7.5E2 LB/MMCF Waste GAS BURNED* 4.0E1 LB/MMCF Waste GAS BURNED* 1.7E1 LB/MMCF Waste GAS BURNED* 1.7E1 LB/MMCF Waste GAS BURNED* 7.8E0 LB/MMCF LANDFILL GAS BURNED** 5.6E0 LB/MMCF WASTE GAS BURNED*

* MMCF WASTE GAS BURNED = MMCF (dry standard) METHANE GENERATED

** MMCF LANDFILL GAS BURNED = MMCF (dry standard) LANDFILL GAS GENERATED. Listed SOX emission factor is based on the default AP-42 concentration for total reduced sulfur (TRS) in landfill gas (46.9 ppmv). If site-specific TRS or hydrogen sulfide analytical results are available, use the equation in Attachment A to calculate an equivalent SOX emission factor. If site-specific data is used, copies of the analytical results should be submitted along with any other supporting documentation with the P-101 form.

EUENCLOSEDFLARES

SCC	DESCRIPTION	POLLUTANT	EMISSION FACTORS
5-01-004-10	Enclosed Flare – passive gas collection system	CO NOX PM10, PRIMARY PM2.5, PRIMARY SOX VOC	7.5E2 LB/MMCF WASTE GAS BURNED* 4.0E1 LB/MMCF WASTE GAS BURNED* 1.7E1 LB/MMCF WASTE GAS BURNED* 1.7E1 LB/MMCF WASTE GAS BURNED* 7.8E0 LB/MMCF LANDFILL GAS BURNED** 5.6E0 LB/MMCF WASTE GAS BURNED
5-03-006-01	Enclosed Flare – active gas collection system	CO NOX PM10, PRIMARY PM2.5, PRIMARY SOX VOC	7.5E2 LB/MMCF Waste GAS BURNED* 4.0E1 LB/MMCF Waste GAS BURNED* 1.7E1 LB/MMCF Waste GAS BURNED* 1.7E1 LB/MMCF Waste GAS BURNED* 7.8E0 LB/MMCF LANDFILL GAS BURNED** 5.6E0 LB/MMCF WASTE GAS BURNED*

* MMCF WASTE GAS BURNED = MMCF (dry standard) METHANE GENERATED

** MMCF LANDFILL GAS BURNED = MMCF (dry standard) LANDFILL GAS GENERATED. Listed SOX emission factor is based on the default AP-42 concentration for total reduced sulfur (TRS) in landfill gas (46.9 ppmv). If site-specific TRS or hydrogen sulfide analytical results are available, use the equation in Attachment A to calculate an equivalent SOX emission factor. If site-specific data is used, copies of the analytical results should be submitted along with any other supporting documentation with the P-101 form.

EUBOILERS

SCC	DESCRIPTION	POLLUTANT	EMISSION FACTORS
1-02-007-01	Process Gas Boiler	CO NOX PM10,PRIMARY PM2.5,PRIMRY SOX VOC	3.5E1 LB/MMCF PROCESS GAS 1.4E2 LB/MMCF PROCESS GAS 8.7E0 LB/MMCF PROCESS GAS 8.7E0 LB/MMCF PROCESS GAS 9.5E2 LB/MMCF-S% PROCESS GAS 2.8E0 LB/MMCF PROCESS GAS

EUPROCESSHEATERS

SCC	DESCRIPTION	POLLUTANT	EMISSION FACTORS
1-02-007-01	Process Gas Heater	CO NOX PM10,PRIMARY PM2.5,PRIMRY SOX VOC	3.5E1 LB/MMCF PROCESS GAS 1.4E2 LB/MMCF PROCESS GAS 8.7E0 LB/MMCF PROCESS GAS 8.7E0 LB/MMCF PROCESS GAS 9.5E2 LB/MMCF-S% PROCESS GAS 2.8E0 LB/MMCF PROCESS GAS

EUICENGINES

SCC	DESCRIPTION	POLLUTANT	EMISSION FACTORS
2-01-008-02	LFG reciprocating engine	CO NOX PM10,FLTRBLE SOX VOC	3.99E2 LB/MMCF LANDFILL GAS 2.84E3 LB/MMCF LANDFILL GAS 1.0E1 LB/MMCF LANDFILL GAS 7.8E0 LB/MMCF LANDFILL GAS* 1.16E2 LB/MMCF LANDFILL GAS

* MMCF LANDFILL GAS BURNED = MMCF (dry standard) LANDFILL GAS GENERATED. Listed SOX emission factor is based on the default AP-42 concentration for total reduced sulfur (TRS) in landfill gas (46.9 ppmv). If site-specific TRS or hydrogen sulfide analytical results are available, use the equation in Attachment A to calculate an equivalent SOX emission factor. If site-specific data is used, copies of the analytical results should be submitted along with any other supporting documentation with the P-101 form.

EUTURBINES

SCC	DESCRIPTION	POLLUTANT	EMISSION FACTORS
2-01-008-01	LFG turbine	CO NOX PM10,TOTAL SOX VOC	1.15E2 LB/MMCF LANDFILL GAS 4.62E2 LB/MMCF LANDFILL GAS 4.4E1 LB/MMCF LANDFILL GAS 7.8E0 LB/MMCF LANDFILL GAS* 1.0E0 LB/MMCF LANDFILL GAS

* MMCF LANDFILL GAS BURNED = MMCF (dry standard) LANDFILL GAS GENERATED. Listed SOX emission factor is based on the default AP-42 concentration for total reduced sulfur (TRS) in landfill gas (46.9 ppmv). If site-specific TRS or hydrogen sulfide analytical results are available, use the equation in Attachment A to calculate an equivalent SOX emission factor. If site-specific data is used, copies of the analytical results should be submitted along with any other supporting documentation with the P-101 form.

EUTREATMENTSYST

SCC	DESCRIPTION	CALCULATION METHOD
5-04-103-10	Soil remediation – active aeration	Use analytical data to determine emissions*
5-04-106-20	Soil remediation – thermal desorber	Use analytical data to determine emissions*
5-04-107-40	Soil remediation – surface bioremediation	Use analytical data to determine emissions*
5-04-103-10	Groundwater remediation	Use analytical data to determine emissions*

* Supporting calculations should be submitted to justify reported emissions.

EUCOLDCLEANER

SCC	DESCRIPTION	POLLUTANT	EMISSION FACTORS
4-01-002-51	Degreasing unit: general – stoddard (petroleum solvent)	VOC	6.58E0 LB/GAL STODDARD
4-01-002-52	Degreasing unit: general – 1,1,1-trichloroethane (methyl chloroform)	VOC	1.125E1 LB/GAL TCE,111
4-01-002-53	Degreasing unit: general – perchloroethylene	VOC	1.36E1 LB/GAL PERC
4-01-002-54	Degreasing unit: general – methylene chloride	VOC	1.098E1 LB/GAL METHYLENE CL
4-01-002-55	Degreasing unit: general – trichloroethylene	VOC	1.22E1 LB/GAL TRICHLORETHY
4-01-002-56	Degreasing unit: general – toluene	VOC	7.2E0 LB/GAL TOLUENE
4-01-002-57	Degreasing unit: general – trichloro trifluoroethane (freon)	VOC	1.306E1 LB/GAL FREON
4-01-002-58	Degreasing unit: general – trichloro fluoromethane	VOC	1.25E1 LB/GAL CFC-11
4-01-002-59	Degreasing unit: general – 1,1,1-Trichloroethane	VOC	1.125E1 LB/GAL TCE,111
4-01-002-95	Degreasing unit: general – other not classified	VOC	7.2E0 LB/GAL SOLVENTS

SAMPLE CALCULATION

For a 20-year-old, active landfill, where the actual year-to-year solid waste acceptance rate is unknown. Calculate the non-methane organic compound (NMOC) emission rate (megagrams per year).

Given:

M_{NMOC} = NMOC emission rate from the landfill (megagrams per year)
k = 0.04/yr *(default value)*
Lo = 100 m^3/Mg *(default value)*
R = 54,000 Mg/yr
t = 20 yrs
C_{NMOC} = 2420 ppmv
c = 0 *(c=0 for active landfills)*
3.6 x 10^{-9} conversion factor

$$\mathbf{M_{NMOC}} = 2L_O R (e^{-kc} - e^{-kt}) (C_{NMOC})(3.6 \times 10^{-9})$$

$$\mathbf{M_{NMOC}} = 2 (100 m^3/Mg) (54{,}000 Mg/yr) [e^{-(0.04)(0)} – e^{-(0.04)(20)}] (2420 ppmv) (3.6 \times 10^{-9})$$

$$\mathbf{M_{NMOC} = 51.8 Mg/yr}$$

51.8 Mg/yr x 1.1023 ton/Mg = **57.11 tons/yr NMOC**

Attachment A:

Conversion of AP-42 default and site specific Landfill Gas sulfur concentrations to equivalent SO_X emission factors

AP-42 Default Total Reduced Sulfur (TRS) Concentration = 46.9 ppmv or 46.9e-6 lb mol S, calculated as H_2S:

$$\frac{46.9e\text{-}6 \text{ lb mol S}}{1 \text{ lb mol LFG}} \times \frac{1 \text{ lb mol LFG}}{386 \text{ scf}} \times \frac{32 \text{ lbs S}}{1 \text{ lb mol S}} \times \frac{2 \text{ lbs SOx}}{\text{lb S}} \times \frac{1e6 \text{ scf}}{\text{MMSCF}} = \frac{\textbf{7.8 lbs SOx}}{\textbf{MMSCF}}$$

EXAMPLE CALCULATIONS USING SITE SPECIFIC DATA

Example where site-specific Landfill Gas analysis available: H_2S concentration = 136 ppmv :

$$\frac{136e\text{-}6 \text{ lb mol S}}{1 \text{ lb mol LFG}} \times \frac{1 \text{ lb mol LFG}}{386 \text{ scf}} \times \frac{32 \text{ lbs S}}{1 \text{ lb mol S}} \times \frac{2 \text{ lbs SOx}}{\text{lb S}} \times \frac{1e6 \text{ scf}}{\text{MMSCF}} = \frac{22.5 \text{ lbs SOx}}{\text{MMSCF}}$$

Example where site-specific Landfill Gas analysis available: TRS concentration = 143 ppmv, calculated as H_2S :

$$\frac{143e\text{-}6 \text{ lb mol S}}{1 \text{ lb mol LFG}} \times \frac{1 \text{ lb mol LFG}}{386 \text{ scf}} \times \frac{32 \text{ lbs S}}{1 \text{ lb mol S}} \times \frac{2 \text{ lbs SOx}}{\text{lb S}} \times \frac{1e6 \text{ scf}}{\text{MMSCF}} = \frac{23.7 \text{ lbs SOx}}{\text{MMSCF}}$$