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National Pollutant Inventory

Emission estimation technique manual for

Municipal Solid Waste (MSW) Landfills Version 2.0

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MSW LANDFILL

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1 Introduction

1.1 The NPI reporting process

The purpose of all emission estimation technique (EET) manuals is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in municipal solid waste landfill activities.

EET MANUAL		Municipal Solid Waste Landfills
ANZSIC CODE	2006	2921 Waste treatment and disposal services

This manual has been developed through a process of national consultation involving state and territory environmental authorities and key industry stakeholders.

NPI substances are those that when emitted at certain levels have potential to be harmful. Australian, State and Territory governments have agreed, in response to international requirements, that industries will report these emissions on an annual basis. NPI substances are set out in the *NPI Guide*. Figure 1 provides an overview of the reporting process.



Figure 1 NPI reporting process

1.2 Structured approach to reporting

The main tasks are consolidated below to provide a suggested approach to reporting.

Box 1. Suggested approach for NPI reporting

Define the process flow

- Construct a system diagram for your landfill identifying:
 - a. the system boundary (this need not be the property boundary),
 - b. inflow and handling of waste,
 - c. landfill gas collection/management/combustion,
 - d. leachate collection/management, and
 - e. outflows (of landfill gas, leachate and products of burning or treatment).

Characterise the landfill

- Dimensions of landfill: surface area (length, width, depth).
- Design capacity (tonnes MSW).
- Year landfill opened (and year closed if applicable).
- Gas collection system efficiency: if present.
- Leachate collection system efficiency: if present.
- Annual rainfall.

Characterise the wastes

- Estimate of the composition of deposited waste, especially the quantity of biodegradable waste.
- Estimate of the quantity of waste deposited.
- Compile estimates for waste characteristics in past years.

Characterise landfill gas and leachate

- Compile any available monitoring data.
 - Is landfill gas combusted by landfill operator or a separate company?
 - If combusted by the landfill operator, then identify the characteristics of the flare or burner and pollutant control technology employed.
- Estimate volume and fate of generated leachate (from hydrogeology models if available) and include treatment, recirculation or evaporation.

Reporting and quality assurance

- Determine which substances need to be included in the report.
- Estimate emissions for the relevant substances.
- Estimate transfers for the relevant substances and record the destination.
- Record the estimation techniques used and the reasons for any 'significant differences to the previous report'.
- Prepare and submit reports to NPI.
- Keep the above records, calculations and copies of reports.

In addition to the above tasks, regularly check the NPI website for the latest reporting information, access to other EETs, and other sources of advice. For site-specific issues, contact your State's or Territory's NPI Team for advice.

Australian NPI reporting is streamlined by international standards. Nonetheless, terms such as *categories*, *substances* and *transfers* have specific NPI definitions and the

reporting process may appear daunting. The suggested approach is intended to maximise the use of existing operational monitoring. Recording quantities of waste and monitoring environmental emissions are standard operations; the specific NPI aspect of these operations involves substances with potential risk to health or environment.

The *NPI Guide* provides the definitive description of the reporting process and this EET manual is intended to be used in conjunction with the *NPI Guide*.

1.3 Additional reporting materials

This manual is written to reflect the common processes employed by landfill facilities. In some cases it will be necessary to refer to other EET manuals to ensure a complete report of the emissions for the facility can be made. Other applicable EET manuals may include, but are not limited to:

- Combustion in Boilers,
- Fuel and Organic Liquid Storage,
- Combustion Engines, and
- Fugitive Emissions.

2 Process description

2.1 Waste management

Landfill has been the most common method of managing solid waste in Australia. 32.4 million tonnes of solid waste were generated in 2002-2003 of which approximately 17.4 million tonnes was deposited in landfills (DEH, 2006, Productivity Commission, 2006, ABS, 2006 and 2007).

There are hundreds of operational landfills in Australia with hundreds more that have been closed, abandoned or converted to green space and recreational (sports) areas. The majority of landfills (closed and operational) are small, receiving less than 5,000 tonnes of waste per year.

With respect to NPI, landfills are atypical reporting facilities representing a permanent storage of unwanted materials in which input is dictated by the facility's local catchments. Solid waste disposed of at a typical landfill may be categorised as having arisen from the following three main sources (Australian Waste Database, 1990 - 1998, DEH and CSIRO):

• Municipal

Waste arising from domestic premises: food, paper, and garden waste and from Council activities associated with servicing residential areas: street sweepings, tree lopping, parks and gardens, and litter bins.

• Commercial and Industrial

Waste arising from institutional, commercial, industrial activities: generally containing higher proportions of metals and plastics than domestic waste.

• Construction and Demolition

Waste arising from demolition and building activities: generally containing high proportions of inert material (concrete, bricks) and low proportions of other materials.

In 2003, 27% of urban waste in Australia was generated from municipal sources; 29% from commercial and industrial sources; and 42% from construction and demolition sources.

Composition	Municipal	Commercial and Industrial	Construction and Demolition
Organics (food and garden)	47	13	1
Paper (and cardboard)	23	22	0
Plastics	4	6	0
Glass	7	2	0
Metals	5	22	7
Concrete (ceramics, stone)	3	3	82
Timber	1	9	4
Other	12	23	6

Table 1.	Composition	(%) of Australian	solid urban wast	te 2002-2003.
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In the past three decades the focus of waste management has shifted and now reduction in waste generation and diversion of waste from deposition are major objectives for solid waste management (DEH 2006).

Recycling is a more resource intensive method of avoiding material disposal to landfill. Councils often operate kerbside collections for recyclables and organise special collections for bulky items. Individuals are also encouraged to transport recyclables to central facilities or collection stations. Further sorting takes place at both material recovery facilities and transfer stations. This form of waste management results in waste being recycled; converted to compost; used as a source of energy or deposited in landfill as the last option.

2.2 Landfill processes

In the past waste was deposited in 'suitable locations' such as natural hollows, old quarries and mine sites. Community attitudes have changed and simple deposition has developed into a more controlled and better engineered process.

Landfills are not closed systems, nor are they inert systems. Deposited materials degrade, gases are emitted and materials leached by percolating rainwater. To prevent contamination of air and groundwater modern landfills have gas collection systems and are usually engineered to contain and collect leachate. A typical construction is illustrated in Figure 2.



Figure 2. Typical landfill design (Tasmanian Department of Primary Industries, 2004)

In Australia landfill waste commonly consists of approximately 30 - 40% biodegradable waste (ABS, 2006).

Bacteria consume the readily degraded fraction of organic material. It can take decades for this fraction to be exhausted. The remaining, refractile, organic material may remain essentially unchanged for centuries. Decomposition is a seamless process but for convenience four phases are recognised (Kjeldsen et al. 2002):

Phase I

Initially, the fresh waste compacted and sealed in the landfill contains oxygen and moisture. Aerobic bacteria begin to digest the organic matter, temperature might increase, carbon dioxide production increases and the proportion of nitrogen in the waste atmosphere decreases.

Phase II

The supply of oxygen generally runs out within a few days and the atmosphere becomes anoxic. Anaerobic bacteria continue the decomposition of organic matter. Hydrolytic and fermentative species exude enzymes which break down complex molecules to their basic components: proteins to amino acids; complex carbohydrates to simple sugars; fats and oils to glycerol and fatty acids. The environment becomes more acidic and acetogenic bacteria feed on these products producing hydrogen and carbon dioxide.

Phase III

The environment moves towards neutral pH and populations of methanogenic bacteria start to consume the accumulated products from biochemical activity of the hydrolytic, fermentative and acetogenic bacteria. Methanogenic bacteria produce methane and carbon dioxide.

Phase IV

Methane production reaches a maximum and pH stabilizes (carboxylic acids are used as quickly as they are formed). Methane and carbon dioxide are generated in virtually equal quantities but a fraction of the carbon dioxide becomes dissolved in water and the gas outflow is usually richer in methane. The general composition of landfill gas produced is shown in Table 2 (refer to Section 3). This is the 'methanogenic phase' and can last for decades. Gradually, as the food supply is exhausted, bacterial activity declines.

After phase IV, only the refractile organic matter (and inert waste) remains. At this stage the waste is 'stable': gas production drops, and the waste may become aerobic.

At large landfills, gas may be used for power generation. Methane produced in landfills is an extractable energy resource, and methane capture is becoming more commonplace at larger metropolitan landfills. Capture efficiency is variable with claims ranging from about 20% to 70% of production: capture of 60% could be expected at landfills implementing best practice (Dever, 2006). Some landfill gas might be flared to reduce methane to carbon dioxide, and thus reduce greenhouse gas emissions.



Water percolating through landfills will pick up and transport chemicals creating leachate: a complex mixture of suspended and soluble substances. The quantity of leachate generated depends principally on rainfall and the state of the landfill. At new, unsealed landfill sites, the total rainfall collects as leachate. With progressive sealing leachate quantity reduces to 10 - 20 % of total rainfall.

The wide range of pollutants in leachate presents difficulties in successfully removing them and producing good quality water. Leachate is typically directed to settling ponds; the supernatant treated onsite, discharged to a sewer, allowed to evaporate or recirculated through the landfill (Tasmanian Department of Primary Industries, 2004).

Specialised onsite or offsite treatments include (IPPC, 2007):

- Biological treatment (activated sludge, biofilms).
- Removal of suspended low density solids by flotation followed by precipitation, flocculation and sedimentation (using conventional agents: aluminium and ferric salts). These processes can remove up to 40% of the pollutants from leachate.
- Pollutant removal using activated carbon and oxidation (usually involves the addition of ozone or hydrogen peroxide, followed by UV irradiation).
- Reverse osmosis or membrane filtration.
- Pollutant stripping, concentration and combustion.
- Passage through artificial wetlands.

Residual waste from some treatment processes can be more concentrated and may be returned to landfill.

Many old, closed landfills were not constructed to contain leachate or to capture landfill gases. For these facilities, risk of environmental harm can be reduced by appropriate aftercare involving a number of containment strategies including:

- Extraction and treatment of contaminated groundwater.
- Construction of impermeable subsurface barriers to prevent groundwater contamination.
- Sealing the surface (impermeable membrane) to prevent entry of water and formation of leachate.
- Increasing the layer of soil cover to minimise risk of exposure.
- Passive extraction and capture of landfill gases.

Such aftercare might need to be maintained for many years and the associated costs could be substantial.

3 Emission sources

Biodegradation processes within waste may transform or generate NPI substances that are subsequently released as gases (landfill gas) or liquid (leachate). Degradation of non-biological material within waste occurs by chemical and physical processes also resulting in generation of NPI substances. Emissions from landfills are discussed below in terms of emissions to air, water and land.

3.1 Emissions to air

Air emissions may be categorised as point source or fugitive emissions. Point source emissions are released into the atmosphere through a single point source such as a vent, stack or flare. If landfill gas is combusted, there will be point source emissions.

Fugitive emissions are not released through a vent or stack. Where landfill gas is not captured for power generation or flaring, the gas mixture will be released to air as a fugitive emission. Where landfill gas is collected, there will be a proportion that will evade collection and escape as a fugitive emission.

A vast assortment of chemicals enters landfills and it is virtually impossible to track the fate of individual substances. A total of 181 volatile organic compounds (VOC) have been found in gases emitted from biodegradable municipal waste (aerobic and anaerobic decomposition). However, the quantities of VOC are several hundred times smaller than those of methane and carbon dioxide (USEPA, 2006). Landfill gas is a mixture of primarily methane and carbon dioxide with small proportions of other compounds, as shown in Table 2.

Component	Landfill gas (% by volume)
Methane	50 - 75
Carbon dioxide	25 - 50
Non-methane volatile organic compounds	0.01 - 0.60
Water vapour	6-6.5
Nitrogen	3.9 - 4.1
Oxygen	0.9 - 1.1
Ammonia	<0.1 - 1

Table 2. Composition of biogas produced by anaerobic decomposition (EC, 2005).

Gas can be collected or left to disperse naturally. Collected gas can be destroyed by flaring or combusted for power generation. Combustion can be onsite or the gas can be piped to offsite facilities, possibly operated by separate companies.

3.2 Emissions to water

Emissions of substances to water can be categorised as discharges to:

- surface waters (lakes, rivers, dams, estuaries),
- coastal or marine waters, and
- stormwater runoff.

The volume of rainfall percolating through the landfill largely determines leachate generation volumes and discharges. In cases where the leachate emerges into a

stormwater system or surface water body, the emissions of tripped substances must be estimated. Emissions to groundwater are considered an emission to land for the purpose of NPI reporting.

Most landfills undertake monitoring of leachate, groundwater and nearby surface water bodies. These existing sampling data can be used to help calculate annual emissions to the NPI.

Appendix B presents additional information on leachate characterisation and emissions.

3.3 Emissions to land

Emissions of substances to land do not include the facility activity, which is the disposal of collected municipal waste to the landfill.

Emissions may occur due to overland flow or spray application of leachate to land (other than directly on the landfill). If leachate is collected and recirculated (added to the landfill) then substances have not been emitted or transferred. They have been retained within the landfill system's boundary and do not have to be reported.

The discharge of substances in leachate to a sewer or evaporation pond (other than directly on the landfill) represents a transfer and it is reportable.

4 Threshold calculations

Thresholds are employed to decide whether the emissions and transfers of substances need to be reported. The application of NPI thresholds to landfills is not as straightforward as it is for some other industries. For landfills, the thresholds are much more concerned with storage while in other industries, the amount of the 'stored' substances is usually low in comparison with the amount of used substances. As discussed in Section 2, landfill processes may continue for decades and thus the threshold calculations must address waste received over the landfill's entire operational life.

4.1 Usage/storage thresholds

Some of the substances of importance to MSW landfills (e.g., ammonia, total nitrogen, total phosphorus, hydrogen sulphide) do not arise from simple direct input; these are generated and transformed depending on the degradation processes, landfill conditions and age of the waste.

Other substances (e.g., metals such as zinc and compounds), are a function of the direct waste input. While landfills may contain a significant amount of metallic waste material, it may be in a form that will not readily leach. For example, a car engine block will leach metals from the exposed surface, but the majority of the mass is encapsulated and does not represent an emission source. These considerations should be taken into account in the threshold calculations.

'Use' and 'usage' is defined as the receipt, storage, handling, manufacture, import, processing, coincidental production or other uses of NPI substances. The NPI Guide provides detailed information on thresholds for all categories. If the 'use' of any NPI substance exceeds the thresholds for Category 1, 1a or 1b, then all of the emissions of that substance from the facility must be reported. This also applies to mandatory transfers.

The Category 1, 1a or 1b thresholds relate to the quantity of substance stored in the landfill. A threshold would be tripped when the cumulative quantity of substance stored equals or exceeds the threshold quantity. Once a substance has tripped a threshold then its fate (emissions and transfers) needs to be tracked and reports prepared for that, and all subsequent years, for the landfill.

Volatile organic compounds (VOC) are most commonly found in fuels, solvents, paints, adhesives, and plastics and a wide variety of other consumer products. MSW will contain VOC as residues or incorporated into the structure of plastic foams, packaging, floor and wall coverings, furniture and similar materials. The non-methane volatile organic compounds (NMVOC) in landfill gas are equivalent to the NPI 'substance' total volatile organic compounds.

Direct measurements have shown that NMVOC form a small proportion of landfill gas. From landfills where no significant hazardous waste has been deposited the quantity of NMVOC in landfill gas varies between 105 and 1481ppm (by volume), with a mean value 595ppm (USEPA 1997).

The Category 1a threshold for VOC is 25 tonnes and the quantity of mixed, wet, MSW that could release this quantity of VOC is about 107,000 tonnes (refer to Box 2). Pragmatically a threshold quantity of 110,000 tonnes of stored MSW could be used as the threshold for reporting VOC emissions (refer to Table 3).

Box 2. Quantity of stored MSW that could yield 25 tonnes of VOC and trip the Category 1a threshold.

Quantity of biodegradable carbon in 1 tonne of wet MSW:

- One tonne of Australian MSW contains about 0.35 tonnes of biodegradable material (ABS 2006).
- Approximately 74% of this (i.e. 0.259 tonnes) is dry biodegradable material.
- About 42 44% of dry (plant derived) MSW is carbon (USEPA 2006; Bidwell 1979) and about 57% of this can be degraded to carbon dioxide and methane (USEPA 2006).
- Accepting that the proportion of completely degradable carbon is 0.24 (0.57*0.42) then 0.259 tonne of dry waste contains 0.06216 tonne of completely degradable carbon.

 $= 0.35 \ge 0.74 \ge 0.42 \ge 0.57 = 0.06216$

Yield of VOC from 1 tonne of wet MSW:

- 0.06216 tonne carbon would produce 0.00518 tonne of methane + carbon dioxide (in equal proportions).
- At standard temperature and pressure this would occupy about 116 m^3 .
- The concentration of VOC in landfill gas is 520ppm (by volume).
- 116 m³ of landfill gas would contain 0.06032 m³ of VOC.
- This weighs 0.233kg of VOC (as hexane equivalents).

= 116 x 0.000520

- $= 0.06032 \text{ m}^3 \text{ of VOC}.$
- = 0.233 kg of VOC

Cumulative weight of wet MSW that could yield 25 tonnes of VOC is therefore approximately 107,000 tonnes (i.e. 25,000/0.233).

Pragmatically, **110,000 tonnes** could be used as the threshold quantity of stored MSW that would trip the Category 1a threshold.

The quantities of stored MSW that could contain threshold quantities of Category 1 and 1b substances can be estimated from their average concentrations in various types of waste. Such estimates, derived from the data in tables in Appendix B (assuming that Australian MSW has a moisture content of 26%). Pragmatic threshold quantities are presented for Category 1, 1a and 1b substances in Table 3.

The thresholds are based on a small dataset and the values within the dataset have large ranges. Consequently it is better to use site specific data where it is representative. The thresholds provided below can be used as a rough guide.

Element	Quantity of MSW containing	
	the threshold quantity	
	(tonnes)	
Zn	7,600	
Pb	12,000	
Cr	27,000	
Cu	36,000	
Hg	37,000	
Sb	70,000	
Cd	260,000	
As	280,000	
Sn	290,000	
Ni	440,000	
Se	2,600,000	
Total VOC	110,000	

 Table 3. Estimated threshold quantities of stored MSW for inorganic elements and Total VOC.

The cumulative quantity of substance stored can be estimated from the total quantity of waste deposited and the concentration of substance in that waste. However, waste is a variable mixture of unknown chemical composition: the quantity delivered each day is largely outside the control of a landfill manager. As such, quantities and chemical composition will likely need to be estimated.

Realistically, separate estimates for each type of waste are needed: it is impractical to estimate chemical composition from samples of 'whole mixed waste'. MSW needs to be segregated into separate categories: the chemical composition and quantity of each type deposited in landfill need to be determined.

Site-specific estimates could be made or the rough guide (below) could be used to decide whether thresholds have been tripped.

Estimating site-specific quantities of MSW deposited

The total quantity of each type of waste deposited in a reporting year may be estimated using methods based on average daily deliveries of waste, or the average weight of waste per class of load.

1. Average daily deliveries (\overline{w}) of certain type of waste can be estimated by sampling. The total annual delivery for this type of waste would then be calculated for the reporting year (Equation 1):

$$m = w * L$$

Equation 1

Where:

m is the total annual delivery

 $\frac{1}{w}$ is the average quantity of each type of waste delivered per day

- L is the number of daily deliveries
- 2. Alternatively, waste loads could be separated into classes based, for example, on size and gross composition. Sampling could be used to estimate the average quantity of each type of waste delivered in each *class of waste load*. The total quantity of this type of waste delivered (for a class) would then be the average for each class multiplied by the number of loads of that class that were delivered. The total quantity of each type of waste delivered in all classes of waste load (refer to Equation 2).

$$m = \sum_{i=1}^{i=n} (\overline{w_i} * l_i)$$
Equation 2

Where:

m	is the dry weight of this waste type deposited in the reporting year
i	is the number of load classes (1 to n)
— Wi	is the average weight of this type of waste in loads of class 'i'
li	is the number of class 'i' loads delivered in the reporting year

Quantity of inorganic substances in storage

To estimate the quantity of inorganic substances in storage, values for two parameters are required (1) the dry weight of waste type deposited and (2) the concentration of substance in that type of waste.

As moisture content differs between types of waste, the weight of each type of waste needs to be converted to dry weight and appropriate conversion factors need to be determined. In the absence of these factors, the values presented in Appendix B could be used as 'defaults' for biodegradable waste. It can also be assumed that other waste (ceramics, stone, concrete, plastics etc) contain zero moisture.

Quantity of substance deposited in a reporting year

For each substance the quantity deposited in a reporting year can be calculated using Equation 3:

$$Q = \sum_{i=1}^{i=n} (m_i * c_i)$$
Equation 3

Where:

- Q is the quantity of substance deposited in the reporting year
- i is the type of waste (types 1 to n)
- $m_i \quad \ is the dry weight of waste of type 'i' deposited in the reporting year$
- c_i is the concentration of substance in waste of type 'i'

Additional information

Chemical composition of each waste type cannot practically be determined by site specific analysis. Chemical composition should be obtained from publicly available data, such as that compiled in Appendix B.

The volume of waste in storage can be estimated from the dimensions of the landfill. The volume (m^3) needs to be converted to a mass (tonnes) by applying a density factor and subtracting out the volume of daily cover and capping material.

Unless information is available, the quantity of substances stored should be estimated by assuming that past depositions had a similar chemical composition as current depositions of MSW.

The *NPI Guide* provides specific advice about what should be measured/analysed for other substances. The advice for ammonia (total) is as follows:

The threshold for 'Ammonia (total)' refers to the total amount of both ammonia (NH_3 CAS number 7664-41-7) and the ammonium ion (NH_4^+) in solution. There is no need to convert the quantity of ammonium ion into an ammonia equivalent.

4.2 Fuel and electricity thresholds

Large facilities employing energy recovery processes may trigger the Category 2a or 2b thresholds for fuel burning waste. A facility that has no combustion processes or fuel / waste burning need not consider the Category 2a or 2b thresholds.

The NPI reporting thresholds for Category 2a are:

- burning of 400 tonnes or more fuel or waste in a year; or
- burning 1 tonne or more of fuel or waste in an hour at any time during the reporting year.

The NPI threshold for Category 2b substances for landfill facilities is:

• burning 2,000 tonnes or more of fuel or waste in a year.

It has become more common at larger landfills for methane to be extracted by specialist companies. Methane is used to generate electricity or perhaps to gain carbon credits by burning the gas. These specialist companies become responsible for reporting emissions. The gas is a resource transferred for the beneficial use of energy recovery. Substances in the transferred gas could be voluntarily reported by the landfill facility as a transfer.

If landfill gas is burned by the landfill operator, they are responsible for reporting to the NPI the relevant set of Category 2a and 2b substances emitted.

The threshold quantities for burning landfill gas, as outlined in the NPI Guide, are:

- Category 2a: 367,000 m³ in the reporting year
- Category 2b: 1,830,000 m³ in the reporting year

Operation of heavy construction vehicles consumes about 1 liter of diesel (0.836kg) per tonne of waste (Bateman, 2006). On this basis, only landfills receiving 479,000 tonnes or more of waste, per year would trip the Category 2a threshold (consumption of 400 tonnes or more of fuel).

If a facility exceeds the fuel burning threshold, refer to the appropriate EET manual, such as *Combustion in Boilers* or *Combustion Engines*.

4.3 Nitrogen and phosphorus thresholds

If your facility emitted to water (excluding groundwater), and/or transferred to a mandatory reporting transfer destination:

- 15 tonnes or more of total nitrogen, or
- 3 tonnes or more of total phosphorus,

then the facility must report the quantities of both substances flowing out of the facility.

Exceeding the threshold for Category 3 at a MSW landfill facility would require a significant volume of discharge to surface water (emission) or to sewer (transfer). For this case, calculating the mass of total nitrogen and total phosphorus is best done using direct measurement techniques.

Total nitrogen (TN) is considered to be the sum of nitrate, nitrite, ammonia, and organic nitrogen all expressed as nitrogen. Total phosphorus (TP) is the sum of all inorganic and organic forms in water, expressed as phosphorus.

Category 3 substances will only be in leachate. The quantity of either TN or TP emitted can be calculated:

$$\mathbf{Q}_{\mathrm{s}} = \mathbf{V} * \mathbf{C}_{\mathrm{s}}$$
 Equation 4

Where:

- Q_s is the quantity of substance s emitted (kg/year)
- V is the release rate of leachate $(m^3/year)$
- C_s is the average concentration of the substance in the leachate (kg/m³)

Only leachate that flows out of the landfill system should be measured. If leachate is not collected and is released, then an estimate of annual discharge can be used:

$$V = 0.15 * R * A$$
 Equation 5

Where:

- V is the volume of leachate discharged in a year $(m^3/year)$
- R is the annual rainfall (m)
- A is the surface area of the landfill (m^2)

If leachate comes from an onsite treatment plant then the flow would be measured routinely.

The average concentration of substance should be determined from analysis of at least five samples. Samples should be taken from the outflow of the onsite treatment plant (preferably at regular intervals if the flow is uniform: otherwise to coincide with periods of high flow). For leachate that diffuses to surface water via groundwater, samples of groundwater should be obtained close to the landfill.

5 Emission estimation techniques

There are five types of emission estimation techniques (EETs) that may be used to calculate emissions from your facility. These are:

- sampling data or direct measurement,
- mass balance,
- fuel analysis or engineering calculations,
- emission factors, and
- an approved alternative.

Select the EET (or mix of EETs) that is most appropriate for your purposes.

This manual seeks to provide the most effective EETs for the NPI substances relevant to MSW landfills. However, the absence of an EET for a substance in the manual does not imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

5.1 Direct measurement

Direct measurement is a good option for reporting to the NPI, particularly if you already undertake sampling and analysis to meet other regulatory requirements.

Direct measurement may be employed for leachate emissions to water. The quantity of substances emitted in leachate can be estimated using the method outlined for estimation of Category 3 thresholds (refer to Section 4.3).

The emission estimation must determine the volume of the leachate entering the surface water body or stormwater system. For a small stream or channel on a landfill's boundary, a surrogate analyte such as electrical conductivity, could be used to estimate the volume of leachate entering the surface water body or stormwater system. Results from upstream of the landfill can be compared with downstream results and leachate results. This can provide an indication of the landfill's contribution to the stream. Apportioning the contribution to NPI substances provides a conservative estimate as the attenuating influence of the soil (e.g., slowing the movement of dissolved metals) is not considered.

5.2 Mass balance

Emissions to air

Computer models must be used for estimation of landfill gas emissions Models estimate methane generation and employ **emission factors** to estimate releases of other pollutants including NPI substances.

Controlled release of pollutants from burning landfill gas can be estimated using computer models or using methods described in the NPI EET Manual *Combustion in Boilers*. These also employ **emission factors**.

Emissions to air of pollutants associated with landfill gas should be estimated using either of one of three freely available computer models: LEA (Landfill Emissions

Assistant, available from DEWHA), LandGEM (available from the US EPA) or GasSimLite (UK Environmental Agency) available from Golders and Associates.

Précis of LEA

The Landfill Emissions Assistant (LEA) tool is a deterministic (Excel) spreadsheet model. It was developed based on updates to the emissions profiles as specified in the USEPA AP42 for Landfills constructed after 1992.

The model uses ambient condition data (average yearly temperature and rainfall) sourced from the Australian Bureau of Meterology. The tool also exports a CSV file which can be uploaded into the NPI online reporting system.

The model treats 'Waste' (inputs for design capacity and acceptance rate) as completely biodegradable. The majority of MSW is not biodegradable waste, it is important to ensure that the annual acceptance rate is for biodegradable waste only. MSW has a dry weight/wet weight ratio of about 0.84 (USEPA, 2006) and about 35% of Australian MSW is biodegradable (ABS, 2006). Therefore the correction factor is $0.84 \times 0.35 = 0.294$.

Précis of LandGEM 3.02

LandGEM (USEPA) is a deterministic (Excel) spreadsheet model. It has built-in default values which can be used to generate NPI reports with minimal background research.

LandGEM (USEPA) treats waste in a similar manner as LEA, therefore the waste value used also needs to be corrected to ensure that it is for the mass of biodegradable waste only.

Précis of GasSimLite V1.54

GasSimLite is a simulation model. It can handle uncertainty in input data (it accepts ranges, different types of distributions of values within the ranges, as well as single values). It yields output as medians and ranges. It estimates emissions from flaring and burning gas for power generation: LandGEM does not.

GasSimLite Version 1.54 uses biodegradable waste in its calculations and its results do not require correction.

The model handles mixtures of waste each with a different degradation rate. It handles differences in moisture content, recirculation of leachate and differences in landfill construction.

It has built-in sets of default values which can be used to generate NPI reports with minimal background research. However, greater knowledge of landfill characteristics is required than for use of LandGEM.

5.3 Engineering calculations

Engineering calculations may be used to estimate emissions and transfers where other methods are insufficient. For example, you may not be able to directly measure data related to non-routine events. The data gaps should be filled with the best available engineering estimates.

Spills, overflows and discharges need to be estimated and their contribution added to the reported process emissions and/or transfers. The emission resulting from a spill is the net emission that is the quantity of the substance spilled, less the quantity recovered or consumed during cleanup operations.

5.4 Emission factors

An emission factor is a tool that is used to estimate emissions to the environment. In this manual, it relates to the quantity of substances emitted from a source though some common activity associated with those emissions. Emission factors are usually expressed as the weight of a substance emitted multiplied by the unit weight, volume, distance or duration of the activity emitting the substance (e.g., kilograms of substance per tonne of product).

When using emission factors, you should be aware of the associated emission factor rating (EFR) code and what the rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor and the target equipment/process from which the factor was derived. The EFR system is:

- A Excellent
- B Above average
- C Average
- D Below average
- E Poor
- U Unrated

Emission factors are used to estimate a facility's fugitive emissions to air when other methods such as development of unit-specific correlation equations or existing correlations are not available.

Generally, the application of an emission factor takes the following form:

E = A x T x EF x [1-(CE/100)] Equation 6

Where:

- E is the emission (kg)
- A is the 'activity' rate (t/hr)
- T is the number of operating hours for the reporting year (hr)
- EF is the uncontrolled emission factor (kg/t)
- CE is the control efficiency (%) for the substance

5.5 Approved alternative

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your State or Territory environmental agency. For example, if your facility has developed site-specific emission factors, you may use these if they have been approved by your environmental agency.

6 Transfers of NPI substances

The NPI requires the mandatory reporting of NPI substances that are transferred as waste to a final destination. Transfers are required to be reported if a Category 1, Category 1b or Category 3 reporting threshold is exceeded. Both emissions and transfers are reportable in kilograms.

The transfer of NPI substances to a destination for reuse, recycling, reprocessing, purification, partial purification, immobilisation, remediation or energy recovery can be reported voluntarily. This is an opportune way for facilities to provide appropriate context about transfers to their local community.

Substances in transferred gas for energy recovery (e.g., to an electricity generator) could be voluntarily reported by the landfill facility as a transfer.

Landfills are mandatory reporting transfer destinations for off-site reporters as they represent the final destination for NPI substances. However, placing materials in the landfill by the landfill operator and moving materials within the landfill's boundary does not constitute a transfer.

If leachate is treated onsite and directed onto the landfill, this is not a transfer as substances have been retained within the landfill system's boundary.

Transfers do not involve soil used in daily cover or capping of landfills.

Leachate that is collected and discharged via the sewerage system for treatment represents a transfer to a mandatory reporting destination. The transfer would need to be reported if a Category 1 threshold had been tripped.

Further information regarding transfers of waste, including how to estimate and report, can be found in *The NPI Guide*.

7 Additional reporting information

This manual has been written to reflect the common processes employed in MSW landfills. To ensure a complete report of the emissions for your facility, it may be necessary to refer to other EET manuals. These include:

- Fossil Fuel Electric Power Generation,
- Fuel and Organic Liquid Storage, and
- Fugitive Emissions.

When you have a complete account of substance emissions from your facility, report these emissions according to the instructions in *The NPI Guide*.

The following advice is compiled from relevant references and is presented below to aid in reporting.

Quantities should be reported to two significant figures. The rounding method used should be in accordance with Australian Standard AS 2706. Rounding should be made in 'one step'. Examples are:

Original Value	Rounds to
8.2501	8.3
8.3499	8.3

If figures to be discarded fall midway between two numbers (i.e. end in a 5) then the value should be rounded to the nearest even number. Examples are:

Original value	Rounds to nearest even value
8.45	8.4
8.5500	8.6

Caution should be taken when reporting an emission of a tripped substance as zero. Emissions should only be reported as zero in circumstances where there is certainty that the NPI substance is not emitted or emissions are negligible.

The reported emission for a substance should be left blank if no emission estimation factors or techniques are available and if there is uncertainty about whether that emission is in fact zero. If a blank emission is included in a report for an NPI substance where usage has tripped the reporting thresholds, written documentation with the appropriate reason must be provided, for example "No emission estimation technique available".

If a result is below the detection limit:

- and you are sure that the substance was not present, then report a zero value,
- otherwise, report a value that is half the detection limit.

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Term	Definition
ANZSIC	Australian and New Zealand Standard Industrial Classification
COD	chemical oxygen demand
EET	emission estimation technique
GAC	granular activated carbon
g	gram; 10 ⁻³ kg
kg	kilogram; SI base unit
L	litre; 10 ⁻³ m ³ (m: metre is an SI base unit)
LFG	landfill gas (methane, carbon dioxide and trace constituents)
mg	milligram; 10 ⁻⁶ kg; (10 ⁻³ g)
MSDS	material safety data sheet
MSW	municipal solid waste
MWh	megawatt hour (used for electrical energy)
NMVOC	non-methane volatile organic compounds
NPI substances	The National Pollutant Inventory contains data on 93 substances that have been listed based on their potential health or environmental impact.
pН	an index of hydrogen ion concentration
ppm	parts per million
t	tonne; 1000kg
TDS	total dissolved solids
TN	total nitrogen
ТР	total phosphorus
TVOC	total volatile organic compounds
UV	ultraviolet radiation
WHO	World Health Organisation
μg	microgram; 10 ⁻⁹ kg; (10 ⁻⁶ g)
μS. cm ⁻¹	microSiemens per centimetre, a unit of electrical conductivity

Appendix A: Abbreviations and Definitions

Appendix B:Leachate and waste characterisation data

The type of material deposited in the landfill determines the composition of the leachate. Composition is also influenced by the rate of biochemical processes in the body of the landfill and varies with the age of the landfill.

A substantial proportion of MSW consists of stable materials: glass; stone; bricks, concrete; ceramics; and a variety of plastics and polymers. These effectively encapsulate any NPI substances present in their matrix (Øygard et al., 2004). For example rigid PVC has been estimated to have a life in excess of 1000 years in landfill; vinyl monomer is not released and loss of heavy metals is at extremely low rates (Scheir, 2003). Only very small quantities of heavy metals are leached (in standard leaching tests) from bricks and foam glass containing recycled cathode ray tubes (ICER, 2004). Release rates could be greater if such inert materials were physically broken into small fragments: release rates are also greater for non-rigid plastics, such as wrapping films (Scheir, 2003).

It is convenient to separate substances present in leachate into four groups (Kjeldsen et al., 2002):

Dissolved Organic Matter

Mainly volatile fatty acids (acetic, propionic and butyric) and fulvic-like and humiclike refractory compounds. Dissolved organic matter is usually measured as a composite: chemical oxygen demand (COD) or total organic carbon (TOC).

Inorganic Components

These are the major inorganic ions: calcium; magnesium; sodium; potassium; ammonium (NH_4^+) , iron; manganese; chloride; sulphate and bicarbonate. Most inorganics remain relatively constant in leachate irrespective of landfill age. One such substance is ammonium ion: derived from digestion of proteins. This is stable under anaerobic conditions and generally occurs in high concentrations in leachate (Table 5). Ammonium concentration might remain high even 30 or more years after a landfill has closed. Phosphorus concentrations are generally low (Table 5) and might even be limiting to bacterial growth and biochemical activity.

Heavy Metals

The main heavy metals present are: cadmium; chromium; copper; lead; nickel and zinc. Their concentrations are highly variable but they are normally present in very low concentrations (Table 5). Only a small fraction (<0.02%) of heavy metals deposited in landfill is leached out (Kjeldsen et al. , 2002; Øygard et al. , 2004). The metals become immobilized by forming complexes with colloids (mainly humic material) and other organic material, and forming insoluble sulphides and carbonates.

Xenobiotic Organic Compounds

These arise from household and industrial chemicals. Some should not be present in MSW but regulations to prevent their deposition in MSW are not completely effective. They are usually present in very low concentrations (<1mg/L) and consist of such substances as: aromatic hydrocarbons; phenols; chlorinated aliphatics; pesticides and plasticizers. Constituents of oil derived fuels: e.g. benzene, toluene, and xylenes can occur in low concentrations. Nicotine, caffeine, and dozens of other organic

compounds can occur in detectable but very low concentrations. Kjeldsen et al. (2002) listed 105 xenobiotic organic compounds present in leachate from landfills in Europe and North America (Table B2).

Trace concentrations of many other substances can be found: organotin (IPPC, 2007) boron; sulphides; arsenic; selenium; barium; lithium; mercury; and cobalt. Mercury when released from products (fluorescent bulbs, batteries, thermometers etc) can evaporate and be emitted to air as part of the gas flow from landfills (NEWMOA, 2006).

Parameter	Units	Range
pH	-	4.5-9
Conductivity	µS.cm ⁻¹	2500-35000
Total solids	mg. L^{-1}	2000-60000
Dissolved Organic Matter		
Total Organic Carbon	mg. L^{-1}	30-29000
BOD ₅	$mg O_2 . L^{-1}$	20-57000
COD	$mg O_2 . L^{-1}$	140-152000
BOD/COD	-	0.02-0.8
Organic nitrogen	mg. L^{-1}	14-2500
Inorganics		
Total Phosphorus	mg. L^{-1}	0.01-10
Ammonium	mg. L^{-1}	50-2200
Chloride	mg. L^{-1}	150-45000
Sulphate	mg. L^{-1}	8-7750
Bicarbonate	mg. L^{-1}	610-7320
Sodium	mg. L^{-1}	70-7700
Potassium	mg. L ⁻¹	50-3700
Calcium	mg. L^{-1}	10-7200
Magnesium	mg. L^{-1}	30-15000
Iron	mg. L^{-1}	3-5500
Manganese	mg. L^{-1}	0.03-1400
Silica	mg. L^{-1}	4-70
Heavy metals		
Arsenic	mg. L^{-1}	0.01-1
Cadmium	mg. L^{-1}	0.0001-0.4
Chromium	mg. L^{-1}	0.02-1.5
Cobalt	mg. L^{-1}	0.005-1.5
Copper	mg. L^{-1}	0.005-10
Lead	mg. L^{-1}	0.001-5
Mercury	mg. L^{-1}	0.00005-0.16
Nickel	mg. L^{-1}	0.015-13
Zinc	mg. L^{-1}	0.03-1000

 Table B1. Composition of landfill leachate from Europe and North America (Kjeldsen et al. ., 2002).

Compound	Range	Compound	Range	Compound	Range conc	Compound	Range conc	Compound	Range conc
	(µg/L)		(µg/L)		(µg/L)		(µg/L)		(µg/L)
Aromatic hydrocarbons		Halogenated hydrocarbons		Phenols		Pesticides		Phthalates	
Benzene	0.2-1630	Chlorobenzene	0.1-110	Phenol	0.6-1200	Amytrin	0.12	Monomethyl phthalate	trace
Toluene	1-12300	1,2-Dichlorobenzene	0.1-32	Ethylphenols	<300	AMPA	3.8-4.3	Dimethyl phthalate	0.1-7.7
Xylene	0.8-3500	1,3-Dichlorobenzene	5.4-19	Cresols	1.0-2100	Atrazin	0.16	Diethyl phthalate	0.1-660
Ethylbenzene	0.2-2329	1,4-Dichlorobenzene	0.1-16	Bisphenol A	200-240	Bentazon	0.3-4.0	Methyl-ethyl-phthalate	2.0-340
Trimethylbenzenes	0.3-250	1,2,3-Trichlorobenzene	trace	3,5-Dimethylphenol	0.7-27.3	Chloridazon	1.6	Mono-(2-ethylhexyl) phthalate	4-14
n-Propylbenzene	0.3-16	1,2,4-Trichlorobenzene	4.3	2,5-Dimethylphenol	0.4-4.5	Chloropropham	26	Di-(2-ethylhexyl) phthalate	0.6-236
t-Butylbenzene	2.1-21	Hexchlorobenzene	0.025-10	2,4-Dimethylphenol	0.1-12.5	Dichlorobenil	0.1-0.3	Mono-butylphthalate	4-16
o-Ethyltoluene	0.5-46	1,1-Dichloroethane	0.6-46	3,4-Dimethylphenol	0.03-10.4	Fenpropimorf	0.1	Di-n-butylphthalate	0.1-70
m-Ethyltoluene	0.3-21	1,2-Dichloroethane	<6	2,6-Dimethylphenol	0.3-1.9	Glyphosate	1.7-27	Di-isobutylphthalate	3.6
p-Ethyltoluene	0.2-10	1,1,1-Trichloroethane	0.01-3810	2-Methoxyphenol	trace	Hexazinon	1.3	Mono-benzylphthalate	6-16
Napthalene	0.1-260	1,1,2-Trichloroethane	2.5-16	2/3-Chlorophenol	0.03-1.6	Hydroxyatrazin	0.7-1.7	Butylbenzyl phthalate	0.2-8
Alkyl phenols		1,1,2,2-Tetrachloroethane	trace	4-Chlorophenol	0.2-1.3	Hydroxysimazin	0.6-1.7	Dioctylphthalate	1-6
Nonylphenol	6.3-7.0	trans-1,2-Dichloroethylene	1.6-6582	4-Chloro-m-cresol	1.2-10.2	Isoproturon	1.2	Phthalic acid	2-14000
Nonylphenolmonocarboxylate	0.5-3.0	cis-1,2-Dichloroethylene	1.4-470	3,5-Dichlorophenol	0.08-0.63	Lindane	0.025-0.95	Aromatic sulphonates	
Phosphonates		Trichloroethylene	0.05-750	2,3,4,6-Tetrachlorophenol	0.079-3.0	Mecoprop	0.38-150	Napthalene-1-sulphonate	506-616
Tri-n-butylphosphate	1.2-360	Tetrachloroethylene	0.01-250	Miscellaneous		MCPA	0.2-9.1	Napthalene-2-sulphonate	1143-1188
Triethylphosphate	15	Dichloromethane	1.0-827	Acetone	6-4400	Propoxuron	2.6	Napthalene-1,5-disulphonate	<2.5-51
		Trichloromethane	1.0-70	2(3H)-benzothiazolone	10-50	Simazine	2.3	Napthalene-1,6-disulphonate	366-397
		Carbon tetrachloride	4.0-9.0	Camphor	21-255	Tridimefon	2.1	Napthalene-2,7-disulphonate	129-145
				Cumene	0.3-7.4	4-CPP	15.0-19.0	2-Aminonapthalene-4,8-disulphonate	73-109
				Fenchone	7.3-83	2,4-D	1.0-5.0	p-Toluenesulphonate	704-1084
				Tertrahydrofuran	9-430	2,4,5-T	trace		
				Indane	0.2-20	2,4-DP	0.3-5.2		
				Methylethylketone	110-6600	2,6-DCPP	0.7-1.3		
				Methyl-iso-butylketone	1.1-176				
				Dimethoxymethane	1.1				
				MTBE	0.8-35				
				Styrene	0.5-1.6				
				Organotin	0.2				

Table B2. Xenobiotic organic compounds in landfill leachate (Kjeldsen et al. ., 2002; IPPC, 2007).

Category	As	Cd	Cr	Sb	Hg	Mn	Pb	Р	Zn	Cu	Ni	¹ Dioxin /furan	² PCB	Source
Paper/cardboard	2	1	20		0.1		42							а
Paper/cardboard	2	11	67		< 0.1		127							b
Paper/cardboard	<5	1	10		0.2		23							с
Paper/cardboard		0.03-	20-30				72-228		80-180					d
(range)		0.3												
Paper/cardboard		5.26	10.9				44.3		393					e
Paper/cardboard		0.4					23		424					f
Wood	6	12	231		1		277							b
Wood	<5	<1	5		< 0.1		21							с
Food waste			7	8					17					g
*Meat waste								8200±2 400	32±21					i
*Fish waste						6±7		20400± 6400	62±12	1±1				i
*Fish and						8±2		1700±4	11±3	4±1				i
vegetable waste								00						
*Restaurant waste							11±16	14400±	17±19	1±1		1.44±0.	5.8±0.5	i
								6300				13	1	
*Household waste		2±5	30±23			55±71	206±36	2000±8	160±22	289±76		1.15±0.	4.0 ± 0.8	i
							0	00	3	4		11	0	
Organic waste	5	1	25		0.1		76							а
Organic waste	37	5	310		< 0.1		188							b
Organic waste	30	1	55		0.5		90							с
Organic waste		1	607				407		1010					e
Organic waste		0.4					37		241					f
Organic waste		0.06-	10-15				20-156		50-100					d
(range)		0.45												
Compost: (mean)		0.69	21		0.2		105		186	53	15			h
Compost: (range)		0.47-	11-33		0.08-		48-219		100-	32-92	11-21			h
		1.12			0.34		1		268					

Table B3. Chemical composition of biodegradable MSW (concentration mg/kg dry weight basis, unless stated otherwise).

Sources: a) Burnley (2007); b) Otte (1995); c) Herring et al. (1999); d) White et al. (1999); e) Chandler et al. (1997); f) Rotter et al. (2004); g) Jung et al. (2006); h) Dimambro et al. (2006); i) Garcia et al. (2005): * mean \pm SD; ¹ ngTEQ/kg; ² ng/g.

Category	As	Cd	Cr	Sb	Se	Hg	Pb	Zn	Cu	Ni	Sn	Р	PCB	Source
Total plastics	3	388	853			< 0.1	302							а
Total plastics (range)		0.39-	20-22.5				32-108	30-80						b
		2.1												
Total plastics		40.4	106				602	284						с
Electrical/electronic		160	900	3500		0.31	1900	2300	18000	1300	2300	1200	5	d
Polymer market		40	50	2600			1900	300	100	30	20	1200		e
Dense plastics	2	32	181			0.1	879							f
Film plastics	4	4	195			0.1	1595							f
Film plastics		1.3					219	730						g
PVC	< 0.5	66	29			0.2	50							h
Plastics		67.4					500	4380						g
Packaging plastics		0.9					109	768						g
Packaging plastics			420	26	0.4		11	50						i
Electrical goods	71	361	1304			17	11000							h
Electrical goods (av)		180	9900	1700		0.68	2900	5100	41000	10300	2400	360	13	d
(±95% conf.limits)		±50	±1700	±200		±0.22	±500	± 800	±3000	±1600	±100	±220	±4	
Textiles	2	1	25			0.1	35							f
Textiles	2	16	934			< 0.1	30							а
Textiles	<5	1	17			< 0.1	35							h
Textiles (range)		0.06-	7.5-10				4-12	10-20						b
		0.3												
Textiles		32.6	3160				773	4000						с
Textiles		1					35	520						g
Paper/textiles/plastic	1.2	0.4	820	880	32		740	6000						i

Table B4. Chemical composition of non-biodegradable MSW (potentially combustible). Concentration mg/kg (dry weight basis).

Sources: a) Otte (1995); b) White et al. (1999); c) Chandler et al. (1997); d) Morf et al. (2007); e) Vehlow and Mark (1997); f) Burnley (2007); g) Rotter et al. (2004); h) Herring et al. (1999); i) Jung et al. (2006)

						· · · · · · · · · · · · · · · · · · ·	.		
Category	As	Cd	Cr	Sb	Se	Hg	Pb	Zn	Source
Batteries	12	53	18			127	10800		a
glass/cans/plastic			80	0.8	1.2		0.4	3.6	b
Glass	6	1	454			0.1	168		с
Glass	287	<1	253			<0.1	381		d
Glass			1				329		a
Glass (range)			22.5-30				8-28	10-20	e
Glass		1.83	275				628	75	f
Glass		1					2	50	g
Miscellaneous	11	3	118			< 0.1	999		с
Miscellaneous	5.6	17.4	860	78	6.8		720	2600	b
Stone/ceramics	91	341	822			< 0.1	1967		d
Stone/ceramics	10	1	80				50		a
Total metals	20	21	156				582		a
Ferrous metal	32	15	1571				1300		с
Ferrous metal	539	<1	1730				520		d
Non-ferrous	4	16	221				4000		С
Non-ferrous	48	19	331				11635		d

Table B5. Chemical com	position of non-biodegrad	lable (and non-combustib	le) MSW. Concentration in	n mg/kg dry weight basis.

Sources: a) Herring et al. (1999); b) Jung et al. (2006); c) Burnley (2007); d) Otte (1995); e) White et al. (1999); f Chandler et al. (1997); g) Rotter et al. (2004)

Category		As	Cd	Cr	Sb	Se	Hg	Pb	Zn	Cu	Ni	Sn
Organics	mean	34	1.3	148	8		0.22	142	6	53	15	
	min	5	0.4	7			0.10	37				
	max	67	5.0	607			0.50	407				
Paper	mean	3	3.1	27			0.10	68	332			
	min	2	0.4	10			0.10	23	180			
	max	5	11.0	67			0.20	150	424			
Plastics	mean	2	73.0	306	2042	0.4	0.16	678	1108	9050	665	1160
	min	1	0.9	21	26		0.10	11	50	100	30	20
	max	4	160.0	900	3500		0.00	1900	4380	18000	1300	2300
Glass	mean	147	1.2	222			0.10	305	45			
	min	6	1.0	1			0.10	18	15			
	max	287	1.8	454			0.10	628	75			
Metals	mean	129	14.4	802				3607				
	min	4	1.0	156				520				
	max	539	21.0	1730				11635				
Concrete/stone/ceramics	mean	29	90.6	470	78	6.8	0.10	934	2600			
	min	6	1.0	80			0.10	50				
	max	91	341.0	860			0.10	1967				
Timber	mean	6	6.5	118			0.55	149				
	min	5	1.0	5			0.10	21				
	max	6	12.0	231			1.00	277				
Other	mean	6	6.2	576	434	11.3	0.13	282	1970			
	min	1	0.2	8	1	1	1.00	0.4	4			
	max	16	33.0	3160	880	32	0.20	773	6000			

Table B6. Chemical composition of various types of waste.

Category	Propn.	As	Cd	Cr	Sb	Se	Hg	Pb	Zn	Cu	Ni	Sn
Organics	0.178	6.05	0.23	26.3	1.42	0	0.0392	25.28	54.47	9.43	2.67	0
Paper, cardboard	0.13	0.39	0.41	3.5	0	0	0.0130	8.84	43.16	0	0	0
Plastics	0.03	0.07	2.19	9.2	61.26	0.012	0.0048	20.34	33.24	272	19.95	34.8
Glass	0.026	3.82	0.03	5.8	0	0	0.0026	7.93	1.17	0	0	0
Metals	0.108	13.93	1.56	86.6	0	0	0	390	0	0	0	0
Concrete, ceramics, stone	0.362	10.64	32.80	170.1	28.24	2.4616	0.0362	338	941	0	0	0
Timber	0.046	0.25	0.30	5.4	0	0	0.0253	6.85	0	0	0	0
Other (Miscellaneous)	0.12	0.76	0.75	69.1	52.08	1.356	0.0156	33.84	236	0	0	0
weighted average conc. (kg/t)		0.036	0.038	0.376	0.143	0.004	0.00014	0.831	1.31	0.281	0.0226	0.0348

Table B7. Weighted average concentrations of inorganic elements in representative MSW deposited in Australian landfills

Material	Dry/wet weight ratio
Cardboard	0.95
Magazines	0.95
Newspaper	0.95
Office paper	0.95
Food waste	0.30
Garden waste: grass	0.30
Garden waste: leaves	0.70
Garden waste: branches	0.90
Mixed biodegradable waste	0.84

Table B8. Dry/wet weight ratios for various types of biodegradable MSW (USEPA, 2006).

Appendix C: Emissions estimation model – quick Guide for NPI Reporting

Quick Guide: Using LEA

1	Facility Information							
Landfill / Facility Name	An example							
Facility ID	12345							
Address	Landfill road, landfill							
Postcode	4053							
Latitude and Longitude or AMG Coordinates (km)	7071.5N 497.75E	Please refer to online reporting system for co-ordinates for your facility						

• Please complete location details for the facility, including facility ID and Latitude & Longitude which are available from the npi reporting system.

2	Landfill Capacity							
Capacity (tonnes)		if unknown, you	must complete section 2B					
or								
2B		Calculate Lar	ndfill Capacity					
Depth (m)	20							
Area (m²)	1000							
Landfill type	compact							
Density of Waste (kg/m ³)	742		Calc. Capacity (tonnes)	14840				

• If the capacity (currently utilised) of the landfill is known, please enter in section 2. If is unknown, please complete the white cells in section 2B.

3		Years of (Operation	
Approx. opening year	1995			
Approx. closure year	2020	you must indicate		
Current year	2009			
			Year(s) since landfill closure	0
			Year(s) since refuse placed	14

• Please enter the year the landfill was opened, approximate closure year and current reporting year.

Δ	Methane Generation		
Climatic Conditions	Australia	Methane generation rate constant "k" (yr ⁻¹)	0.058
CH ₄ conc. (%)	55	Methane generation potential " L_o " (m ³ / t)	100
CO ₂ + other constituents conc. (%)	45		

• Unless there is site specific information available for your facility, the default values in these cells should not be altered.

5	Operating Conditions & VOC Concentration			
Average Annual Acceptance Rate during Active Life (t/yr)	500	Putrescible / mu	nicipal solid waste only	
Accepted Hazardous Waste?	No			
		-		
Operating Conditions	Australia			
Site Specific VOC conc (ppmv)		lf known, otherw	ise leave blank	
Temperature of Landfill (°C)	25	Refer to Average	Temp Chart	
		4	VOC conc. (ppmv)	520

- Please enter the average acceptance rate in t/yr for the facility.
- The model treats 'Waste' (inputs for design capacity and acceptance rate) as completely biodegradable. The majority of MSW is not biodegradable waste, it is important to ensure that the annual acceptance rate is for biodegradable waste only. MSW has a dry weight/wet weight ratio of about 0.84 (USEPA, 2006) and about 35% of Australian MSW is biodegradable (ABS, 2006). Therefore the correction factor is 0.84*0.35 = 0.294.



• The average temperature of the landfill gas should be higher than the ambient temperature indicated in the manual for your facility's location.

6	Leachate Generation			
Is the landfill lined?	х	Indicate with X if	yes, otherwise leave blank	
Site-specific collection efficiency? (%) Site-specific leachate		Leave blank unle	ess site-specific data is know	'n
		1		
6B		Calculate Leac	hate Generation	
Annual rainfall (mm)	1000	Refer to Average	Rainfall	
Efficiency of leachate collection (%)	70			
			Leachate generation (L/t)	8.76

Please enter X in Section 6 if your facility is lined, and the annual rainfall data for your facility's location



7	Complete	only if the landfi	II has a gas collection system
Gas Collection Gas collection and control system? Site-specific reduction efficiency? (%)	n System X	Indicate if yes only, otherwise leave blank Leave blank unless site-specific data is known	
Gas Collection System	Flare		
Efficiency of reduction system (%)	60		
Flow rate before control (m ³ /min)	0.10		
CH ₄ flow rate (m ³ /min)	0.05		
		J	
SUBSTANCE	Calculated Values	Site Specific	L
NMOC	99.2		% if known
Halogenated species	97.7		% if known
Non-halogenated species	99.7		% if known
Mercury	0		% if known
Sulphur conc. in gas (ppmv)			if known
Choride conc. in gas (ppmv)			if known
		-	_

- If you answered yes to having a gas collection and control system, you will need to import the CSV file "gas_collection" otherwise you will need to import worksheet "no_gas_collection" These worksheets will be generated once you export the report using the "Export to CSV" button in section 8.
- If there is a gas collection system, please indicate if the gas is flared, used for steam generation, in a gas turbine or in an internal combustion engine.
- If there is an ERROR displayed in the cells relating to the calculate values of NMOC, Halogenated species, and Non-halogenated species and you have answered yes to having a gas collection and control system, you will either need to enter a site specific values or select one option out of control options (Turbine, Flare, Gas Turbine or IC Engine). If you do not have a gas collection system in place, please ignore error message.

8	Push button to export	Export to CSV

Both of the following models produce more information than is required for NPI reporting: the 'quick guides' below indicate which results should be used for NPI reporting. The guides are not substitutes for the User Manuals: it is essential that these are read and understood before operating the software. **They should be the primary reference**.

Appendix D: Modifications to the MSW landfill emission estimation technique (EET) manual (Version 2.0, February 2010)

Page	Outline of alteration
2	added Section 1.2 Structured approach to NPI reporting
4	revised Figure 2 Processes
5,8	added Figures 3
6, 7	added Table 1
12-19	added Chapter 4 Threshold calculations
25	added Chapter 6 Transfer of NPI substances
26	added Chapter 7 Additional reporting information
28, 29	augmented Chapter 8 References
30	added Appendix A Abbreviations and definitions
31 - 38	added Appendix B Leachate and waste characterisation data
39	added Appendix C Emissions modelling