Study of Stabilized Landfill
Final Report

Prepared for
Niagara Region, The City of Hamilton and The City of Toronto

Submitted by
Gartner Lee Limited

March, 2007

Gartner Lee

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In association with
Golder Associates

March, 2007

Reference: **GLL 60-984**

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March 7, 2007

Mr. Brad Whitelaw, BA, CIM, CPM, P.Mgr.
Program Manager
Waste Management Services Division
Regional Niagara
2201 St. David's Road, PO Box 1042
Thorold, ON L2V 4T7

Dear Mr. Whitelaw:

Re: GLL 60-984 – Final Report: Study of Stabilized Landfill

We are pleased to provide you with our final report of our Stabilized Landfill research study. The report was jointly prepared by Gartner Lee Limited and Golder Associates Ltd., and presents the main findings from Tasks 1 and 2 as described in our study proposal. The report incorporates comments received from Niagara Region, the City of Hamilton, the City of Toronto during our working meetings in 2006 and 2007 as well as the comments provided in your letters of January 26, 2007 and March 1, 2007.

We appreciate the opportunity to work with Regional Niagara and its partners.

Yours very truly,
GARTNER LEE LIMITED

Mark A. Sungaila, M.A.Sc., P.Eng., PMP
Consulting Engineer
Principal

MAS:tmc
Attach.

300 Town Centre Boulevard, Suite 300, Markham, Ontario, L3R 5Z6 tel 905.477.8400 fax 905.477.1456
www.gartnerlee.com

Executive Summary

Introduction

Niagara Region and the City of Hamilton have partnered to undertake the WastePlan EA Study to develop long-term disposal capacity for municipal waste remaining after diversion serving the needs of both municipalities. In December 2005, a report was prepared entitled '*Draft Report on the Evaluation of "Alternatives To" and Selection of a Preferred Disposal System*', which recommended thermal technology with recovery of recyclables as the preferred option. Mechanical/biological treatment and stabilized landfill was identified as the second preferred alternative. Following release of the report, the EA study's Joint Working Group requested additional information on stabilized landfill technology, and in particular, on the pros and cons of stabilized landfill technology relative to conventional technology landfill. Subsequently, the team of Gartner Lee Limited and Golder Associates Ltd. were retained to conduct a study on stabilized landfill.

A *stabilized landfill* accepts waste materials which have been pre-processed, or *stabilized*, mainly to reduce the readily biodegradable organic fraction of the waste prior to landfilling, so that the potential for landfill gas generation is diminished and leachate strength is reduced. Stabilization of the waste stream occurs through a group of processes known as *mechanical/biological treatment (MBT)*, which can include removal of recyclables, shredding, removal of refuse- derived fuel (RDF), aerobic or anaerobic composting, and desiccation.

The term MBT can refer to a range of technologies which may be combined together to achieve some desired target of stabilization. The specific combination of processes influences the degree of waste stabilization achieved and thus the physical and chemical properties of the stabilized waste. Therefore, it is important to understand the specific components of an MBT process when considering the environmental performance and potential nuisance impacts from a landfill that receives residue from that process. In general, the higher the degree of stabilization, the lower the amount of landfill gas and odour that are produced by the waste, and the lower the concentration of organic constituents in landfill leachate.

Stabilized landfills are more common in the European Union (EU) than in North America, as a result of a regulatory framework which requires that the organic fraction be stabilized. However, MBT processes differ in various jurisdictions. In Ontario, the approval, design, and operation of a solid waste landfill facilities is governed by Ontario Regulation 232/98, termed the 'Landfill Standards'. This regulation does not differentiate between conventional technology landfills and stabilized landfill. As such, a landfill proposal, whether based on conventional or stabilized technology, would be evaluated according to the same regulatory criteria.

Data Collection

The data collection phase included surveys of two conventional landfills (Trail Road and Moose Creek in Canada) and three stabilized landfills (Otter Lake in Canada and Cavaglia and Villafalletto in Italy). For each site, a questionnaire was filled out, which addressed all main aspects of the landfill, including site operations, surrounding land uses, engineered control systems in place, and waste, leachate, and gas characteristics. A site visit was also carried out to the Canadian stabilized landfill site, the Otter Lake Facility in Nova Scotia. In addition to the site surveys, a literature review was carried out, which focused on stabilized landfill technology in Europe and on identifying the current EU regulatory context pertaining to stabilized landfills.

The information collected by the data collection phase can be summarized as follows:

a) Stabilized waste is produced when municipal solid waste is subjected to MBT, which typically includes processing to remove recyclables and possibly refuse-derived fuel, shredding, and then either aerobic or anaerobic composting. This process results in the reduction of the readily biodegradable organic fraction of the waste.

b) The properties of stabilized waste can vary significantly from conventional municipal solid waste and the differences in properties are highly dependent on the degree of processing. Key differences include stabilized waste typically has much lower organic matter content, as well as lower levels of leachable TOC, COD, and total N.

c) The total landfill gas production potential for well-stabilized waste is much lower than for unstabilized waste.

d) Waste stabilization has a number of beneficial effects on landfill operations relative to unstabilized waste, including reduction of odour emissions, less off-site development restrictions, fewer bird nuisance issues, potential increase in the service life of leachate collection systems, and smaller total and differential settlement of the waste mass.

e) Waste stabilization can, however, have some negative effects on landfill operations relative to unstabilized waste, including greater potential for wind-blown litter from the working face (if refuse-derived fuel is not removed) and increased potential for horizontal leachate flow in the waste mound leading to leachate seeps.

f) MBT and stabilized landfill technology is practiced much more extensively in Europe than North America. A key reason for this difference is the requirements of the European Union’s Landfill Directive 1999/31/CE, which states that only pre-treated wastes are allowed to be landfilled after July 2001, and that the amount of biologically degradable MSW to be landfilled must be reduced in a phased approach. The EU directive does not specify the minimum degree of waste stabilization that must be achieved and EU countries have set their own national measures.

g) The treatment process at the Otter Lake facility in Nova Scotia consists of mechanical shredding, followed by aerobic composting for a period of 3 weeks. This is a lower degree of processing than is often carried out in Europe (especially Germany), which often includes longer composting periods (e.g., four to six months), as well as drying (bio-desiccation) of the product.

Review of WastePlan EA Facility Land Requirement Assumptions

The WastePlan EA Facility Land Assumptions for the stabilized and conventional landfill system alternatives were reviewed relative to the data collected during this study.

The WastePlan EA assumptions for elements such as landfill size, height, depth, and waste density are generally supported by the data collected. A sensitivity analysis was carried out during this study to examine how variations in assumed apparent waste density and waste depth can impact site land requirements. It was found that if apparent waste density is increased from 750 t/m^3 to 1,000 t/m^3 (e.g., to the maximum value identified in the data collection), and if the waste depth below grade is increased from 5 m to 10 m (e.g., to a landfill design depth that may be reasonable depending on location in the Niagara and Hamilton areas) the minimum site area required (e.g., waste footprint plus 100 m buffer) decreases by approximately 27%.

One of the assumptions made in the WastePlan EA was that a stabilized landfill facility could not likely be sited within an urban or industrial area. This assumption cannot be refuted or substantiated based on the limited number of stabilized landfills examined as part of this study and the absence of information regarding EU siting processes and site specific management information. However, the data collected during this study indicates that there are stabilized landfills in the EU which co-exist with various land uses.

Conclusions

The following main conclusions are drawn from this study:

a) Stabilized waste is produced when municipal solid waste is subjected to mechanical/biological treatment (MBT), which typically includes processing to remove recyclables, and possibly refuse-derived fuel, shredding, and either aerobic or anaerobic composting. The properties of stabilized waste can vary significantly from conventional municipal solid waste and the differences in properties are highly dependent on the degree of processing.

b) Characteristics of highly-stabilized waste, relative to conventional solid waste, can include:

- one-tenth the leachable TOC, COD and Total N content;
- half the total organic matter content;

- similar range of in-place apparent waste density;
- similar friction angle;
- potentially lower apparent cohesion (due to the smaller particle sizes following) shredding;
- half the settlement potential from waste decomposition; and
- potentially lower hydraulic conductivity (due to smaller/platy particles following shredding, which can align horizontally at high compactive effort and form a low permeability layer).

c) The total landfill gas production potential for well-stabilized waste (<10-45 L/kg) is approximately 10% of that for unstabilized waste (200-500 L/kg), reflecting the removal of the readily-degradable organic fraction by composting. For the same reason, the peak landfill gas generation rate for well-stabilized waste (<3 L/m^2/hr) may be less than half of that for unstabilized waste (~ 6 L/m^2/hr).

d) Comparison of the literature concentrations for stabilized waste leachate with those for unstabilized waste leachate from the Trail Road and Moose Creek sites indicate that stabilized waste leachate has lower levels of ammonia-N, BOD, COD, DOC and volatile organic compounds. Leachate concentrations for heavy metals and inorganic salts (e.g., sodium, calcium and chloride) are comparable for stabilize and unstabilized waste, indicating that these parameters are not significantly affected by the pre-processing.

e) Waste stabilization can have a number of beneficial effects on landfill operations, relative to unstabilized waste, including:

- reduction of odour emissions;
- less off-site development restrictions;
- fewer bird nuisance issues;
- potential increase in the service life of leachate collection systems;
- smaller total and differential settlement of the waste mass, which facilitates final cover construction and after-use implementation.

f) Waste stabilization can have some negative effects on landfill operations relative to unstabilized waste, including:

- greater potential for wind-blown litter from the working face (although this potential is reduced if the RDF is removed); and
- lower permeability and ‘platy’ nature, which increases potential for horizontal leachate flow in the waste mound leading to leachate seeps.

g) MBT treatment and stabilized landfill technology is practiced much more extensively in Europe than North America. A key reason for this difference is the requirements of the European Union's Landfill Directive 1999/31/CE, which states:

- only pre-treated wastes are allowed to be landfilled after July 2001; and
- the amount of biologically degradable MSW to be landfilled must be reduced in a phased approach to 75% by July 2006, to 50% by July 2009, and to 35% by July 2016 of the total amount of biologically degradable MSW produced in 1995.

h) The treatment process at the Otter Lake facility in Nova Scotia consists of mechanical shredding followed by aerobic composting for a period of 3 weeks. This is a lower degree of processing than is often carried out in Europe (especially Germany), which often includes longer composting periods (e.g., four to six months) as well as drying (bio-desiccation) of the product.

i) The WastePlan EA Facility Land Assumptions were reviewed relative to the data collected during this study. The assumptions for elements such as landfill size, height, depth, and waste density are generally supported by the data collected.

j) A sensitivity analysis was carried out during this study to examine how variations in assumed apparent waste density and waste depth can impact site land requirements. It was found that if apparent waste density is increased from 750 t/m^3 to 1,000 t/m^3 (e.g., to the maximum value identified in the data collection) and if the waste depth below grade is increased from 5 m to 10 m (e.g., to a landfill design depth that may be reasonable depending on location in the Niagara and Hamilton areas) the minimum site area required (e.g., waste footprint plus 100 m buffer) decreases by approximately 27%. It is recognized that these variables are affected by numerous factors, including degree of waste stabilization, landfill equipment used, waste to cover ratio, site specific conditions, and landfill design approach).

k) The WastePlan EA assumption regarding facility location (i.e., that a stabilized landfill facility could not likely be sited within an urban or industrial area) cannot be refuted or substantiated based on the limited number of stabilized landfill site settings examined, as part of this research study and the absence of information regarding the siting processes used in the EU and other site specific impact management information (e.g., compensation, community relations measures, etc). While the likelihood of siting success and the magnitude of impacts will be very site specific and dependent upon the nature of the siting process, the data collected regarding highly stabilized landfills in the EU and domestic experience with conventional landfill sites suggests that the siting of a highly stabilized landfill site is possible in a variety of land use settings.

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1. Introduction

1.1 Background

Niagara Region and the City of Hamilton have partnered to undertake the WastePlan EA Study to develop long-term disposal capacity for municipal waste remaining after diversion serving the needs of both municipalities. Eight distinct disposal options were considered and evaluated in the study. The options can be organized into three general categories as follows:

1. Mechanical and biological treatment (MBT) and landfilling of stabilized residuals (with an option to include biogas recovery).
2. Thermal treatment (with options including recovery of materials from the ash/char, alternative fuel, and biogas recovery).
3. Conventional landfill (including an option of landfill gas recovery and utilization).

In December of 2005 a report was prepared entitled '*Draft Report on the Evaluation of "Alternatives To" and Selection of a Preferred Disposal System*' which recommended thermal technology with recovery of energy and recyclables as the preferred option. MBT and stabilized landfill was identified as the next preferred alternative, and was the preferred landfill-based option.

Following release of the December 2005 report a number of comments were received from the public and other stakeholder groups regarding the study and its recommendations. While many of these supported the recommended option, some comments from some non-governmental organizations as well as the public opposed the preferred option. In particular, questions were raised about the evaluation of the stabilized landfill options. These comments led the WastePlan Joint Working Group to request additional information on stabilized landfill technology, and in particular a comparison of stabilized landfill technology relative to conventional technology landfill.

1.2 Definition of Stabilized Landfill

A *stabilized landfill* accepts waste materials which have been pre-processed, or *stabilized*, mainly to reduce the readily biodegradable organic fraction of the waste prior to landfilling so that the potential for landfill gas generation is diminished and leachate strength is reduced. Stabilization of the waste stream occurs through a group of processes typically known as *mechanical and biological treatment (MBT)*, which can include removal of recyclables, shredding, removal of refuse derived fuel (RDF), aerobic or anaerobic composting, and desiccation. Waste delivered to an MBT facility has typically already undergone some form of source separation.

The term MBT can refer to a range of technologies which may be combined together to achieve some desired target of stabilization. The specific combination of processes influences the degree of waste stabilization achieved and thus the physical and chemical properties of the stabilized waste. Therefore, it is important to understand the specific components of an MBT process when considering the environmental performance and potential nuisance impacts from a landfill that receives residue from that process. Important variables include:

- the degree to which the waste is mechanically broken down prior to being biologically treated;
- whether or not refuse derived fuel (e.g. such as plastic film) is removed prior to biological processing;
- the nature of the biological treatment (e.g. aerobic, anaerobic, and the length of time that the waste is treated); and
- how the material is cured following biological treatment, and whether or not it is further dried prior to landfilling.

In general, the higher the degree of stabilization, the lower the amount of landfill gas and odour that are produced by the waste, and the lower the concentration of organic constituents in landfill leachate. The removal of refuse derived fuel from the waste also contributes to reduction of litter impacts. The relationship of these variables to the design and operations of a stabilized landfill is discussed in greater detail in Section 2 of this report.

Stabilized landfills are more common in the European Union (EU) than in North America as a result of a regulatory framework which requires that the organic fraction be stabilized. However, MBT processes differ in various jurisdictions. In some cases (i.e., Italy) the stabilized material is placed in newer dedicated landfills while in other cases (i.e., typical of Austria and Germany) the stabilized waste is placed in traditional conventional landfills. The EU does not stipulate a minimum degree of stabilization to be achieved and many countries have adopted country specific targets and test methods which have dictated the manner and degree to which the organic fraction is stabilized in each country. Some of these different approaches are described in greater detail in this report.

The approval, design, and operation of a solid waste landfill facilities in Ontario is governed by Ontario Regulation 232/98, termed the 'Landfill Standards'. This regulation does not differentiate between conventional technology landfills and stabilized landfill. As such, a landfill proposal, whether based on conventional or stabilized technology, would be evaluated according to the same regulatory criteria which address, among others, issues such as environmental and nuisance impacts.

1.3 Scope of Work

Niagara Region has retained the team of Gartner Lee Limited and Golder Associates Ltd. to conduct this research study on stabilized landfill. Niagara Region, the City of Hamilton and the City of Toronto are equal partners with Niagara in this research study.

The overall objectives of this research study are two-fold:

Task 1:....... Obtain technical information on the nature and, where known, impacts of stabilized landfill in relation to a state-of-the-art conventional landfill.

Task 2:....... Review the December 8, 2005 WastePlan EA Report and provide comment regarding the facility land requirement assumptions for the stabilized and conventional landfill system alternatives.

Section 2 of this report presents the results of Task 1, the data collection. This includes the following:

a) Site-specific data from five sites including general site information, geological/hydrogeological setting, waste characteristics, containment systems, leachate quality and management, and gas characteristics and management. The sites consisted of:

- Two MSW sites in Ontario: Trail Road Landfill, and Moose Creek Landfill;
- Three stabilized landfills: Otter Lake in Nova Scotia, and Cavaglia and Villafalleto in Northern Italy.

b) A review of information available in the literature on other stabilized landfills located in the European Union (EU) and general experience with such landfills in the EU. The search focused on the EU because of the relatively large number of MBT/Stabilized Landfill sites present there relative to North America or elsewhere.

c) A review of information available on the overall policy context within which stabilized landfills were developed within the EU.

Section 3 of this report presents a review of the assumptions made in the WastePlan EA specifically regarding facility land requirements. The WastePlan EA assumptions are tabulated and reviewed relative to information gathered. Commentary on whether or not the collected data supports the assumptions EA is provided, where data was available.

Section 4 presents a brief summary of the main conclusions derived from this study.

2. Task 1 – Data Collection

Technical information on landfill design and performance was obtained by surveying three active stabilized and two active conventional landfill facilities. In addition, a literature review was carried out to supplement the survey data and to check that the survey data generally falls within the range of reported values for these types of facilities and waste types. The methodology and results of the survey and literature review are presented in the following sections.

2.1 Survey of Existing Stabilized and Conventional Landfill Facilities

Surveys were carried out for two active stabilized waste landfills in northern Italy (Cavaglia and Villafalletto facilities) and for one active stabilized waste landfill in eastern Canada (Otter Lake facility, Halifax). For conventional landfills, surveys were carried out for two active state-of-the-practice Ontario sites (Trail Road and Moose Creek facilities) with which Golder has extensive experience.

A single common questionnaire was prepared to obtain the same types of data for each site, including:

a) general site information (e.g., location, landfilling period, waste placement rate, fill capacity, fill area, site area, maximum height of waste fill, site setting (i.e., surrounding land uses) and applicable regulations);

b) geological / hydrogeological setting;

c) characteristics of landfilled wastes (e.g., pre-treatment processes, organic matter content, particle sizes, chemical composition and in-place apparent density);

d) waste containment system design;

e) leachate quality/management (e.g., representative peak leachate concentrations, leachate collection rates and leachate management/treatment methods); and

f) landfill gas characteristics/management (e.g., gas composition, maximum generation rate, collection/venting system design and odour impacts.

For the conventional landfills, the questionnaire was completed by Golder staff using data primarily from the design and operations report for each landfill and from annual monitoring reports. Where required, additional information was obtained directly from site operations staff. For the two Italian stabilized waste landfills, the questionnaire was completed by site operations staff with assistance by Golder. The Otter Lake Facility was visited by Golder to obtain "first hand" the information required to complete the questionnaire. Mr. Steve Copp, P.Eng. of Mirror Nova Scotia (landfill operator) provided a guided a tour of the facility and was very helpful in providing information to facilitate Golder in completing the questionnaire.

The completed questionnaires for the stabilized and conventional landfills are provided in Appendix A and B, respectively. Table 2-1 provides a summary comparison of the data obtained for the different sites. Key findings from the comparison are outlined below:

a) All sites receive waste from residential and ICI sources. The Otter Lake site also receives C&D waste (~17% of the waste landfilled at site).

b) The stabilized waste landfill sites that have on-site waste pre-treatment facilities (i.e., Otter Lake and Villafalletto sites) have a total site area 3 to 4 times larger than the approved waste fill area. For the Cavaglia site, the waste pre-treatment facility is located off-site.

c) The conventional landfill sites have a total site area 2 to 3 times larger than the approved waste fill area.

d) The two Italian stabilized landfills have relatively small waste fill areas (~3 Ha) compared to the Otter Lake site (55 Ha) and the conventional landfills (~70-90 Ha). However, the waste thickness for the Italian sites (10 m - 30 m) is within the range of waste thickness for the other sites and is typical of landfills servicing small to medium size communities in Ontario. Furthermore, the Italian sites are relatively new (< 4 years old) and reflect current landfilling practice consistent with the requirements of the European Landfill Directive 99/31/EC. Therefore, although these sites have relatively small fill areas, they do provide useful data with respect to stabilized landfill design, operation and performance. In addition, the two Italian sites are dedicated to receiving only stabilized waste materials, whereas other sites in the EU dispose the stabilized material at older sites that also contain unstabilized waste.

e) All sites have waste mound heights in the range of 10 m to 30 m above perimeter ground surface elevation.

f) All sites are located in a setting that can be largely characterized as rural. Surrounding land uses vary from site to site and include: agricultural lands, quarries, other landfill sites and some industrial facilities(Cavaglia); agricultural lands and forest areas (Villafalletto); and forested areas (Otter Lake). The Cavaglia site is similar to the conventional waste landfill site at Trail Road, both having adjacent quarries and landfill sites.

Table 2-1. Comparison of Survey Data for Stabilized and Conventional Landfills

Data	Stabilized Waste Landfills			Conventional Landfill Facilities	
	Otter Lake (Halifax)	**Cavaglia (Northern Italy)**	**Villafalletto (Northern Italy)**	**Trail Road (Ottawa)**	**Moose Creek (Eastern Ontario)**
A. GENERAL SITE INFORMATION					
Start of Landfilling	1999	2003	2005	1980	2000
Waste Placement Rate (tonnes/year)	120,000	70,000	20,000	203,000	200,000
Approved Total Waste Fill Capacity (Mm^3)	4.3	0.55	0.26	13	7.4
Approved Waste Fill Area (Ha)	55	2.8	3.6	88	66
Total Site Area Including Buffer Zone and Site Facilities (Ha)	160 (waste processed on-site)	3.5 (waste processed off-site)	14 (waste processed on-site)	150	200
Ratio: Total Site Area/Approved Fill Area	2.9	1.3	3.9	1.7	3.0
Approved Maximum Height of Waste Fill Relative to Perimeter Ground Surface (m)	30	11	8.3	28	10
Surrounding Land Use	Forested area	Rural agricultural, quarries, other landfills	Rural agricultural, wooded area	Rural agricultural/sand and gravel pits	Agricultural
Distance to Nearest Populated Area (km)	2.5	1.5	2.0	2.6	2.5
Distance to Nearest Residence (km)	2.5	0.05	0.2-0.5	1.5	1.5
B. GEOLOGICAL/HYDROGEOLOGICAL SETTING					
Type/Thickness of Overburden Beneath Landfill	Silty Clayey Sand to Sandy Clay Till ≤1m	Sand and Gravel (bedrock at great depth)	Sand and Gravel (bedrock and great depth)	Sand 0-6m Silty Clay 0-22 m Sand & Gravel 2-28m Silt Till 0-6m	Silty Clay 7-18m Sand Till 0-3m
Depth to Groundwater Surface Below Base of Landfill Cells (m)	1	10	8	1.5	<0 (hydraulic trap)
Does Existing Natural (unimpacted) Groundwater in Underlying Aquifer Unit Meet Drinking Water Quality Standards?	Yes	No	No	Yes	Yes
Current Uses of Groundwater Within 5km of Landfill	Drinking water	Agricultural watering, drinking water	Agricultural watering	Agricultural watering, drinking water	Agricultural watering, drinking water
C. WASTE CHARACTERISTICS					
Waste Pre-Treatment Processes	<u>Off-Site</u> • Source separation of recyclables, organics (including food waste, yard waste, box board, non-recyclable paper and wood shavings) and household hazardous waste* [Residential and ICI sources]* • Data on the composition of the waste received is attached to the Otter Lake questionnaire in Appendix A. <u>On-Site</u> • Mild shredding to open bags • Screening to remove >150 mm size fraction • Sorting of >150 mm and <150 mm fractions to remove recyclables	<u>Off-Site</u> • Source Separation of recyclables and yard wastes [Residential and ICI sources] <u>Off-Site MBT Facility</u> • Mild shredding to open bags • Screening to remove >100mm size fraction for RDF • Magnetic separation of metals • Aerobic compositing in windrows (indoor) with forced air flow for approx. 2 weeks (no turning of windrows)	<u>Off-Site</u> • Source separation of recyclables and yard waste • [Residential and ICI sources] <u>On-Site</u> • Mild shredding to open bags • Screening to remove >100 mm size fraction for RDF • Magnetic separation of metals • Aerobic composting in windrows (indoor) with forced air flow for approx. 2 weeks (no turning of windrows)	<u>Off-Site</u> • Source separation of recyclables and leaf/yard wastes	<u>Off-Site</u> • Some source separation of recyclables and leaf/yard wastes

Data	Stabilized Waste Landfills			Conventional Landfill Facilities	
	Otter Lake (Halifax)	Cavaglia (Northern Italy)	Villafalletto (Northern Italy)	Trail Road (Ottawa)	Moose Creek (Eastern Ontario)
	• Shredding of non-recyclable fraction to<50mm size • Aerobic composting for approx. 3 weeks(indoors) • Drying to <40% moisture content	• Drying by bio-desiccation (forced air flow through 4 m-6 m thick windrows for approx. 2 to 3 weeks) • Further sorting to remove low-degradable RDF component • Bailing of stabilized waste for transport to landfill	• Drying by bio-desiccation (forced air flow through 4 m-6 m thick windrows for approx. 2 to 3 weeks) • Further sorting to remove low-degradable RDF component		
Total Waste Processing Time	• Approx. 3 weeks	• Approx. 5 weeks	• Approx. 5 weeks	• N/a	• N/a
Primary Components of Landfilled Waste	• 83% stabilized waste from on-site waste treatment facility comprised of shredded paper, plastic, wood, decayed organic matter and inerts • 17% non-processed industrial and C&D waste	• 100% stabilized waste (components not analyzed) • Static respiration index =428 mgO2/kg VS/hr	• 100% stabilized waste (components not analyzed) • Static respiration index <400 mgO2/kg VS/hr	• MSW and IC&I wastes	• MSW and IC&I Wastes
Moisture Content of Landfilled Waste (% dry wt. basis)	<40%	Not analyzed	Not analyzed	Not analyzed	Not analyzed
In-place Apparent Density of Waste (Tonnes per m^3 air space)	0.77	0.6	0.6	0.75	1.0
D. WASTE CONTAINMENT SYSTEM					
Base Liner Components (from top down)	1.5mm HDPE 0.85 m compacted till 0.15 m compacted bentonite amended till 1.5 mm HDPE (secondary liner)	2 mm HDPE 0.5 m compacted clay	2mm HDPE 2mm HDPE (secondary liner) 1.0 m compacted clay (secondary liner)	2mm HDPE 0.6m compacted clay [old Stages 1 and 2 are unlined]	Natural clay deposit serves as base liner
Leachate Collection System Components (from top down)	0.3 m - 75mm clear stone drainage layer 0.3 m -25 mm clear stone drainage layer 0.3m - sand cushion Geonet (secondary leachate collection system)	0.5 m granular drainage layer	0.3m granular drainage layer 0.5 m granular drainage layer (secondary LCS)	0.6 m clear stone drainage layer	0.15 m sand filter geotextile filter 0.5m clear stone drainage layer geotextile separator
Final Cover Components (from top down)	0.6 m local till Geocomposite drainage layer 1.0mm HDPE	1.0 m cover soil 0.5 m drainage layer 0.5 m compacted clay 0.5 m inert material	1.0 cover soil 0.5 m sand drainage layer 0.5 m compacted clay 0.5 m granular LFG venting layer	0.75m cover material incorporating a low permeability barrier (Stages 1 to 4) 0.75m permeable soil cover (future Stage 5)	0.15 m topsoil 0.85 nominally compacted local clayey soil
Percentage of Fill Area Currently Capped with Final Cover (%)	20	0	0	0	5
Types of Daily Cover	Mostly wood chip, some shredded C&D waste	Soil	Gravel, grinded inert waste	Soil, automobile shredder waste	Soil, tarps, auto shredder fluff
Waste: Daily Cover Ratio (by volume)	5:1	10:1	20:1	4:1	4:1
E. LEACHATE QUALITY/MANAGEMENT					
Representative Peak concentration of key leachate parameters (mg/L, except for pH)					
pH (range)	6.2-8.4	6.7-7.8	7.3-7.6	5.9-8.4	6.8-9.3
DOC	1,300	N/A	N/A	5,000	1,000
BOD	1,000	250	700	12,000	2,000
COD	2,500	9,040	1,670	10,000	2,800

Data	Stabilized Waste Landfills			Conventional Landfill Facilities	
	Otter Lake (Halifax)	Cavaglia (Northern Italy)	Villafalletto (Northern Italy)	Trail Road (Ottawa)	Moose Creek (Eastern Ontario)
Ammonia-N	400	580	290	800	300
Phenols	N/A	1.82	0.54	5	1.0
Chloride	1,500	1,600	278	2,000	1,500
Calcium	300	N/A	N/A	1,500	250
Cadmium	<0.003	0.008	0.005	0.01	<0.001
Lead	0.05	0.122	0.185	0.05	<0.01
Zinc	2.0	2.31	1.44	2	<0.1
Benzene	0.003	N/A	N/A	0.035	0.001
1, 4-Dichlorobenzene	0.0015	N/A	N/A	0.020	0.0008
Dichloromethane	0.05	N/A	0.25	0.100	0.180
Toluene	0.04	0.01	0.02	1.0	0.030
Vinyl Chloride	<0.002	N/A	N/A	0.1	0.060
Aromatic Solvents (sum)	N/A	<0.1	0.86	N/A	N/A
Chlorinated Solvents (sum)	N/A	<0.1	<0.5	N/A	N/A
Chlorinated Pesticides (sum)	N/A	<0.1	<0.1	N/A	N/A
Typical Current Leachate Collection Rate (mm/year/Ha)	500	100	93	275	347
Total Annual Precipitation	1,240	800	800	945	945
Typical Current Leachate Collection Rate as a Percentage of Total Annual Precipitation (%)	40	12	12	30	37
Is Leachate Recirculated?	No	No	No	Yes, From 1991 to 1996	No
Means of Leachate Treatment	Trucked to off-site waste water treatment facility	Trucked to off-site waste water treatment facility	Trucked to off-site waste water treatment facility	Trucked to off-site waste water treatment facility	On-site treatment using peat filter and engineered wetlands
F. LANDFILL GAS CHARACTERISTICS/MANAGEMENT					
Means of Landfill Gas Management	Active collection with flaring	Passive venting	Passive venting	Active collection with flaring, 5 MW generating station	Passive venting
Landfill Gas Composition	1% O_2 47% CH_4 35%CO_2 0.1 - 0.3% CHS, H_2S	Not monitored	Not monitored	27% CH_4 16%CO_2 <0.1ppm H_2S	Not monitored
Complaints of Off-site Odour Impacts?	Avg. 2 complaints per month	No	No	Infrequent	Yes-due to start up of new raw leachate holding pond
Use of Odour Suppressants	Tried various suppressants - none worked	No	No	No	Yes-Air misting system around raw leachate holding pond
Peak Landfill Gas Generation Rate (L/m^2/hr	~20	Not measured	Not measured	~6	Nor measured

g) Within the rural settings for these sites, the distances to the nearest individual residence, hamlet/community also varies from site to site. The nearest individual residence is located within 50 m of the stabilized landfill site at Cavaglia, 500 m at Villafalletto and approximately 2.5 km from the Otter Lake facility. The distance to the nearest populated area (e.g., hamlet or community) ranges from 1.5 km (Cavaglia) to 2.5 km (Otter Lake). At the Cavaglia site, the nearest industrial facility is within 200 m of the site.

h) All sites are founded within overburden. The overburden types range from sand and gravel (e.g., Cavaglia and Villafalletto sites) to silty clay (e.g., Moose Creek site).

i) All sites, except for Moose Creek, are founded at least 1 m above the groundwater table. The Moose Creek facility, which is founded on silty clay overburden, has base grades that extend below the groundwater table (i.e., hydraulic trap design).

j) All sites, except for Villafalletto, are located in an area where groundwater is potable and is used for drinking water supply.

k) The waste pre-treatment process for the stabilized landfills includes sorting to remove recyclables and refuse derived fuel (RDF), shredding, aerobic composting and drying to reduce the moisture content. The C&D waste received at the Otter Lake site is not pre-treated and is landfilled as-received.

l) Aerobic composting for the three stabilized landfills is done indoors. The duration of composting is 3 weeks for Otter Lake and 2 to 3 weeks for the Italian sites, although the Italian sites use forced air injection to expedite aerobic decomposition. Off-gases from the composting process are treated using bio-filters.

m) The stabilized waste at the Italian sites has static respiration index values of approximately 400 mg O_2/kg Volatile Solids/hr or less, which meets the target value of <500 mg O_2 /kg VS/hr set out in the Italian Regulation. This level of stabilization, however, is less intensive than that achieved in other European countries such as Germany and Austria which target an AT_4 respiration index of $\leq$ 5 mg O_2/g dry mass after 96 hours and $\leq$ 7 mg O_2/g dry mass after 96 hours, respectively. Therefore, the stabilized waste for the two Italian sites is not considered representative of stabilized waste in general in other European counties.

n) Except for monitoring of respiration index (Italian sites) and moisture content (Otter Lake site), the stabilized waste leaving the MBT plant for landfilling is not characterized with respect to physical and chemical characteristics.

o) The in-place apparent density of the stabilized waste at the Italian sites is relatively low (i.e., 0.6 t/m^3), possibly reflecting a relatively low moisture content following "bio-desiccation". Bio-desiccation of the waste for these sites is carried out after the aerobic composting phase and involves forced air flow upward through 4 m to 6 m high windrows over a period of 15 to 18 days. Data on the final moisture content after bio-desiccation is not available.

a) The in-place apparent density of the stabilized waste at the Otter Lake site (0.77 t/m^3) is comparable to that for the Trail Road site (0.75 t/m^3).

b) The in-place apparent density for the Moose Creek site (1.0 t/m^3) is relatively high, reflecting a higher proportion of contaminated soil and IC&I waste.

c) All sites, except for Moose Creek, have base liners consisting of High Density Polyethylene (HDPE) geomembrane and compacted clay barrier layers. The Moose Creek site is founded on a thick low permeability natural clay deposit which serves as the base liner.

d) All sites have granular drainage layers beneath the waste fill for leachate collection. Two of the stabilized landfills (Otter Lake and Villafalletto) include a secondary leachate collection layer beneath the primary base liner.

e) All of the stabilized landfills are designed to have a low permeability final cover system, incorporating either a geomembrane or compacted clay infiltration barrier layer and an overlying drainage layer. The primary purpose of the low permeability final cover is to minimize moisture infiltration and hence leachate generation.

f) The two conventional landfills utilize relatively permeable soil final covers to allow some infiltration which in turn promotes waste decomposition and flushing of the contaminant mass from the waste fill. This is a typical design approach used for new or expanding sites in Ontario, and is consistent with the design philosophy in Ontario Regulation 232/98.

g) The stabilized landfills use much less daily cover (waste: daily cover ratios ranging from 5:1 to 20:1) compared to the conventional landfills (4:1). The smaller quantity of daily cover used for the stabilized landfills is due to the low initial odour generation and the low gull (bird) populations, both of which relate to the removal of the readily degradable organic matter (e.g., food wastes) by composting.

h) All sites utilize various daily cover materials, including soil, shredded wood, shredded C & D waste, tarps and auto shredder fluff.

i) Leachate from the stabilized landfills has lower concentrations of biological oxygen demand (BOD) than leachate from the conventional landfills, reflecting the lower content of readily degradable organic matter following composting.

j) Leachate pH, chloride, calcium, phenols, ammonia-N and heavy metal concentrations are fairly similar between the stabilized and conventional landfills surveyed.

k) Due to limited available data for the stabilized landfills surveyed, it is not possible to draw any conclusions regarding dissolved organic carbon (DOC) and volatile organic compound (VOC) concentrations in stabilized landfill leachate relative to conventional landfill leachate.

l) The leachate generation rate for the Italian stabilized landfills is relatively low (i.e., 12% of total annual precipitation), possibly reflecting a low initial water content of the waste following "bio-desiccation" and hence a higher moisture uptake capacity of the waste. The Otter Lake site has a leachate generation rate comparable to that of the conventional landfills (i.e., 30% - 40% of the total annual precipitation).

m) All sites with the exception of Moose Creek, have their leachate trucked to an off-site wastewater treatment facility. For the Moose Creek site, leachate is currently treated on-site using a peat filter and engineered wetlands.

2.2 Literature Review

The purpose of the literature review was to obtain additional data to supplement the survey data, and to confirm that the survey data generally falls within the range of reported values for stabilized and conventional landfill facilities. The review focused on waste characteristics (physical and chemical), gas production rates, leachate quality and landfill operations experience. With respect to stabilized landfills, relevant information was obtained from the following technical articles that capture the current experience primarily in Germany and Austria where such facilities are common:

- Robinson *et al.* 2004. *Improved Definition of Leachate Source Term from Landfills. Phase 1: Review of Data from European Landfills*. Report prepared for Environmental Agency, England.
- Leikam and Stegmann. 1999. *Influence of Mechanical-Biological Pre-Treatment of Municipal Solid Waste on Landfill Behaviour*. Waste Management & Research. Vol. 17. pp 424-429.
- Munnich *et al.* 2005. *Landfilling of Pre-treated Waste – Consequences for the Construction and Operation of Landfills*. Conference on the Future of Residual Waste Management in Europe 2005.
- Greenpeace Environmental Trust. 2003. *Cool Waste Management. A State-of the – Art Alternative to Incineration for Residual Waste Management*. Published by Greenpeace Environmental Trust.

- Juniper Consultancy Services Ltd. Mechanical-Biological Treatment: A Guide for Decision Makers: Processes, Policies, and Markets.
- Adani *et al*. 2002. Static and Dynamic Respirometric Indexes – Italian research and Studies.
- Salhofer and Binner 2006. Waste Recycling and Composting LVA 813.359: Mechanical and Biological Treatment {Austrian Research}.

Data collected from the literature review are presented in Tables 2-2 to 2-5. Where appropriate, the data for stabilized landfills is qualified with respect to the duration of composting (refer to footnotes in each table). The following is a summary of the key findings.

Waste Characteristics

Table 2-2 provides data on waste characteristics for stabilized and unstabilized MSW. Unstabilized waste (i.e., residual municipal solid waste after "effective source separation" including diversion of bio-waste) typically has the following average composition (dry weight basis), as reported by Greenpeace (2003):

- Paper .... ~ 22%
- Plastics .... ~ 16%
- Textiles .... ~ 4%
- Glass .... ~ 3%
- Wood.................................... ~ 8%
- Metals .... ~ 13%
- Food and Yard Wastes.......... ~ 30%
- Other .... ~ 4%

Data on the composition of stabilized waste after mechanical separation of RDF (by sieving) and aerobic composting of the residual fraction is not reported in the literature reviewed. Based on the three stabilized landfills surveyed, it appears that stabilized waste from MBT facilities is characterized only for moisture content, percent organic matter and biological respiration rate.

Stabilized waste which has undergone two to six months of composting (e.g., as is practiced in Germany) exhibits the following characteristics in comparison to unstabilized waste:

a) one tenth the leachable TOC, COD and N content;

b) half the total organic matter content;

c) similar range of in-place apparent waste density;

d) similar friction angle;

Table 2–2. Comparison of Waste Characteristics for Stabilized versus Unstabilized Wastes

Waste Characteristic	Stabilized (MBT) Waste	Unstabilized Residual MSW (after source separation)
Readily Leachable TOC (mg/kg)	~500[1] (Leikam and Stegmann, 1999)	~8,000 (Leikam and Stegmann, 1999)
Readily Leachable COD (mg/kg)	~2,000[1] (Leikam and Stegmann, 1999)	~28,000 (Leikam and Stegmann, 1999)
Readily Leachable N (mg/kg)	~300[1] (Leikam and Stegmann, 1999)	>2,000 (Leikam and Stegmann, 1999)
Maximum Particle Size (mm)	40 to 60 (Munnich *et. al*. 2005) 50 (Otter Lake Facility)	> 500
Organic Matter Content (LOI) (% dry mass basis)	<31[2] (Munnich *et. al*. 2005) 20-40[1] (Leikam and Stegmann) 38[3] (Robinson *et. al*. 2004) 33[4] (Robinson *et. al*. 2004)	~75% [estimated from compositional data reported by Greenpeace, 2003] 60[5]% [Robinson *et. al*. 2004]
Water Content (% dry mass)	28-40[2] (Munnich *et. al*. 2005) <40 (Otter Lake Facility)	66[5] (Robinson *et. al*., 2004)
In-place Apparent Density of Waste (tonnes/m^3)[6]	0.7-1.0 (Munnich *et. al*., 2005) 0.77 (Otter Lake Facility) 0.6 (Villafalletto Facility) 0.6 (Cavaglia Facility)	0.8 (Munnich *et. al*., 2005) 0.75 (Trail Road Facility) 1.0 (Moose Creek Facility)
Friction Angle (degrees)	23-40[2] (Munnich *et. al*. 2005)	20-40 (typical values based on data from Singh and Murphy, 1990)
Cohesion (kN/m^2)	5-50[2] (Munnich *et. al*. 2005)	5-100
Decomposition Settlement (% of initial height)	5[2] (Munnich *et. al*. 2005)	~ 10 (estimated using Sowers Method with $C\alpha = 0.07$ and e_o=0.4)
Hydraulic Conductivity (cm/s)	$<10^{-7}$ to 10^{-2} (Munnich *et. al*. 2005)[2]	10^{-6} to 10^{-2} (typical values based on Golder experience)

Notes:

1. *MBT Waste after 4 months of composting (reflects high intensity composting)*
2. *Typical value(s) for MBT residual MSW meeting German Waste Storage Ordinance AbfABIV, ANONYM, 2001 [AT4 Respiration Index < 5,000 mgO2/kg dry solids /96hr] (reflects high intensity composting)*
3. *MBT Waste after 6 months of composting (reflects high intensity composting)*
4. *MBT waste after 16 weeks composting (reflects high intensity composting)*
5. *Residual MSW after source separation and mechanical separation to remove RDF*
6. *Mass of in-place compacted waste ÷ total air space occupied (including daily cover)*

Table 2–3. Comparison of Gas Production for Stabilized versus Unstabilized Waste

Waste Characteristic	Stabilized (MBT) Waste	Unstabilized Residual MSW (after source separation)
Total Landfill Gas Production Potential [L/kg dry mass]	<10-45 [1] [Munnich *et al*., 2005]	200 [Leikam and Stegmann, 1999] 520 [McBean *et al*, 1995]
Peak Methane Gas Generation Rate [L/m^2/h]	<3 [1] [Munnich *et al*., 2005] ~20 [Otter Lake Facility]	~6 [Trail Road Landfill, Ottawa]

Notes: 1. Range of values for MBT Waste meeting German Waste Storage Ordinance AbfABIV, ANONYM, 2001 [AT4 Respiration Index <5,000 mgO2/kg dry solids/96 hr] (reflects high intensity composting)

Table 2-4. Comparison of Leachate Quality for Stabilized versus Unstabilized Waste [1]

Parameter	Stabilized (MBT)-Waste - This Study (representative peak values)[2]			Stabilized (MBT) Waste - Literature Values (Robinson et. al. 2004)[2,3]				Unstabilized Waste - This study (Representative Peak Values)	
	Otter Lake Halifax	Villafalleto (North Italy)	Cavaglia (North Italy)	Low -Medium Intensity Composting		High Intensity Composting[4]			
				Max.	*Min.*	*Max.*	*Min.*	*Trail Road*	*Moose Creek*[5]
pH	6.2-8.4	7.3-7.6	6.7-7.8	8.5	7.5	8.0	-	7.1	7.4
Conductivity (µS/cm)	12,000	3,490	25,000	20,000	5,000	10,000	2,000	15,000	30,000
Total Dissolved Solids	7,000	—	—	—	—	—	—	—	25,000
Alkalinity	4,000	—	—	6,000	1,500	2,000	400	7,000	6,268
Ammonia-N	400	290	580	1,000	50	200	40	800	300
Total Kjeldahl -N	—	—	—	1,300	100	260	50	1,000	350
Biological Oxygen Demand	1,000	700	250	200	20	30	6	12,000	2,000
Chemical Oxygen Demand	2,500	1,670	9,040	5,000	1,000	1,500	300	10,000	2,800
Dissolved Organic Carbon	1,300	—	—	2,000	400	500	100	5,000	1,000
Phenols	—	0.54	1.82	absent	absent	absent	absent	5	1.0
Arsenic	0.2	0.003	0.016	0.1	0.01	0.006	0.001	0.1	1.0
Barium	0.3	—	—	—	—	—	—	1.0	0.5
Boron	10	—	—	—	—	—	—	7.0	15
Cadmium	<0.003	0.005	0.008	0.1	0.005	0.003	0.0006	0.01	<0.001
Calcium	300	—	—	800	100	300	60	1,500	250
Chloride	1,500	278	1,600	8,000	1,600	2000	400	2,000	1,500
Chromium	0.3	8.9	1.7	0.5	0.1	0.1	0.02	0.2	0.2
Copper	1.0	1.4	1.14	0.5	0.1	0.2	0.04	0.3	<0.01
Iron	40	14	102	20	4	10	2	50	10
Lead	0.05	0.185	0.122	0.4	0.08	0.04	0.008	0.05	<0.01
Manganese	—	2.6	6.4	2.0	0.5	3	0.6	—	3.0
Magnesium	100			400	80	100	20	350	120
Mercury	<0.0001	0.056	0.003	0.01	0.0001	0.0001	0.00002	0.004	0.0006
Nitrate-N	15	0.01	1.60	<1	<1	<1	<1	0.2	5
Nitrite-N	0.1	<1	0.10	<1	<1	<1	<1	0.1	<1
Phosphorous	2	—	11.10	15	1	3	1	10	25
Potassium	450	—	—	2,000	400	800	160	1,000	280
Sodium	1,500	—	—	4,000	800	1,200	240	1,500	5,000
Sulphate	300	28	750	5,000	1,000	500	100	600	5,000
Zinc	2	1.44	2.31	3	0.5	0.2	0.04	2	<0.1
Benzene	0.003	—	—	absent	absent	absent	absent	0.04	0.001
1,4-Dichlorobenzene	0.0015	—	—	absent	absent	absent	absent	0.02	0.0008
Dichloromethane	0.05	0.25	0.01	absent	absent	absent	absent	0.1	0.18
Toluene	0.04	0.02	—	absent	absent	absent	absent	1.0	0.03
Vinly Chloride	<0.002	—		absent	absent	absent	absent	0.1	0.06
PAH	—	—	—	absent	absent	absent	absent	—	—

Notes:
1. *All units are in mg/L except where noted*
2. *Waste stabilized by screening, separating, milling and composting*
3. *Literature values are based on data for stabilized waste landfills in the Netherlands, Germany and Austria*
4. *High intensity composting includes active aeration in containerized system followed by further composting in open windrows*
5. *Moose Creek Site is only 5 years old and therefore current representative peak values may underestimate future peak values.*

Table 2–5. Landfill Operations Advantages / Disadvantages of Stabilized Waste

Landfill Operations Activity	Advantages (high intensity composting)	Advantage (Low-medium intensity composting)	Disadvantages (high intensity composting)	Disadvantage (Low-medium intensity composting)
Landfill Gas Management	▪ lower content of readily degradable organic matter results in 80%-90% reduction in total volume of landfill gas to be managed ▪ lower peak generation rate of landfill gas reduces odour emissions thereby allowing passive venting through landfill cover rather than active collection / flaring ▪ less off-site development restrictions related to potential odour impacts (e.g. <500 m based on Italian sites surveyed)	▪ lower content of readily degradable organic matter results in 80%-90% reduction in total volume of landfill gas to be managed	▪ no significant disadvantages	▪ potentially higher peak landfill gas production rate due to incomplete decomposition of relatively degradable organic fraction and the enhanced reactivity of the waste upon shredding to small particle sizes (e.g., <50 mm) of high specific surface area.
Litter Control	▪ no significant advantages	▪ no significant advantages	▪ small particle sizes (e.g., <50 mm) and low density of stabilized waste components (e.g., paper, plastic) increases potential for wind blown litter from the active face of the landfill. However, MBT facilities which separate out RDF likely have less potential for wind blown litter due to the removal of a large portion of the paper and plastics	▪ small particle sizes (e.g., <50 mm) and low density of stabilized waste components (e.g., paper, plastic) increases potential for wind blown litter from the active face of the landfill. However, MBT facilities which separate out RDF likely have less potential for wind blown litter due to the removal of a large portion of the paper and plastics
Gull Management	▪ food wastes are largely decomposed therefore fewer gulls	▪ food wastes are largely decomposed therefore fewer gulls	▪ no significant disadvantages	▪ no significant disadvantages
Leachate Collection / Management	▪ lower BOD and COD concentrations in leachate reduce potential for bio-chemical clogging of leachate drainage layer / collection pipes ▪ lower ammonia-N, BOD and DOC concentrations in leachate reduce leachate treatment costs and minimize interferences on waste water treatment process at receiving sewage treatment plant.	▪ lower BOD and COD concentrations in leachate reduce potential for bio-chemical clogging of leachate drainage layer / collection pipes	▪ potentially low permeability of compacted waste fill (e.g., 10^{-6} cm/s) can lead to horizontal flow of leachate within waste mound and therefore leachate seeps along landfill slopes	▪ potentially low permeability of compacted waste fill (e.g., 10^{-6} cm/s) can lead to horizontal flow of leachate within waste mound and therefore leachate seeps along landfill slopes

Table 2–5. Landfill Operations Advantages / Disadvantages of Stabilized Waste

Landfill Operations Activity	Advantages (high intensity composting)	Advantage (Low-medium intensity composting)	Disadvantages (high intensity composting)	Disadvantage (Low-medium intensity composting)
Waste Placement / Compaction	▪ smaller particles sizes (e.g., < 50 mm) may allow a high level of compaction with a lighter weight compactor.	▪ smaller particles sizes (e.g., < 50 mm) may allow a high level of compaction with a lighter weight compactor.	▪ no significant disadvantages	▪ no significant disadvantages
After Care	▪ lower organic content and greater uniformity in waste material composition / particle sizes reduces potential for large differential settlement that can damage the landfill cover system and increase moisture infiltration / leachate generation ▪ reduced settlement minimizes interferences on end uses of landfill (e.g., passive recreational uses)	▪ lower organic content and greater uniformity in waste material composition / particle sizes reduces potential for large differential settlement that can damage the landfill cover system and increase moisture infiltration / leachate generation ▪ reduced settlement minimizes interferences on end uses of landfill (e.g., passive recreational uses)	▪ potentially low permeability of compacted waste fill (e.g., 10^{-6} cm/s) can lead to horizontal flow of leachate within waste mound and therefore leachate seeps along landfill slopes	▪ potentially low permeability of compacted waste fill (e.g., 10^{-6} cm/s) can lead to horizontal flow of leachate within waste mound and therefore leachate seeps along landfill slopes
Dust and Noise Control	▪ No significant advantages	▪ No significant advantages	▪ No significant disadvantages	▪ No significant disadvantages
Potential Contaminating Lifespan	▪ no significant advantages since the key non-degradable parameters which typically control the contaminating lifespan, such as chloride and metals, are at concentrations / mass inventories comparable to those for non-stabilized waste	▪ no significant advantages since the key non-degradable parameters which typically control the contaminating lifespan, such as chloride and metals, are at concentrations / mass inventories comparable to those for non-stabilized waste	▪ no significant disadvantages	▪ no significant disadvantages
Waste Slope Stability	▪ no significant advantages	▪ no significant advantages	▪ potentially lower apparent cohesion and friction angle of waste (due to smaller and uniform particle sizes), but slopes will be stable at the 4(H) : 1(V) grade typically used for final perimeter slopes	▪ potentially lower apparent cohesion and friction angle of waste (due to smaller and uniform particle sizes), but slopes will be stable at the 4(H) : 1(V) grade typically used for final perimeter slopes

e) potentially lower apparent cohesion (due to the smaller particle sizes following) shredding;

f) half the settlement potential from waste decomposition; and

g) potentially lower hydraulic conductivity (due to smaller/platy particles following shredding, which can align horizontally at high compactive effort and form low permeability layers within the landfill).

The above characteristics of stabilized waste have important implications on landfill operations and performance, as discussed later in this section.

Comparison of the literature and survey data for the waste characteristics in Table 2-2 was possible only for in-place apparent waste density, as data for the other characteristics does not exist for the surveyed sites. The in-place apparent density for the Otter Lake site (0.77 t/m^3) is consistent with literature values for stabilized waste (0.7 to 1.0 t/m^3), whereas the apparent density values for the Italian stabilized landfills (0.6 t/m^3) are slightly lower. The in-place apparent density for the Trail Road site (0.75 t/m^3) is consistent with the literature value for unstabilized waste (0.8 t/m^3) whereas the density for the Moose Creek site (1.0 t/m^3) is significantly higher.

Landfill Gas Production

Table 2-3 provides data on landfill gas production rates for stabilized and unstabilized MSW. The total landfill gas production potential for well stabilized (e.g., as is practiced in Germany) waste (<10-45 L/kg) is approximately 5 to 10% of that for unstabilized waste (200-500 L/kg), reflecting the removal of the readily degradable organic fraction (e.g., food waste and plant wastes) by composting. Therefore, potential total greenhouse gas emissions from a stabilized landfill may be on the order of 10% of that from an unstabilized waste landfill of similar size. However, this comparison does not takes into account the greenhouse gas emissions from the MBT facility itself. Data on emissions from MBT facilities are provided by Greenpeace (2003).

The peak landfill gas generation rate for well stabilized waste (<3 $L/m^2/hr$) may be less than half of that for unstabilized waste (~6 $L/m^2/hr$). However, as noted for the Otter Lake site, waste which is shredded to a small particle size (i.e., ≤50 mm) and composted for a relatively short period of time (e.g., ~ 3 weeks) may actually have a higher peak landfill gas production rate (20 $L/m^2/hr$), albeit of shorter duration, than unstabilized waste.

The higher peak landfill gas production rate for the Otter Lake site may relate to the incomplete decomposition/stabilization of the relatively degradable organic fraction (e.g., food and plant wastes) over the relatively short composting period and to the enhanced reactivity of the residual organic component imparted by shredding of the waste to small particle sizes of relatively high specific surface area. As a consequence, the Otter Lake site regularly receives odour complaints (due to landfill gas emissions) from residents more than 2 km from the site, particularly when inactive waste areas are not covered with interim or final cover and/or when the gas flaring system is not functional. Nevertheless, it is likely that the period of peak landfill gas production rate will be limited to the landfilling period due to the relatively low total organic matter content of the stabilized waste, whereas for unstabilized waste it can extend beyond closure of the facility.

Leachate Quality

Table 2-4 presents a comparison of leachate quality for stabilized versus unstabilized waste based on data from the literature review and from the surveyed sites. The literature values for stabilized waste are from a study by Robinson et. al (2004) and reflect "low-medium intensity" and "high intensity" aerobic composting. However, this reference as well as the other literature reviewed, do not clearly define the criteria used for differentiating between these different intensities of composting. Based on our interpretation, it appears that high intensity composting involves active aeration in a containerized system followed by composting in windrows, over a total period of 4 months or more. This is typical of current practice in Germany and Austria. Low-medium intensity compositing involves composting in windrows for periods of several weeks (e.g., 3 weeks for the Otter Lake site and 2 weeks with forced air flow followed by 15 to 18 days of bio-desiccation for the Italian sites).

Comparison of the leachate quality data from the surveyed stabilized landfills with the literature data for stabilized waste (Table 2-4), supports that the surveyed stabilized landfills represent low-medium intensity composting. This is evident, for example, by comparing the BOD concentrations: 250 to 1,000 mg/L for the surveyed stabilized landfills versus the literature values of 6 to 30 mg/L for high intensity composting and 20 to 200 mg/L for low-medium intensity composting. Another good indicator is ammonia-N: 290 to 580 mg/L for the surveyed stabilized landfills versus literature values of 40 to 200 mg/L for high intensity composting and 50 to 1,000 mg/L for low-medium intensity composting.

Comparison of the literature concentrations for stabilized waste leachate with those for unstabilized waste leachate from the Trail Road and Moose Creek sites, indicates that stabilized waste leachate has lower levels of ammonia-N, BOD, COD, DOC and volatile organic compounds. Leachate concentrations for heavy metals and salts (e.g., sodium, calcium and chloride) are comparable for stabilized and unstabilized waste, indicating that these parameters are not significantly affected by the pre-processing.

Landfill Operations

Table 2-5 presents the advantages and disadvantages of stabilized waste relative to unstabilized waste, with respect to various landfill operations activities based on published opinion and our own findings and interpretation. Considering the stabilized waste data provided in Tables 2-2 to 2-4, the major advantages relative to landfill operations that are provided by high intensity waste stabilization are summarized in Table 2-6.

A disadvantage of stabilized waste with respect to landfill operations is the increased potential for wind blown litter from the active face. This relates to the small particle sizes (e.g., <50 mm) and low density of the predominantly paper and plastic components of the processed waste. Another key disadvantage is that the potentially low permeability of compacted highly stabilized waste (e.g., $<10^{-6}$ cm/s) can result in horizontal flow within the waste mound, leading to leachate seeps along the landfill slopes.

Golder's European experience indicates that tipping costs range from $125 per tonne to $180 per tonne for waste taken to a private MBT/stabilized landfill facility.

Table 2–6. Major Advantages of High Intensity Waste Stabilization for Landfill Operations

	Advantages of Stabilized Waste*
Landfill Gas Management	▪ lower total volume and peak rate of landfill gas generation reduces odour emissions, thereby allowing passive venting through the cover rather than active collection/flaring of landfill gas. ▪ less off-site development restrictions related to odour management (e.g., residences <500 m based on Italian sites surveyed).
Gull Control	▪ fewer gulls due to absence of undegraded food wastes.
Leachate Collection/ Management	▪ lower BOD, COD, NH_3-N and DOC concentrations in leachate reduces the intensity of biological activity within the leachate collection system, which in turn reduces the potential for bio-chemical clogging of the drainage system (i.e., increases the potential service life of the leachate drainage system). ▪ lower NH_3-N, BOD and DOC concentrations in leachate reduce leachate treatment costs and minimize interferences to the waste water treatment process.
After Care	▪ lower organic matter content and uniformity in waste material composition/particle sizes reduces the total and differential settlement of the finished landfill surface, which in turn reduce maintenance requirements / costs for the landfill cap.

*Note: * Major advantages of stabilized waste relative to unstabilized waste, with respect to landfill operations.*

2.3 European Union Context on Stabilized Landfills

2.3.1 Overview

The consensus in the EU has been that landfilling of municipal solid waste (MSW) has to be reduced for a variety of reasons. The current practice of landfilling mixed MSW is of high impact, as well as unpopular and ultimately unsustainable. The main driver for stabilized landfill development in the European Union (EU) countries was Landfill Directive 1999/31/EC (EU Directive), which states:

a) only pre-treated wastes are allowed to be landfilled after July 2001; and

b) the amount of biologically degradable MSW to be landfilled must be reduced in a phased approach to 75% by July 2006, to 50% by July 2009, and to 35% by July 2016 of the total amount of biologically degradable MSW produced in 1995.

The EU Directive does not specify the minimum degree of stabilization that must be achieved and thus EU countries have developed their own national measures.

Common national measures and tools to fulfil the requirements of the EU Directive are:

a) recycling targets for waste streams (e.g., Italy);
b) diversion targets for the organic part of the waste to be landfilled (e.g., Germany);
c) separate collection targets for biowaste (e.g., Sweden);
d) taxes on landfilling, on incineration or eco-taxes (e.g., Sweden, Italy);
e) tradable landfilling certificates (e.g., UK); and
f) acceptance criteria for the waste to be landfilled (e.g., Germany, Austria).

The EU Directive also does not contain any siting or buffer land requirements specific to stabilized landfills. Such requirements are contained within country-specific regulations developed for landfills, with no differentiation between conventional and stabilized landfills.

A copy of EU Directive 1999/31/EC, dated April 26, 1999 is presented in Appendix C of this report.

2.3.2 Italy

As part of the drive to comply with the Landfill Directive and Italian regulations (Italian Decree 36/2006), Italy has experienced a significant development of mechanical and biological treatment (MBT) systems in the last 15 years, also as a consequence of the implementation of a specific regulation on waste which introduced source separation and recycling (Italian Decree 22/1997).

After the promulgation of both the National Waste Management Act and of Directive 1999/31/CE on landfilling, the stabilization (i.e., MBT) prior to landfilling has undergone a substantial increase in order to comply with provisions of these regulations. In particular, between 2002 and 2004 the amount of MBT processed waste increased by about 30%. In 2004 there were 117 existing MBT plants in Italy. Landfill disposal in 2004 accounted for 54% of all waste produced for a total of 30 million tonnes, as summarized in Table 2-7.

Table 2–7. Summary of MSW Disposal in Italy During 2004 (Estimated)

Landfill (all sources)	54%
Incineration	11%
MBT + RDF	22%
Recycling/composting	13%
Total MSW disposed 2004	30,000,000 tonnes

Over the last ten years, there has been a noticeable increase in MBT as an instrument to reduce biologically degradable waste destined to landfill, to reduce transport costs from sites to landfill, and to produce refuse derived fuel (RDF). These plants have been built above all in the southern regions of Italy to overcome the dependence upon landfill, to reduce volumes destined to landfill, and to produce RDF. The problems related to this process are however that there are still very few incineration plants capable of using the RDF. However, MBT has played a huge role in reducing volumes destined to landfill in these southern regions and has continued in the central northern regions, where the plants are less common, to reduce landfill volumes. The advantage of these plants is that, as source separated collection of biodegradable MSW develops, MBT plants can be adapted into composting facilities (i.e., as part of the technology is common to the two) within a short time frame and with relatively small expenditure. The regulation sets the target of waste stabilization at a static respiratory index value of < 500 mg O_2/ kg Volatile Solids/ hour.

The public opinion, especially in Italy, has not produced effects or influences, direct or indirect, on the development of MBT plants and consequently on the stabilized landfills. In fact there are no differences or political implications to make it easier to permit stabilized landfills in comparison to conventional landfills. In general, the permit processes for either are complex and last for a long time in any case.

2.3.3 Germany

The application of 1999/31/EC was reflected in Germany with the introduction of the German Waste Strategy Ordinance in 2001 (TASi) which required that all wastes, not only MSW but also organic residues from IC&I, be pre-treated prior to landfilling. Specific pre-treatment quality targets have been established as well as specific design (i.e., liner) criteria for stabilized waste landfills. Using aerobic pre-treatment in-place waste densities on the order of 0.78 to 1.45 tonnes per cubic metre can be achieved with particle sizes of less than 60 millimetres. The high emphasis of pre-treatment in Germany has resulted in low levels of gas and leachate production from these sites.

In many jurisdictions, MBT facilities, with residues to stabilized landfills, was preferred over a waste incinerator, the likely alternative. Generally, there are three main configurations:

1. An aerobic MBT process to prepare a material that meets the TASi target for stabilization and landfill disposal with a residual fraction (i.e., larger particle size) going to an incinerator (~20,000 kJ/kg).
2. An anaerobic process with a final aerobic curing stage that meets the TASi target for stabilization and landfill disposal with a residual fraction going to cement kilns (~ 15,000 kJ/kg).
3. MBT of the waste to prepare a dry material suitable for direct incineration.

The Germans generally consider that 30 to 50% of the waste processed in MBT plants, the residuals, must be either landfilled or incinerated. As of 2001 there were over 20 MBT facilities in Germany processing over 1 million tonnes of waste per year. The situation created by these regulations caused there to be a lack of MBT/incinerator capacity which is estimated to be about 5 to 6 million tones per year in 2006. The regulation sets criteria for the degree of stabilization using a respiratory index value set at ≤ 5 mg O_2/g dry mass after 96 hours (i.e., different test method than used in Italy).

Many of the German stabilized landfill sites were former conventional landfill sites (i.e., co-disposal of stabilized wastes on top or adjacent to former unstabilized wastes). The size of these facilities ranges from small (70,000 m^3) to large (13 million m^3). In some cases the sites are within 750 m of residential communities and highways (e.g., Rhein-Mann) while others are in more rural settings (e.g., Neumunster) and others are in settings similar to the Cavaglia site (e.g., Segeberg and Lubeck).

The types of processing technology at the German facilities varies as does the processing time which typically ranges from 14 to 16 weeks.

2.3.4 Austria

The application of 1999/31/EC was reflected in Austria with the introduction of new waste regulations (Austrian Landfill Ordinance) which required that residual wastes be pre-treated prior to landfilling. Specific pre-treatment quality targets have been established with the target respiration index for stabilization set at ≤ 7 mg O_2/g dry mass after 96 hours. The high emphasis of pre-treatment in Austria has resulted in low levels of gas and leachate production from these sites. The size of stabilized landfills in Austria ranges from small (i.e., less than 100,000 m^3 to large (i.e., 3 million m^3). The sites are typically in rural settings but are at times in close proximity to highways.

The types of processing technology at the Austrian facilities varies as does the processing time which typically ranges from 14 to 36 weeks.

2.3.5 Overview of MBT Technologies

Mechanical and biological treatment (MBT) although a relatively new term has been in one form or another used since the 1970s. The concept initially revolves around a mechanical pre-treatment of a mixed waste stream, even though in many cases some form of source separation of recyclables is undertaken, to essentially separate easily degradable organics, metals, and a high-calorific value component which have a low value as recyclables. The organic waste fraction is composted while the high-calorific value waste is either used as Refuse Derived Fuel (RDF) in waste to energy plants or landfilled.

The organic waste fraction is either processed through aerobic composting or anaerobic fermentation processes. The various types of aerobic composting operations include:

1. Encapsulated static primary composting by dry stabilization with retention times of 1 to 2 weeks.
2. One stage encapsulated, quasi-accelerated composting with active aeration and waste air treatment, and regular turning with retention times of 3 to 5 weeks.
3. Two-stage composting with a short encapsulated process (of 1 to 5 weeks) followed by a downstream process (i.e., open, covered, aerated, un-aerated) of 7 to 26 weeks.
4. Open static composting without aeration and with or without turning, with retention times of 12 to 18 weeks.

Leikam and Stegmann (1999) report that, depending on the type of aerobic composting operation, the total mass reduction due to the decrease in water content and organics may amount to between 20% and 40%.

The nature of the type of composting technology selected is related to the degree of stabilization sought. The greater the degree of stabilization the lesser the potential for environmental impacts related to the landfilling of the final end product. In the case of siting a stabilized waste landfill in developed area, a high level of stabilization involving for example two stage composting over a duration of 16 weeks or more may be appropriate from the stand-point of minimizing odour impacts and leachate strength, but may require too large of a land area to accommodate an on-site MBT facility with the required holding capacity. The selection of the method /intensity of stabilization in this case would therefore require a detailed study of the various options, taking into account land requirements/availability, potential environmental impacts and costs.

There are some limited installations that have incorporated anaerobic fermentation (e.g., Valorga technology) as the process to stabilize the organic fraction. It is yet too soon to consider the full-scale viability of these installations in consideration that at least 5 years of well-documented operational data must be available to substantiate the performance of such installations.

2.3.6 EU Context Summary

The development of MBT and stabilized landfill sites in EU were driven by the need to comply with the EU directive 1999/31/CE which required a progressive ban on the disposal of biologically degradable organics in landfills. Italy and Germany have introduced different national regulations to comply with the EU directive with a key difference being the extent of stabilization required prior to landfill. The advent of MBT plants is also on the horizon in the United Kingdom with several facilities just getting into operation or well into the permitting phase. In all the cases indicated above, significant efforts are in place to implement 3R programs to reduce the volumes of material needing to be processed, efforts which in many cases lead to source separation programs, all to varying degrees.

A fraction of the MBT processed material is processed in incinerators prior to final disposal since the process can generate RDF material with a relatively high calorific value.

In certain jurisdictions, MBT and stabilized landfill sites are seen as preferable to the alternative of incinerators (conventional landfills are no longer an option in EU countries except in the UK which is using an allowance for an additional 4 years to comply)The main drivers for this preference are (Faviano, 2005):

a) lower cost;
b) greater flexibility (e.g., don't have to meet a minimum through-put and calorific value of the waste for cost effectiveness and efficient operation); and
c) proven examples of successful facilities.

Nevertheless, approvals processes for stabilized landfills are not substantially different from the historic conventional landfills, require a long period of time and are complex.

3. Task 2 – Review of WastePlan EA Facility Land Requirement Assumptions

3.1 Overview of WastePlan EA Comparison Criteria

The WastePlan EA assumptions that are reviewed in this Section are as presented in the report entitled '*Draft Report on the Evaluation of "Alternatives To" and Selection of a Preferred Disposal System', prepared by MacViro and Jacques Whitford dated December 8, 2005.*

Table 3-1 presents a summary of the main criteria and the specific measures that were used to evaluate the eight system options in the WastePlan EA. It is apparent that the 'amount of land' required for the systems evaluated was an important measure as it is used in three different criteria/considerations, as shown in the highlighted sections of Table 3-1.

3.2 Comment on WastePlan EA Facility Land Requirement Assumptions

The specific facility land requirement assumptions utilized in the WastePlan EA are discussed in detail in Annex E-2 of the December 8, 2005 report. These assumptions are summarized in attached Table 3-2 which presents a comparison of the WastePlan EA assumptions to values found from the data collection phase of this study, as well as comments on the similarities or differences. We are of the opinion that the assumptions are, with some exceptions, generally supported by the data collected. A discussion of each assumption follows.

Landfill Site Size

The landfill site sizes presented in Annex E-2 of the WastePlan EA were independently checked by computer methods using 'Land Development Desktop' in conjunction with AutoCAD. Generic landfill 'designs' were created using the other WastePlan EA assumptions (e.g., total tonnage to landfill, waste density, height, depth) and by assuming a simple rectangular footprint (length = 2x width). From the generic design the area of the waste footprint, as well as the area of waste footprint plus various buffers was calculated.

The results of the calculations are presented in Table 3-3. The shaded portion of the table shows the comparison of the calculations carried out during this study with the site sizes calculated in the WastePlan EA. The calculated site sizes were approximately 7 to 9% smaller than the site sizes presented in the WastePlan EA. Given the relatively simple geometry of the generic designs it is considered that the calculations agree reasonably well with the WastePlan EA.

Table 3-1: Review of WastePlan EA Comparison Criteria

Category	Criteria/Consideration	Measure
Natural Environment Considerations	1. Environmental Burden at a Global or Macro Level	
	• Emissions to Air	• Net Annual Lifecycle emissions to Air (includes greenhouse gases, acid gases, smog precursors, heavy metals and organics emitted from all facilities and offsets achieved by generating energy and recycling of materials)
	• Emissions to Water	• Net Annual Lifecycle emissions to Water (includes Lead, Mercury, Cadmium, Biological Oxygen Demand and Dioxins emitted from all facilities as well as offsets achieved by generating electricity and recycling of materials)
	• Need to Manage Hazardous Residues	• Residual Waste (tonnes)
	• Impacts to Land Resources	• Hectares of Land Required for New Facilities
	2. Conservation/Preservation of Non-Renewable Environmental Resources	• Net Annual Lifecycle of Energy Consumption (includes consumption of heat, fuel and electricity by all facilities and generation of electricity as well as energy saved by recycling materials)
	3. Potential for Destruction or Disruption of Sensitive Terrestrial/Aquatic Resources	• Hectares of Land Required for New Facilities, land use setting
	4. Potential to Increase Disposal Diversion Rate and/or Make Best Use of Residual Waste Materials	• % of Materials to Disposal and to Landfill
Social/Cultural Considerations	5. Potential Land Use Conflicts from Siting of Facilities Required for System	• Hectares of Land Required for New Facilities
Technical Considerations	6. Technical Risks Associated with Waste Management System	• System reliability (based on simplicity of system) • Flexibility to Changes in Residual Waste Quantities and Composition
Economic/Financial Considerations	7. Net System Costs Per Tonne of Waste Managed	• Overall System Cost per Tonne (includes operating and capital costs net of revenue from sales of energy and recyclable material over the 25 yr planning period)
	8. Sensitivity of System Costs to External Resources	• Reliance on revenues/subsidies to maintain estimated cost per tonne of waste managed
Legal Considerations	9. Legal/Contractual Risks Associated with Waste Management System	• Potential for a Successful Approval Process (diversion potential, ability to site primary facility within area appropriately designated land uses) • Reliance on partnerships/contractual arrangements to implement and operate

Table 3-2 Summary of WastePlan EA Facility Land Requirement Assumptions

Assumption	Value(s) Assumed in WastePlan EA	Value(s) Obtained from Literature Search	Comment
Landfill Site Size (Footprint + 100 m buffer)	• Stabilized Landfill = 49 Ha • MSW Landfill = 62 Ha	N/a	Site sizes are reasonable given other assumptions used (e.g. density, height, depth). See sensitivity analysis Table 3-3.
Landfill Site Size (Footprint + 500 m buffer)	• Stabilized Landfill = 227 Ha • MSW Landfill = 255 Ha	N/a	Site sizes are reasonable given other assumptions used (e.g. density, height, depth). See sensitivity analysis Table 3-3.
Total Tonnage to Landfill	• Stabilized Landfill = 2,900,000 tonnes • MSW Landfill = 4,100,000 tonnes	N/a	Comparison with surveyed sites and literature values not relevant. EA assumption based on specific waste generation, population growth, diversion rates, etc, for Niagara/Hamilton.
Landfill Life	25 years	N/a	Comparison with surveyed sites and literature values not relevant. EA assumption based on specific waste generation, population growth, diversion rates, etc, for Niagara/Hamilton.
In-place waste density	• Stabilized Landfill = 750 kg/m^3 • MSW Landfill = 700 kg/m^3	• For stabilized landfill, literature review suggests range of 600 to 1,000 kg/m^3 • For MSW landfill, literature review suggests range of 750 to 1000 kg/m^3	• EA assumption for stabilized waste density falls near middle of data range. See sensitivity analysis Table 3-3. • EA assumption for MSW density is low compared to literature values. Notable that high end of data range is from a Canadian site. As such, EA sizes noted for MSW options could reasonably be smaller. See sensitivity analysis Table 3-3.
Maximum Landfill Height	25 m above grade	N/a	• EA assumption considered reasonable. • Landfill height constraints are very site specific.
Maximum Landfill Depth	5 m below grade	N/a	• EA assumption considered reasonable, although consider that a deeper landfill could be developed in Niagara/Hamilton areas. See sensitivity analysis Table 3-3.

Table 3-2 Summary of WastePlan EA Facility Land Requirement Assumptions

Assumption	Value(s) Assumed in WastePlan EA	Value(s) Obtained from Literature Search	Comment
Landfill Side Slopes	3H to 1V	No specific data collected.	• EA assumption reflects steeper landfill slopes than permitted by Ontario landfill regulations (Ont. Reg. 232/98 dictates 4H to 1V side slopes). • Difference on footprint between sites with 3H to 1V or 4H to 1V slopes considered minor.
Cell Configuration	Rectangular or Square	N/a	• EA assumption reasonable for comparative purposes. Actual footprint shape very site specific.
Lands Required for MBT Processing Facility	• 5 ha for MBT facility • 2 ha for compost windrows	N/a. Literature search did not specifically target size of MBT facilities as opposed to landfill portion.	• EA assumption that MBT/windrows could be located within a 100 m landfill buffer zone considered reasonable.
Facility Location	Stabilized Landfill could not likely be sited in an urban/industrial area	Evidence of stabilized landfills existing within industrial areas in EU.	• Assumption supported by current circumstances at Otter Lake Facility but not necessarily supported by EU experience with stabilized landfills. • Highly dependent upon specific setting and land uses.
Zone of Landfill Impact	Facility Land requirements = 500 m (costing purposes = 300 m)	Surveyed sites and literature review indicate various land uses within 500 m of stabilized landfills.	• From viewpoint of nuisance effects (e.g. odour), assumption supported by current circumstances at Otter Lake Facility but not necessarily supported by EU experience with stabilized landfills. • Consider that various land uses possible within 500 m of landfill sites. Notable that natural habitats would certainly be disrupted by the landfill footprint but not necessarily within the buffer beyond landfill limits.

Table 3-3 also presents a sensitivity analysis that shows how the land area requirements can change when assumptions such as waste density and landfill depth are varied. A discussion of this analysis is included in the following subsections entitled In-Place Waste Density and Maximum Landfill Depth.

Tonnage to Landfill

The WastePlan EA indicated that the total tonnage to landfill for the stabilized landfill and conventional MSW landfill options were 2,900,000 tonnes and 4,100,000 tonnes respectively. A comparison with the surveyed sites and the literature values is not comparable as these are specific Niagara/Hamilton requirements. The waste generation rates (e.g., the Mass Balance and Diversion Rates as presented in Annex E-1) in the WastePlan EA were not reviewed in this study.

Landfill Life

A required landfill life of 25 years was presented in the WastePlan EA. A comparison with the surveyed sites and the literature values is not relevant to this evaluation as this is a specific Niagara/Hamilton requirement.

In-Place Waste Density

An in situ waste density of 750 kg/m^3 was used for stabilized landfill in the WastePlan EA. This value falls well within the range of 600 kg/m^3 to 1,000 kg/m^3 identified in the data collection.

An in situ waste density of 700 kg/m^3 was used for conventional MSW landfill in the WastePlan EA. This value falls below the low end of the range of 750 kg/m^3 to 1,000 kg/m^3 identified in the data collection. It is noteworthy that values near the high end of the range are routinely achieved at large, well-run North American landfills.

The sensitivity analysis presented in Table 3-3 shows the relationship between assumed apparent waste density and land requirements. For example, if the density of the stabilized landfill is increased from 750 kg/m^3 to 1,000 kg/m^3 (e.g. to the highest value identified in the data collection) then the size of the waste footprint + 100 m buffer is reduced from 44.5 ha to 35.5 ha, a reduction of about 20%.

It is noteworthy that landfill density actually achieved in practice will depend on a number of factors that include the degree of waste stabilization achieved as well as the operating practices used (e.g. type of landfill equipment, how the equipment is operated, waste to cover ratio).

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Table 3-3: Impact of Geometry Assumptions on Facility Land Requirements

	Assumptions							Calculation Results				
Scenario	*Total Tonnage to Landfill (tonnes)*	*Apparent Density (t/m3)*	*Required Capacity (m3)*	*Above Grade Slopes*	*Max Height (m)*	*Below Grade Slopes*	*Max Depth (m)*	*Airspace Volume Calculated (m3, assuming rectangular footprint)*	*Waste Footprint (ha)*	*Footprint plus 100 m buffer (ha)*	*Footprint plus 300 m buffer (ha)*	*Footprint plus 500 m buffer (ha)*
			Stabilized Landfill									
WastePlan EA Scenarios 1a, 1b	2,900,000	0.75	not specified	3 to 1	25	not specified	5	not specified	not specified	49.0	not specified	227.0
ST1	2,900,000	0.75	3,867,000	4 to 1	25	3 to 1	5	3,900,000	20.7	44.5	219.7	231.4
ST2	2,900,000	1	2,900,000	4 to 1	25	3 to 1	5	2,912,000	15.9	35.5	101.7	198.9
ST3	2,900,000	1	2,900,000	4 to 1	25	3 to 1	10	2,926,000	13.5	32.5	94.5	188.5
			MSW Landfill									
WastePlan EA Scenarios 3a, 3b	4,100,000	0.7	not specified	3 to 1	25	not specified	5	not specified	not specified	62.0	not specified	255.0
MSW1	4,100,000	0.7	5,857,000	4 to 1	25	3 to 1	5	5,900,000	29.8	57.8	137.8	249.8
MSW2	4,100,000	0.8	5,125,000	4 to 1	25	3 to 1	5	5,134,000	25.9	51.7	127.3	234.9
MSW3	4,100,000	0.9	4,556,000	4 to 1	25	3 to 1	10	4,590,000	19.8	42.1	110.7	211.3

Maximum Landfill Height

A maximum landfill height of 25 m was assumed in the WastePlan EA. This assumption is considered to be reasonable, although landfill height constraints are site specific and depend on factors such as surrounding land uses (e.g., visual impacts) as well as subsurface conditions (e.g., landfill foundation considerations).

Maximum Landfill Depth

A maximum landfill depth of 5 m was assumed in the WastePlan EA. This is not considered unreasonable for a landfill excavation developed within overburden soil. It is noteworthy that overburden depths can vary considerably depending on location within the Niagara and Hamilton areas. As well, overburden depth (or depth to groundwater, for that matter) is not necessarily a limiting factor in landfill design. There are several examples of engineered landfills developed within bedrock excavations and below the groundwater table in Southern Ontario (e.g., landfills within quarries including the Niagara Waste Systems Landfill in Thorold and the Newalta Landfill in Stoney Creek).

Landfill depth is one of the variables included in the sensitivity analysis presented in Table 3-3. If the depth of the stabilized landfill is increased from 5 m to 10 m *combined* with a density increase from 750 kg/m^3 to 1,000 kg/m^3 then the size of the waste footprint + 100 m buffer is reduced from 44.5 ha to 32.5 ha, a reduction of about 27%.

Landfill Side Slopes

Above grade side slopes of 3H to 1V were assumed in the WastePlan EA, however slope data for the surveyed sites was not collected. It is noteworthy that this value is steeper than the 4H to 1V slopes required by Ontario Regulation 232/98, the 'Landfill Standards'.

If side slopes are flattened from 3H:1V to 4H:1V the landfill footprint size will increase marginally. Based on Gartner Lee's landfill design experience, the sensitivity of side slopes to land requirements is considered to be a minor factor and was not evaluated.

Cell Configuration

A rectangular or square landfill footprint shape was assumed in the WastePlan EA. The footprint shape is not an applicable comparison criteria and was not considered in this evaluation. However, preliminary calculations carried out during the preparation of Table 3-3 indicate that there is minimal difference on land requirements between square or rectangular geometries when other assumptions are held constant.

Lands Required for MBT Processing Facility

The WastePlan EA assumed a land requirement of 5 ha for an MBT facility and an additional 2 ha for compost windrows assuming a 7 to 12 week process. Minimal data could be found regarding specific land requirements for these plants in the data collection exercise, although the assumed values are believed to be reasonable. It is also reasonable to assume that these facilities could be located within the minimum 100 m buffer required by Ont. Reg. 232/98.

Facility Location

An assumption made in the comparison between the various WastePlan EA options was that a stabilized landfill facility could not likely be sited within an urban or industrial area. This assumption was identified in the final pair-wise comparison between the WastePlan EA System 1 and System 2B (e.g., Table 8-1 on page 55 of the WastePlan EA). We understand that the rationale for applying this assumption was based largely on the results of public consultation undertaken as part of the WastePlan EA process.

The data collected as part of this research study indicates that the stabilized landfills studied are located in largely rural settings (e.g., agricultural lands and forested areas) and, in one case, coexist with farming operations, quarries, other landfill sites (Cavaglia). For the Italian sites, the MBT plant was located in a different location than the stabilized landfill. Individual residences are located within 50 m of the stabilized landfill site at Cavaglia; 500 m at Villafalletto and approximately 2.5 km from the Otter Lake facility. The distance to the nearest populated area (e.g., hamlet or community) ranges from 1.5 km (Cavaglia) to 2.5 km (Otter Lake). As such, the WastePlan EA assumption cannot be refuted or substantiated based on the limited number of stabilized landfill site settings (i.e., three sites) examined as part of this research study and the absence of information regarding the siting processes used in the EU and other site specific impact management information (e.g., compensation, community relations measures, etc).

Notwithstanding this conclusion, other data collected as part of this research study suggests that:

a) the higher the degree of waste processing and stabilization, the lower the gas and odour emissions from the stabilized landfill facility. Wastes at both of the Italian stabilized landfill sites examined (i.e., Cavaglia and Villafalletto) have undergone stabilization to a static respiration index of less than approximately 400 mgO_2/kgVS/hr and there have apparently been no odour complaints. This is despite the fact that residences exist 50 to 500 m from the landfill site (respectively). The Otter Lake facility uses a relatively low degree of processing and odour complaints occur routinely (i.e., 2 complaints per month) as far from the landfill as 2.5 km;

b) modern landfill technology has evolved to the point that longer-term environmental impacts (such as from leachate) can be controlled by well-designed and well-constructed control systems such as liners, leachate collection systems, and covers;

c) waste management systems with separated MBT plants and stabilized landfill sites will tend to reduce haul traffic to the landfill site itself. No traffic or transportation data was collected as part of this research study; and

d) stabilized landfills are likely to result in fewer nuisance bird/gull problems than at conventional landfill sites. No specific data was collected as part of this research study.

Zone of Landfill Impact

The WastePlan EA identifies a 'Total Area Impacted by New Landfill' as 500 m, although it is acknowledged that a buffer zone of 300 m was used for evaluating the cost of WastePlan EA systems, including a stabilized landfill. Gartner Lee has assumed that the rationale for this assumption was based on the fact that 500 m has often been used in conventional landfill siting exercises as representing the area within which typical landfill nuisance impacts (i.e., odour, noise, dust, birds/gulls) are most likely to be the greatest. Although this is a common assumption used, we are not aware of any specific scientific basis for this value. We also recognize that some Ontario municipalities restrict land uses within 500 m of a landfill site.

Nevertheless, the data collected are part of this research study indicates that where there is a high degree of waste processing and stabilization, odour impacts and potentially other nuisance impacts at stabilized landfill sites can be reduced over conventional landfills. This conclusion is supported by experience at the two Italian stabilized landfill sites where the facility exists in proximity to individual rural residences and more populated areas with apparently no odour complaints. As such, the 500 m zone of impact assumption for a highly stabilized landfill site may be conservative.

4. Conclusions

The following main conclusions are drawn from this study:

a) Stabilized waste is produced when municipal solid waste is subjected to mechanical/biological treatment (MBT) which typically include processing to remove recyclables and possibly refuse derived fuel, shredding, and either aerobic or anaerobic composting. The properties of stabilized waste can vary significantly from conventional municipal solid waste and the differences in properties are highly dependent on the degree of processing.

b) Characteristics of highly-stabilized waste relative to conventional solid waste can include:

- one tenth the leachable TOC, COD and Total N content;
- half the total organic matter content;
- similar range of in-place apparent waste density;
- similar friction angle;
- potentially lower apparent cohesion (due to the smaller particle sizes following) shredding;
- half the settlement potential from waste decomposition; and
- potentially lower hydraulic conductivity (due to smaller/platy particles following shredding, which can align horizontally at high compactive effort and form a low permeability layer).

c) The total landfill gas production potential for well-stabilized waste (<10-45 L/kg) is approximately 10% of that for unstabilized waste (200-500 L/kg), reflecting the removal of the readily degradable organic fraction by composting. For the same reason, the peak landfill gas generation rate for well-stabilized waste (<3 $L/m^2/hr$) may be less than half of that for unstabilized waste (~6 $L/m^2/hr$).

d) Comparison of the literature concentrations for stabilized waste leachate with those for unstabilized waste leachate from the Trail Road and Moose Creek sites indicate that stabilized waste leachate has lower levels of ammonia-N, BOD, COD, DOC and volatile organic compounds. Leachate concentrations for heavy metals and inorganic salts (e.g., sodium, calcium and chloride) are comparable for stabilize and unstabilized waste, indicating that these parameters are not significantly affected by the pre-processing.

e) Waste stabilization can have a number of beneficial effects on landfill operations relative to unstabilized waste, including:

- reduction of odour emissions;
- less off-site development restrictions;
- fewer bird nuisance issues;
- potential increase in the service life of leachate collection systems;
- smaller total and differential settlement of the waste mass which facilitates final cover construction and after-use implementation.

f) Waste stabilization can have some negative effects on landfill operations relative to unstabilized waste, including:

- greater potential for wind-blown litter from the working face (although this potential is reduced if RDF is removed); and
- lower permeability and 'platy' nature which increases potential for horizontal leachate flow in the waste mound leading to leachate seeps.

g) MBT treatment and stabilized landfill technology is practiced much more extensively in Europe than North America. A key reason for this difference is the requirements of the European Union's Landfill Directive 1999/31/CE which states:

- only pre-treated wastes are allowed to be landfilled after July 2001; and
- the amount of biologically degradable MSW to be landfilled must be reduced in a phased approach to 75% by July 2006, to 50% by July 2009, and to 35% by July 2016 of the total amount of biologically degradable MSW produced in 1995.

h) The treatment process at the Otter Lake facility in Nova Scotia consists of mechanical shredding followed by aerobic composting for a period of 3 weeks. This is a lower degree of processing than is often carried out in Europe (especially Germany) which often includes longer composting periods (e.g., four to six months) as well as drying (bio-desiccation) of the product.

i) The WastePlan EA Facility Land Assumptions were reviewed relative to the data collected during this study. The assumptions for elements such as landfill size, height, depth, and waste density are generally supported by the data collected.

j) A sensitivity analysis was carried out during this study to examine how variations in assumed apparent waste density and waste depth can impact site land requirements. It was found that if apparent waste density is increased from 750 t/m^3 to 1,000 t/m^3 (e.g. to the maximum value identified in the data collection) and the waste depth below grade is increased from 5 m to 10 m (e.g. to a landfill design depth that may be reasonable depending on location in the Niagara and Hamilton areas) the minimum site area required (e.g. waste footprint plus 100 m buffer) decreases by about 27%. It is recognized that these variables are affected by numerous factors including degree of waste stabilization, landfill equipment used, waste to cover ratio, site specific conditions, and landfill design approach).

k) The WastePlan EA assumption regarding facility location (i.e., that a stabilized landfill facility could not likely be sited within an urban or industrial area) cannot be refuted or substantiated based on the limited number of stabilized landfill site settings examined as part of this research study and the absence of information regarding the siting processes used in the EU and other site specific impact management information (e.g., compensation, community relations measures, etc). While the likelihood of siting success and the magnitude of impacts will be very site specific and dependent upon the nature of the siting process, the data collected regarding highly stabilized landfills in the EU and domestic experience with conventional landfill sites suggests that the siting of a highly stabilized landfill site is possible in a variety of land use settings.

Report Prepared By:

Gartner Lee Limited
Mark A. Sungaila, M.A.Sc., P.Eng., PMP
Consulting Engineer, Principal

Golder Associates Ltd.
Michael Snow, M.A.Sc., P.Eng., ing.
Principal

Frank S. Barone, Ph. D., P. Eng.

Appendices

Appendix A

Completed Survey Questionnaires for Stabilized Landfills (Cavaglia, Villafalletto, Otter Lake)

STABILIZED WASTE LANDFILL DATA
SITE: Cavaglià Piemonte (North Italy)
November 2006

PART A - GENERAL SITE INFORMATION

	Required Information	Data	Comments/Notes/References
A.1	Location (City/Province)	Cavaglià, Piemonte, Italy	~60 km north east of Torino, northern Italy
A.2	Start Date of Landfilling	October 2003	
A.3	Estimated Closure Date	June 2008	
A.4	Current Waste Placement Rate (tonnes/year)	Approx. 70,000 t/y	
A.5	Approved Total Waste Fill Capacity (tonnes or m^3 of waste fill, not including cover soils)	550,000 m^3	
A.6	Existing Quantity of Waste Fill in Place (tonnes or m^3 of waste fill-not including cover soils)	255,000 m^3 al 31/12/2005	
A.7	Approved Waste Fill Area (Ha)	2.75 ha	There is an adjacent industrial waste landfill (IWLF); the stabilized waste landfill partially covers the IWLF
A.8	Existing Waste Fill Area (Ha)	2.75 ha	
A.9	Total Site Area Including Buffer Zone and Site Facilities (Ha)	Approx. 3.5 ha	Ratio: $\frac{\text{Total Site Area}}{\text{Approved Waste Fill Area}} = \frac{3.5\text{ Ha}}{3.0\text{ Ha}} = 1.2$ 50% of the adjacent service area (in common with the IWLF). The waste pre-treatment plant (i.e. composting facility) is located just outside of the site.
A.10	Typical Cell Excavation Depth (average depth of cell below original ground surface)	Approx. 20 m	
A.11	Approved Maximum Height of Waste Fill Relative to Perimeter Ground Surface (m)	Approx. 11m	
A.12	Surrounding Land Use (existing)	Agriculture/quarries/other landfills	
A.13	Distance to Nearest Populated Area (km)	1.5 km	
A.14	Distance to Nearest Residence (km)	0.05 km (50 m)	
A.15	Currently Proposed Post-Closure Land Use	Green area	
A.16	Applicable Regulations (list titles)	Dlgs 36/03 following EU Directive 1999/31/CEE	

STABILIZED WASTE LANDFILL DATA
SITE: Cavaglià Piemonte (North Italy)
November 2006

PART B - GEOLOGICAL/HYDROGEOLOGICAL SETTING

Required Information		Data	Comments/Notes/References
B.1	Typical Depth to Bedrock Relative to Base of Landfill Cells (m)	N.A.	There is no bedrock within reasonable depths
B.2	Type/Thickness/Hydraulic Conductivity of Overburden Layers Beneath Base of Landfill Cells (list layers and corresponding thickness/hydraulic conductivity, starting from the base of landfill)	Gravel/sand and silt layer 10^{-3} m/s	
B.3	Bedrock Type(s) (uppermost 10m of bedrock for landfills founded in overburden or to a maximum of 30m depth below the base of landfill for landfills cells founded in rock)	N.A.	
B.4	Typical Depth to Groundwater Surface Below Base of Landfill Cells (m)	10 m	Multilevel aquifer Surficial groundwater surface: approx. 30 m below ground level Deep groundwater surface: approx. 80 m below ground level
B.5	Primary Aquifer Unit (e.g., a specific overburden layer and/or upper fractured bedrock)	Gravel and sand layer, approximately 80 m below ground level	
B.6	Does Existing Natural (unimpacted) Groundwater in Aquifer Unit Meet Regulatory Requirements for Drinking Water Quality? (Yes or No)	No (Shallow Aquifer) Yes (Deep Aquifer)	
B.7	What are the Current Uses (if any) of Groundwater Within 5 km of the Landfill (e.g., drinking water, agricultural watering, livestock water)?	Agricultural watering Drinking water	Surficial wells: approx. 30 m bgl (agricultural) Deep well: approx. 100 m (drinking water)

STABILIZED WASTE LANDFILL DATA
SITE: Cavaglià Piemonte (North Italy)
November 2006

PART C - WASTE CHARACTERISTICS

	Required Information	Data	Comments/Notes/References
C.1	Waste Pre-Treatment Processes (e.g., source separation, shredding, composting, anaerobic digestion, etc.)	- Residual waste after source separation of recyclables and yard wastes Off-Site MBT Facility - shredding to open bags - screening to remove >100 mm size fraction for RDF - magnetic separation of metals - off-site aerobic stabilization by compositing in windrows (indoor) with forced air flow for 2 weeks (no turning of windrows) - drying by bio-desiccation (forced air flow through 4 m-6 m thick windrows for 15-18 days) - Bailing of treated waste for transport to landfill	- Waste is pre-treated off-site
C.2	Organic Matter Content of As-Received Waste (% dry weight basis)	N.A.	Static respiration index: 428 mg O_2/kg VS/h
C.3	Primary Components of Landfilled Waste (e.g., C&D wastes, plastics, glass, metal, wood, soil, textiles-indicate measured or estimated percentages by dry weight for each)	N.A.	
C.4	Particle Size Range of As-Received Waste (mm)	N.A.	
C.5	Elemental Composition of As-Received Waste		
	C_{total} (g/kg dry wt. basis) $C_{organic}$ N_{total} $N_{organic}$ S Fe Cl Ca Na	Arsenic: 3.9 mg/kg Cadmium: 1.9 mg/kg Chromium: 167 mg/kg Chromium VI: < 1 mg/kg Mercury: 0.85 mg/kg Nickel: 123 mg/kg Lead: 248 mg/kg Soluble Copper: 9.9mg/kg Copper: 189 mg/kg	

STABILIZED WASTE LANDFILL DATA
SITE: Cavaglià Piemonte (North Italy)
November 2006

	Required Information	Data	Comments/Notes/References
	Pb Cd Zn Moisture	Zinc: 300 mg/kg	
C.6	Maximum Leachable BOD (g/kg dry wt. basis)	N.A.	
C.7	Maximum Leachable COD (g/kg dry wt. basis)	N.A.	
C.8	In-place Apparent Waste Density (tonnes of in-place waste per m^3 of landfill air space volume)	0.6 t/m^3	

STABILIZED WASTE LANDFILL DATA
SITE: Cavaglià Piemonte (North Italy)
November 2006

PART D - WASTE CONTAINMENT

	Required Information	Data	Comments/Notes/References
D.1	Base Liner Profile (indicate layer types/thickness from top down)	Geotextile 500 gr/m^2 HDPE 2 mm 100 cm Clay 10^{-7} cm/s	On slopes: Geotextile 500 gr/m^2 HDPE 2 mm Clay geocomposite (geosynthetic clay liner)
D.2	Components of Leachate Collection System (indicate layer types/thicknesses from top down, perforated pipe diameter/spacing)	50 cm drainage layer HDPE pipes (250 and 400 mm) - Variable spacing (< 90 m)	
D.3	Components of Final Cover System (indicate material types/thicknesses from top down)	100 cm cover soil 50 cm drainage material Geotextile 300 gr/m^2 50 cm Clay 10^{-6} cm/s Geotextile 300 gr/m^2 50 cm Inert material	A key objective of the final cover is to minimize infiltration and hence leachate generation. European directive requires 2.5 m thick final cover comprised of barrier, drainage, vegetative and gas venting layers.
D.4	Percentage of Approved Fill Area Currently Capped with Final Cover (%)	0%	
D.5	Type(s) of Daily Cover (e.g., soil, C&D waste, tarps etc.)	Soil	
D.6	Waste: Daily Cover Ratio	10%	By volume No regulatory standard

PART E - LEACHATE QUALITY/MANAGEMENT

	Required Information	Data				Comments/Notes/References
E.1	Raw leachate Quality (approx. representative peak concentration-mg/L based on available monitoring data, except where noted)					
	pH (give range of values)	pH		7.84	6,70	
	Conductivity (µS/cm)	Cond. Spec.MS		25.0		
	Total Dissolved Solids	BOD 5	*mg/l*	250		
	Alkalinity	Ammonia-N	*mg/l*	580.0		
	Ammonia-N	Chloride	*mg/l*	1600		
	Total Kjeldahl Nitrogen	Sulphate	*mg/l*	750.0		
	Biological Oxygen Demand	Fluoride	*mg/l*	6.7		
	Chemical Oxygen Demand	Arsenic	*mg/l*	0.016		
	Dissolved Organic Carbon	Cadmium	*mg/l*	0.008		
	Phenols	Chromium VI	*mg/l*	< 0.1		
	Arsenic	Chromium Total	*mg/l*	1.7		
	Barium	Iron	*mg/l*	102.0		
	Boron	Phosphorus	*mg/l*	11.10		
	Cadmium	Manganese	*mg/l*	6.41		
	Calcium	Mercury	*mg/l*	0.033		
	Chloride	Nickel	*mg/l*	0.516		
	Chromium	Lead	*mg/l*	0.122		
	Copper	Copper	*mg/l*	1.140		
	Iron	Zinc	*mg/l*	2.310		
	Lead	C.O.D.	*mg/l*	9040		
	Magnesium	Nitrate-N (NO_3 – N)	*mg/l*	1.60		
	Mercury	Nitrite-N (NO_2 – N)	*mg/l*	0.10		
	Nitrate	Total Phenols	*mg/l*	1.82		
	Nitrite	Chlorinated Solvents *(sum)*	*mg/l*	< 0.1		
	Phosphorous	Chlorinated Pesticides *(sum)*	*mg/l*	< 0.1		
	Potassium Sodium	Nitrogen-Phosphorus Pesticides *(sum)*	*mg/l*	< 0.01		
	Sulphate	Aromatic Solvents *(sum)*	*mg/l*	< 0.1		
	Zinc	Toluene	*mg/l*	0.01		
		o- + p-xylene	*mg/l*	0.02		

STABILIZED WASTE LANDFILL DATA
SITE: Cavaglià Piemonte (North Italy)
November 2006

	Required Information	Data	Comments/Notes/References
	Benzene 1,4-Dichlorobenzene Dichloromethane Toluene Vinyl Chloride		
E.2	Typical Current Leachate Collection Rate (m^3/year)	Max 300-400 m^3/month (~3,100 m^3/year assuming 260 m^3/month avg.*) *Average leachate collection rate assumed to be 75% of peak value of 350 m^3/month	Leachate Collection Rate: = 3,100 m^3/year 3.0 Ha = 100 mm/yr (12% of total precip*) Low production rate due to the low water content of the treated waste (i.e. waste adsorbs infiltration) *800 mm/year total precip.
E.3	Is Collected Leachate Recirculated Through Waste Fill? (if yes, give percentage that is recirculated)	No	
E.4	Is Collected Leachate Discharged to Sanitary Sewer System? (If you give percentage that is discharged to sewer)	No	Leachate is trucked to an off-site waste water treatment facility
E.5	Is Collected Leachate Treated or Pre-Treated On Site? (indicate type of treatment/pre-treatment system and the receptor of the treatment system effluent)	No	

PART F - LANDFILL GAS CHARACTERISTICS/MANAGEMENT

	Required Information	Data	Comments/Notes/References
F.1	Method(s) of Landfill Gas Management (e.g., passive venting through cover soils, landfill gas collection/utilization system)	passive venting	
F.2	Landfill Gas Composition (% by volume) (give ranges) Methane (CH_4) Carbon Dioxide (CO_2) Mercaptans (CHS) Hydrogen Sulphide (H_2S)	Max 35% methane (for a short period, then methane drops significantly)	Very low gas production
F.3	Are there Complaints of Of-site Odour Impacts? (indicate approximate frequency of complaints)	No	
F.4	Are odour suppressants (other than cover soils) used? (specify types)	No	
F.5	Estimated or Measured Maximum Landfill Gas Generation Rate (m^3/dry kg of waste /year)	N.A.	

Notes: Avg annual total precipitation = 800 mm/year

STABILIZED WASTE LANDFILL DATA
SITE: OTTER LAKE RESOURCE MANAGEMENT FACILITY
October 28, 2006

PART A - GENERAL SITE INFORMATION

	Required Information	Data	Comments/Notes/References
A.1	Location (City/Province)	Halifax Regional Municipality	
A.2	Start Date of Landfilling	1999	(Ref. 1)
A.3	Estimated Closure Date	2023	(Ref. 1)
A.4	Current Waste Placement Rate (tonnes/year)	120,000 t/yr	~ 99,000 t/yr goes through the on-site pre-treatment system; therefore the landfill receives approximately 21,000 tonnes/yr of waste that does not go through the pre-treatment system (mostly inert industrial waste and C & D waste) (Ref. 1)
A.5	Approved Total Waste Fill Capacity (tonnes or m^3 of waste fill, not including cover soils)	3.1 M tonnes 4.3 Mm^3	(Ref. 1)
A.6	Existing Quantity of Waste Fill in Place (tonnes or m^3 of waste fill-not including cover soils)	~ 1M tonnes ~ 1.4 M m^3	(Ref. 2)
A.7	Approved Waste Fill Area (Ha)	55 Ha (138 acres)	Total of nine cells; each cell has 2-3 year filling period (Ref. 1)
A.8	Existing Waste Fill Area (Ha)	~ 16 Ha	(Ref. 2)
A.9	Total Site Area Including Buffer Zone and Site Facilities (Ha)	160 Ha (400 acres)	A minimum buffer zone of 30 m is provided around the landfill (Ref. 1 and 2) Ratio: $\frac{\text{Total Site Area}}{\text{Approved Waste Fill Area}} = \frac{160\ \text{Ha}}{55\ \text{Ha}} = 2.9$
A.10	Typical Cell Excavation Depth (average depth of cell below original ground surface)	~ 2 m – 3 m	Approximately 1m or less of native soil remaining between base of cell and bedrock (Ref. 2)
A.11	Approved Maximum Height of Waste Fill Relative to Perimeter Ground Surface (m)	~ 30 m (max elevation 111.5 m)	Average waste thickness ~ 23m (Ref. 1)
A.12	Surrounding Land Use (existing)	Mostly forested land with some small communities, including Timberlea (2.5 km), Lakeside (3 km) and Goodwood (~ 4 km).	(Ref. 1)
A.13	Distance to Nearest Populated Area (km)	2.5 km to community of Timberlea	(Ref. 2)

STABILIZED WASTE LANDFILL DATA
SITE: OTTER LAKE RESOURCE MANAGEMENT FACILITY
October 28, 2006

	Required Information	Data	Comments/Notes/References
A.14	Distance to Nearest Residence (km)	2.5 km	(Ref. 2)
A.15	Currently Proposed Post-Closure Land Use	No plans yet	Mirror is responsible for maintaining/monitoring site for 30 years post closure. City of Halifax then takes full ownership (Ref. 2)
A.16	Applicable Regulations (list titles)	Draft Nova Scotia Standards and Guidelines Manual for Landfills, July 1994	(Ref. 1)

PART B - GEOLOGICAL/HYDROGEOLOGICAL SETTING

	Required Information	Data	Comments/Notes/References
B.1	Typical Depth to Bedrock Relative to Base of Landfill Cells (m)	< 1m typical	(Ref. 2)
B.2	Type/Thickness/Hydraulic Conductivity of Overburden Layers Beneath Base of Landfill Cells (list layers and corresponding thickness/hydraulic conductivity, starting from the base of landfill)	≤ 1m of stiff to hard, reddish brown, silty clayey sand to sandy clay [Till] with some gravel and cobbles / boulders $k \sim 1 \times 10^{-5}$ cm/s	- Surrounding overburden thickness = 0-11m - no significant clay mineral content (Ref. 3)
B.3	Bedrock Type(s) (uppermost 10m of bedrock for landfills founded in overburden or to a maximum of 30m depth below the base of landfill for landfills cells founded in rock)	Granite	- most fractured in upper 2 m – 3 m depth - $k \sim 5 \times 10^{-4}$ cm/s but can be as high as 3×10^{-2} cm/s (Ref. 3)
B.4	Typical Depth to Groundwater Surface Below Base of Landfill Cells (m)	~ 1 m	Regulations for Nova Scotia require ≥ 1 m depth to water table below cell. Cell 1 required underdrain to meet this criteria. (Ref 2) Primary direction of groundwater flow is west to northwest to Nine Mile River (Ref. 3)
B.5	Primary Aquifer Unit (e.g., a specific overburden layer and/or upper fractured bedrock)	Upper fractured bedrock	
B.6	Does Existing Natural (unimpacted) Groundwater in Aquifer Unit Meet Regulatory Requirements for Drinking Water Quality?	- Meets all applicable drinking water guidelines except for naturally occurring iron, manganese and isolated occurrences of arsenic, uranium and chromium - Considered potable	(Ref. 3)
B.7	What are the Current Uses (if any) of Groundwater Within 5 km of the Landfill (e.g., drinking water, agricultural watering, livestock water)?	Upper granite bedrock aquifer is the primary water resource for most of the residences in Goodwood and areas to the south (upgradient of site)	Nearest downgradient communities (Timberlea and Lakeside) are on municipal water supply from Nine Mile River (Ref. 2 and 3)

STABILIZED WASTE LANDFILL DATA
SITE: OTTER LAKE RESOURCE MANAGEMENT FACILITY
October 28, 2006

PART C - WASTE CHARACTERISTICS

	Required Information	Data	Comments/Notes/References
C.9	Waste Pre-Treatment Processes (e.g., source separation, shredding, composting, anaerobic digestion, etc.)	Off-site: - source separation of recyclables and yard wastes On-site: - separation of large, bulky items - screening through 6" tromell - separation of > 6" and < 6" fractions to remove recyclables - shredding of non-recyclable fraction to 2" minus - aerobic composting in an enclosed building - drying to 40% moisture content (dry weight basis) after composting	- composting is done in 12 windows ~ 4 m width (~ 3 week residence time) - composting facility is enclosed; gas from composting facility is discharged to a large outdoor bio-filter bed where it is passed through a wood chip filter layer; no residual odour from bed; wood chip is occasionally turned and is replaced every two years (Ref. 2)
C.10	Initial Organic Matter Content of Landfilled Waste (% dry weight basis)	Not measured	~ 10% - 15% organics in shredded waste prior to composting (Ref. 2)
C.11	Primary Components of Landfilled Waste (e.g., C&D wastes, plastics, glass, metal, wood, soil, textiles-indicate measured or estimated percentages by dry weight for each)	- approximately 75% shredded paper, plastics and inerts - 25% shredded wood, decayed organic matter	Waste is from residential and ICI sources in City of Halifax.
C.12	Particle Size Range of Landfilled Waste (mm)	<50 mm (typical)	Waste is shredded to < 50 mm prior to composting; however, landfill also receives some loads of industrial inert waste greater than 50 mm that do not go through on-site pre-treatment system (Ref. 2)
C.13	Elemental Composition of Landfilled Waste C_{total} (g/kg dry wt. basis) $C_{organic}$ N_{total} $N_{organic}$ S Fe Cl Ca Na Pb	No data on elemental composition <40% moisture content	(Ref. 2)

STABILIZED WASTE LANDFILL DATA
SITE: OTTER LAKE RESOURCE MANAGEMENT FACILITY
October 28, 2006

	Required Information	Data	Comments/Notes/References
	Cd Zn Moisture		
C.14	Maximum Leachable BOD (g/kg dry wt. basis)	No data	
C.15	Maximum Leachable COD (g/kg dry wt. basis)	No data	
C.16	In-place Apparent Waste Density (tonnes of in-place waste per m^3 of landfill air space volume)	0.77 tonnes/m^3	Calculated by landfill staff based on tonnes of waste placed and total volume of fill (waste and cover soil). Considering a waste: daily cover ratio of 5:1, the actual waste density is ~920 kg/m^3 (Ref. 2)

PART D - WASTE CONTAINMENT

	Required Information	Data	Comments/Notes/References
D.7	Base Liner Profile (indicate layer types/thickness from top down)	Primary Liner: - 60 mil HDPE - 850 mm compacted soil ($k \leq 5x10^{-6}$ cm/s) - 150 mm bentonite amended soil ($k \leq 1x10^{-8}$ cm/s) Secondary Liner: - 60 mil HDPE	(Ref. 1)
D.8	Components of Leachate Collection System (indicate layer types/thicknesses from top down, perforated pipe diameter/spacing)	Primary LCS: - 300 mm cushion layer (75 mm clear stone) - 300 mm collection layer (25 mm clear stone) - 300 mm collection layer (sand) Secondary LCS: - geonet	(Ref. 1)
D.9	Components of Final Cover System (indicate material types/thicknesses from top down)	- 600 mm local till (hydroseeded) - geocomposite - 40 mil HDPE	(Ref. 1)
D.10	Percentage of Approved Fill Area Currently Capped with Final Cover (%)	20% (11 Ha)	Three of nine cells are filled and capped (Ref. 2)
D.11	Type(s) of Daily Cover (e.g., soil, C&D waste, tarps etc.)	Mostly wood chip with some shredded C & D waste. No dry wall is accepted.	- very few gulls present at time of visit - often have problems with wind blown litter during waste placement due to small particle size of waste (<50 mm) and low density of constituents (e.g., paper, plastics) - fine debris screens required to prevent litter from blowing off-site (Ref. 2)
D.12	Waste: Daily Cover Ratio	5 waste: 1 cover material	(Ref. 1 and 2)

PART E - LEACHATE QUALITY/MANAGEMENT

	Required Information	Data	Comments/Notes/References
E.6	Raw leachate Quality (approx. representative peak concentration-mg/L based on available monitoring data, except where noted)		(Ref. 4) BOD and COD data provided separately from City.
	pH (give range of values)	6.2-8.4	
	Conductivity (µS/cm)	12,000	
	Total Dissolved Solids	7,000	
	Alkalinity	4,000	
	Ammonia-N	400	
	Total Kjeldahl Nitrogen	N/A	
	Biological Oxygen Demand	1,000	BOD/COD ratio typically ranges from 0.03 – 0.2 indicating very short acetogenic phase of decomposition. BOD is typically less than 200 mg/L COD is typically less than 2000 mg/L
	Chemical Oxygen Demand	2,500	
	Dissolved Organic Carbon	1,300	
	Phenols		
	Arsenic	0.2	
	Barium	0.3	
	Boron	10	
	Cadmium	<0.003	
	Calcium	300	
	Chloride	1,500	
	Chromium	0.3	
	Copper	1	
	Iron	40	
	Lead	0.05	
	Magnesium	100	
	Mercury	<0.0001	
	Nitrate	15	
	Nitrite	0.1	
	Phosphorous	2	
	Potassium	450	
	Sodium	1,500	
	Sulphate	300	
	Zinc	2	

STABILIZED WASTE LANDFILL DATA
SITE: OTTER LAKE RESOURCE MANAGEMENT FACILITY
October 28, 2006

	Required Information	Data	Comments/Notes/References
	Benzene	0.003	
	1,4-Dichlorobenzene	0.0015	
	Dichloromethane	0.05	
	Toluene	0.04	
	Vinyl Chloride	<0.002	
E.7	Typical Current Leachate Collection Rate (m^3/year)	100 M Litres in 2005 80 M Litres in 2006	Average leachate collection rate = $\frac{80{,}000\ m^3}{16\ Ha}$ = 500 mm/yr (40% total precip.) Total Precip. = 1,240 mm/year (Ref. 2)
E.8	Is Collected Leachate Recirculated Through Waste Fill? (if yes, give percentage that is recirculated)	No	(Ref. 2)
E.9	Is Collected Leachate Discharged to Sanitary Sewer System? (If you give percentage that is discharged to sewer)	No	Leachate pumped into tanker trucks and taken off-site to City water treatment facility (Ref. 2)
E.10	Is Collected Leachate Treated or Pre-Treated On Site? (indicate type of treatment/pre-treatment system and the receptor of the treatment system effluent)	No	Leachate holding tank has a bubbler for aeration that is occasionally used; there are no pre-treatment criteria for discharge to the sanitary sewer. (Ref. 2)

PART F - LANDFILL GAS CHARACTERISTICS/MANAGEMENT

	Required Information	Data	Comments/Notes/References
F.6	Management Method(s) of Landfill Gas (e.g., passive venting through cover soils, landfill gas collection/utilization system)	LFG has been collected and flared on-site since 2003	LFG collection system was originally not part of the landfill design. It was installed to control odour emissions that were not originally anticipated. Design consists of gas wells on a 25m grid spacing. Wells are installed after a cell has been filled to final contours. (Ref. 2)
F.7	Landfill Gas Composition (% by volume) (give ranges) Oxygen (0_2) Methane (CH_4) Carbon Dioxide (CO_2) Mercaptans (CHS) Hydrogen Sulphide (H_2S) Other	Typical average values: 1% 47% 35% 0.1 – 0.3% (1,000-3,000 ppm) 3-4%	(Ref. 2) Landfill Gas Temp. = 27°C - 38°C
F.8	Are there Complaints of Of-site Odour Impacts? (indicate approximate frequency of complaints)	Yes. Approx. 2 complaints per month on average	Complaints started in 2003 and are usually associated with operational issues (e.g. flare not working, inactive waste areas not yet covered with interim or final cover). (Ref. 2)
F.9	Are odour suppressants (other than cover soils) used? (specify types)	Tried various suppressants but none worked well	
F.10	Estimated or Measured Peak Landfill Gas Generation Rate	~ 110 cfm per hectare (~20L/m^2/hr)	- Calculated based on 1,200 cfm currently going to flare for 11 Ha capped area. - It takes approximately two years for the waste to undergo the maximum rate of anaerobic decomposition and landfill gas production. The peak LFG generation rate is very high likely due to shredding of waste (gives high surface area). The LFG generation rate then drops off quickly. (Ref. 2) - Total volume of landfill gas generation over life of facility is likely to be less than conventional landfill due to removal of organics by composting process

Reference:
1. *Halifax Regional Municipality Residuals Disposal Facility Design Report – Site "A" – Porter Dillon Ltd. (January, 1997)*
2. *Steve Copp (Mirror Nova Scotia) personal communication (October 28, 2006)*
3. *Geotechnical and Hydrogeological Investigation of Site "A", by Jacques Whitford Environmental Ltd. (April, 1996)*
4. *2004 Annual Surface and Groundwater Operational Monitoring Report (Dillon, 2005)*

STABILIZED WASTE LANDFILL DATA
SITE: Villafalletto, Piemonte, Italy
November 2006

PART A - GENERAL SITE INFORMATION

	Required Information	Data	Comments/Notes/References
A.1	Location (City/Province)	Villafalletto, Cuneo, Piemonte, Italy	~150 km south of Torino, northern Italy
A.2	Start Date of Landfilling	May 2005	
A.3	Estimated Closure Date	December 2011	
A.4	Current Waste Placement Rate (tonnes/year)	Approx. 20,000 t/y	
A.5	Approved Total Waste Fill Capacity (tonnes or m^3 of waste fill, not including cover soils)	260,000 m^3	272,500 m^3 including cover soils
A.6	Existing Quantity of Waste Fill in Place (tonnes or m^3 of waste fill-not including cover soils)	77,500 m^3 al 30/09/2006	Including cover soils
A.7	Approved Waste Fill Area (Ha)	3.6 ha	
A.8	Existing Waste Fill Area (Ha)	3.6 ha	
A.9	Total Site Area Including Buffer Zone and Site Facilities (Ha)	Approx. 14 ha	Including treatment plant (in the same fenced area). Ratio: $\frac{\text{Total Site Area}}{\text{Approved Waste Fill Area}} = \frac{14\text{ Ha}}{3.6\text{ Ha}} = 3.9$
A.10	Typical Cell Excavation Depth (average depth of cell below original ground surface)	Approx. 3.3 m	
A.11	Approved Maximum Height of Waste Fill Relative to Perimeter Ground Surface (m)	Approx. 8.3 m	
A.12	Surrounding Land Use (existing)	Agriculture, woods area	
A.13	Distance to Nearest Populated Area (km)	2.0 km	
A.14	Distance to Nearest Residence (km)	0.2 – 0.5 km	Farms
A.15	Currently Proposed Post-Closure Land Use	Green area	
A.16	Applicable Regulations (list titles)	Italian Decree 36/03 following EU Directive 1999/31/CEE	

PART B - GEOLOGICAL/HYDROGEOLOGICAL SETTING

	Required Information	Data	Comments/Notes/References
B.8	Typical Depth to Bedrock Relative to Base of Landfill Cells (m)	N.A.	There is no bedrock within reasonable depth
B.9	Type/Thickness/Hydraulic Conductivity of Overburden Layers Beneath Base of Landfill Cells (list layers and corresponding thickness/hydraulic conductivity, starting from the base of landfill)	Sand and Gravel layer 10^{-3} m/s	
B.10	Bedrock Type(s) (uppermost 10m of bedrock for landfills founded in overburden or to a maximum of 30m depth below the base of landfill for landfills cells founded in rock)	N.A.	
B.11	Typical Depth to Groundwater Surface Below Base of Landfill Cells (m)	7-8 m	
B.12	Primary Aquifer Unit (e.g., a specific overburden layer and/or upper fractured bedrock)	N.A.	
B.13	Does Existing Natural (unimpacted) Groundwater in Aquifer Unit Meet Regulatory Requirements for Drinking Water Quality? (Yes or No)	No	
B.14	What are the Current Uses (if any) of Groundwater Within 5 km of the Landfill (e.g., drinking water, agricultural watering, livestock water)?	Agricultural watering	No drinking water wells around the landfill

PART C - WASTE CHARACTERISTICS

	Required Information	Data	Comments/Notes/References
C.17	Waste Pre-Treatment Processes (e.g., source separation, shredding, composting, anaerobic digestion, etc.)	- Residual waste after source separation of recyclables and yard wastes - Mild shredding to open bags, - Screening to remove >100 mm size fraction for RDF - Magnetic separation of metals - Aerobic stabilization by compositing (indoors) with forced air flow for two week period (windrows are not turned). Off-gases are treated by bio-filter - Drying by bio-dessication which involves forced air flow force through 4 m to 6 m thick windrows for 15-18 days (loose between 15% and 20% in bulk weight due to moisture loss) - Further sorting of treated waste to remove low - degradable RDF (required by final destination, cement kiln)	MBT Plant on-site
C.18	Organic Matter Content of As-Received Waste (% dry weight basis)	N.A.	Static respirometric index : < 400 mg O_2/kg VS^{-}/ h^{-}
C.19	Primary Components of Landfilled Waste (e.g., C&D wastes, plastics, glass, metal, wood, soil, textiles-indicate measured or estimated percentages by dry weight for each)	N.A.	
C.20	Particle Size Range of As-Received Waste (mm)	N.A.	

STABILIZED WASTE LANDFILL DATA
SITE: Villafalletto, Piemonte, Italy
November 2006

	Required Information	Data	Comments/Notes/References
C.21	Elemental Composition of As-Received Waste C_{total} (g/kg dry wt. basis) $C_{organic}$ N_{total} $N_{organic}$ S Fe Cl Ca Na Pb Cd Zn Moisture	N.A.	
C.22	Maximum Leachable BOD (g/kg dry wt. basis)	N.A.	
C.23	Maximum Leachable COD (g/kg dry wt. basis)	N.A.	
C.24	In-place Apparent Waste Density (tonnes of in-place waste per m^3 of landfill air space volume)	0.6 t/m^3	

PART D - WASTE CONTAINMENT

	Required Information	Data	Comments/Notes/References
D.13	Base Liner Profile (indicate layer types/thickness from top down)	Geotextile 400 gr/m^2 HDPE 2 mm Geotextile 400 gr/m^2 HDPE 2 mm 100 cm Clay 10^{-9} m/s	On slopes: Geotextile 400 gr/m^2 HDPE 2 mm Geosynthetic Clay Liner Geotextile 400 gr/m^2 HDPE 2 mm 60 cm Clay 10^{-9} m/s
D.14	Components of Leachate Collection System (indicate layer types/thicknesses from top down, perforated pipe diameter/spacing)	Primary LCS 30 cm gravel with HDPE pipes (160 and 200 mm) at variable spacing (< 20 m) Secondary LCS 50 cm drainage layer HDPE pipes (160 and 200 mm) - Variable spacing (< 20 m)	
D.15	Components of Final Cover System (indicate material types/thicknesses from top down)	100 cm cover soil 50 cm drainage sand 50 cm clay 10^{-6} cm/s 50 cm biogas venting layer	A key objective of final cover is to minimize infiltration and hence leachate generation. European directive requires 2.5 m thick final cover comprised of barrier, drainage, vegetative and gas venting layers.
D.16	Percentage of Approved Fill Area Currently Capped with Final Cover (%)	0%	
D.17	Type(s) of Daily Cover (e.g., soil, C&D waste, tarps etc.)	Drainage inert material (gravel) and/or grinded inert waste	
D.18	Waste: Daily Cover Ratio	5%	By volume No regulatory standard

PART E - LEACHATE QUALITY/MANAGEMENT

	Required Information	Data			Comments/Notes/References
E.1	Raw leachate Quality (approx. representative peak concentration-mg/L based on available monitoring data, except where noted)				
	pH (give range of values)	pH		7.25-7.63	
	Conductivity (µS/cm)	Cond. Spec.	*mS/cm*	3.49	
	Total Dissolved Solids	COD	*mg/l*	1670	
	Alkalinity	BOD 5	*mg/l*	700	
	Ammonia-N	Chloride	*mg/l*	278	
	Total Kjeldahl Nitrogen	Sulphate	*mg/l*	27.6	
	Biological Oxygen Demand	Iron	*mg/l*	14.2	
	Chemical Oxygen Demand	Manganese	*mg/l*	2.63	
	Dissolved Organic Carbon	Arsenic	*mg/l*	0.003	
	Phenols	Copper	*mg/l*	1.44	
	Arsenic	Cadmium	*mg/l*	0.005	
	Barium	Chromium	*mg/l*	8.93	
	Boron	Chromium VI	*mg/l*	< 0,1	
	Cadmium	Mercury	*mg/l*	0.056	
	Calcium	Nickel	*mg/l*	0.57	
	Chloride	Lead	*mg/l*	0.185	
	Chromium	Zinc	*mg/l*	1.44	
	Copper	Ammonia-N	*mg/l*	290	
	Iron	Carcinogenic Aliphatic Chlorinated Solvent *(sum)*	*mg/l*	<0.5	
	Lead	Chloroform	*mg/l*	0.18	
	Magnesium	Dichloromethane	*mg/l*	0.25	
	Mercury Nitrate	Non-Carcinogenic Aliphatic Chlorinated Solvent *(sum)*	*mg/l*	< 0,5	
	Nitrite Phosphorous	Carcinogenic Aliphatic Halogenated Solvent *(sum)*	*mg/l*	< 0,5	
	Potassium	Total Phenols	*mg/l*	0.54	
	Sodium	Aromatic Solvent *(sum)*	*mg/l*	0.86	
	Sulphate	Fluoride	*mg/l*	< 1	
	Zinc	IPA	*mg/l*	< 0,1	
		Total Cyanide	*mg/l*	< 0,01	
		Nitrogen Nitrite	*mg/l*	< 1	

STABILIZED WASTE LANDFILL DATA
SITE: Villafalletto, Piemonte, Italy
November 2006

Required Information		Data	Comments/Notes/References
		Nitrogen Nitrate *mg/l* 0.01 Chlorinated Pesticides *(sum)* *mg/l* < 0,1 Nitrogen Phosphorus Pesticides *(sum)* *mg/l* < 0,1 Organic Nitrogen Compounds *(sum)* ***mg/l*** < 0,1 Chlorinated Solvents ***mg/l*** < 0,5	
	Benzene 1,4-Dichlorobenzene Dichloromethane Toluene Vinyl Chloride	Toluene *mg/l* 0.02 Ethyl benzene *mg/l* 0.58 o- + p-xylen *mg/l* 0.24 m-xylen *mg/l* 0.02	
E.12	Typical Current Leachate Collection Rate (m^3/year)	Max 350-400 m^3/month (~ 3,360 m^3/year assuming 280 m^3/month avg.*) *Average leachate collection rate assumed to be 75% of peak value of 375 m^3/month.	Leachate Collection Rate: = $\frac{3,360\ m^3/year}{3.6\ Ha}$ =93 mm/year (12% of total precip.*) *Total Precipitation ~ 800 mm/year (avg) Low production due to the low water content of the treated waste (i.e. waste adsorbs infiltration)
E.13	Is Collected Leachate Recirculated Through Waste Fill? (if yes, give percentage that is recirculated)	No	
E.14	Is Collected Leachate Discharged to Sanitary Sewer System? (If you give percentage that is discharged to sewer)	No	Leachate is trucked directly to an off-site waste water treatment facility.
E.15	Is Collected Leachate Treated or Pre-Treated On Site? (indicate type of treatment/pre-treatment system and the receptor of the treatment system effluent)	No	

PART F - LANDFILL GAS CHARACTERISTICS/MANAGEMENT

Required Information		Data	Comments/Notes/References
F.11	Method(s) of Landfill Gas Management (e.g., passive venting through cover soils, landfill gas collection/utilization system)	Passive venting	
F.12	Landfill Gas Composition (% by volume) (give ranges) Methane (CH_4) Carbon Dioxide (CO_2) Mercaptans (CHS) Hydrogen Sulphide (H_2S)		Very low gas production No methane detected in air monitoring No specific monitoring in vents
F.13	Are there Complaints of Of-site Odour Impacts? (indicate approximate frequency of complaints)	No	
F.14	Are odour suppressants (other than cover soils) used? (specify types)	No	
F.15	Estimated or Measured Maximum Landfill Gas Generation Rate (m^3/dry kg of waste /year)	N.A.	

NOTES:
Average annual precipitation (mm per year) is 700÷900 mm/year

Appendix B

Completed Survey Questionnaires for Conventional Landfills (Trail Road, Moose Creek)

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

PART A - GENERAL SITE INFORMATION

	Required Information	Data	Comments/Notes/References
A.1	Location (City/Province)	Moose Creek, Ontario	
A.2	Start Date of Landfilling	December 21, 2000	
A.3	Estimated Closure Date	At 200,000 tonnes/year lifespan of 22 years	
A.4	Current Waste Placement Rate (tonnes/year)	200,000 tonnes/year	
A.5	Approved Total Waste Fill Capacity (tonnes or m^3 of waste fill, not including cover soils)	7,400,000m^3	
A.6	Existing Quantity of Waste Fill in Place (tonnes or m^3 of waste fill-not including cover soils)	571,831m^3	
A.7	Approved Waste Fill Area (Ha)	66ha	
A.8	Existing Waste Fill Area (Ha)	13ha	
A.9	Total Site Area Including Buffer Zone (Ha)	200ha	Ratio: $\frac{\text{Total Site Area}}{\text{Approved Fill Area}} = \frac{200\text{ Ha}}{66\text{ Ha}} = 3.0$
A.10	Typical Cell Excavation Depth (average depth of cell below original ground surface)	5 m	
A.11	Approved Maximum Height of Waste Fill Relative to Perimeter Ground Surface (m)	10m	
A.12	Surrounding Land Use (existing)	Rural, agricultural	
A.13	Distance to Nearest Populated Area (km)	Hamlet of Tayside 2.5km to the southeast, Town of Casselman 5.7km to the Northeast	
A.14	Distance to Nearest Residence (km)	1.5km	
A.15	Currently Proposed Post-Closure Land Use	Unknown	
A.16	Applicable Regulations (list titles)	O.Reg. 232/98 O.Reg. 347 Certificate of Approval for a Waste Disposal Site under the EPA Section 27 Certificate of Approval for sewage discharge under the OWRA EPA Section 53.	

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

PART B - GEOLOGICAL/HYDORGEOLOGICAL SETTING

	Required Information	Data	Comments/Notes/References
B.1	Typical Depth to Bedrock Relative to Base of Landfill Cells (m)	19.69 -28.58m	
B.2	Type/Thickness/Hydraulic Conductivity of Overburden Layers Beneath Base of Landfill Cells (list layers and corresponding thickness/hydraulic conductivity, starting from the base of landfill)	-Silty clay 7 to 18m thick $5.5x10^{-8}$ cm/sec -Sand/glacial till 0 to 3 m thick 1 $x10^{-5}$cm/sec -Bedrock (Limestone, Ottawa Formation) 1 $x10^{-4}$ cm/sec	
B.3	Bedrock Type(s) (uppermost 10m of bedrock for landfills founded in overburden or to a maximum of 30m depth below the base of landfill for landfills cells founded in rock)	Ottawa Formation (Limestone)	
B.4	Typical Depth to Groundwater Surface Below Base of Landfill Cells (m)	<0 (hydraulic trap)	
B.5	Primary Aquifer Unit (e.g., a specific overburden layer and/or upper fractured bedrock)	-Glacial Till -Bedrock	
B.6	Does Existing Natural (unimpacted) Groundwater in Aquifer Unit Meet Regulatory Requirements for Drinking Water Quality? (Yes or No)	Typical ODWQS exceedances in Bedrock: Na, TDS, DOC. Typical ODWQS exceedances in Glacial Till: Na, TDS, DOC. Typical ODWQS exceedances in Clay: DOC, Fe, Mn	
B.7	What are the Current Uses (if any) of Groundwater Within 5km of the Landfill (e.g., drinking water, agricultural watering, livestock water)?	Residential, agricultural watering	

PART C - WASTE CHARACTERISTICS

	Required Information	Data	Comments/Notes/References
C.1	Waste Pre-Treatment Processes (e.g., source separation, shredding, composting, anaerobic digestion, etc.)	None	
C.2	Organic Matter Content of As-Received Waste (% dry weight basis)	Unknown	
C.3	Primary Components of As-Received Waste (e.g., C&D wastes, plastics, glass, metal, wood, soil, textiles-indicate measured or estimated percentages by dry weight for each)	MSW and I, C & I	
C.4	Particle Size Range of As-Received Waste (mm)	Unknown	
C.5	Elemental Composition of As-Received Waste C_{total} (g/kg dry wt. basis) $C_{organic}$ N_{total} $N_{organic}$ S Fe Cl Ca Na Pb Cd Zn Moisture	Unknown	
C.6	Maximum Leachable BOD (g/kg dry wt. basis)	Unknown	
C.7	Maximum Leachable COD (g/kg dry wt. basis)	Unknown	
C.8	In-place Apparent Waste Density (tonnes of in-place waste per m^3 of landfill air space volume)	1.01 tonnes/m^3 of air space	

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

PART D - WASTE CONTAINMENT

	Required Information	Data	Comments/Notes/References
D.1	Base Liner Profile (indicate layer types/thickness from top down)	Natural Clay Liner; Perimeter berms lined with GCL	
D.2	Components of Leachate Collection System (indicate layer types/thicknesses from top down, perforated pipe diameter/spacing)	0.15m Sand Filter geotextile 0.3 to 0.5m crushed stone or tire shreds Separator geotextile Leachate collecting pipes 200mm diameter HDPE, 40 m spacing	
D.3	Components of Final Cover System (indicate material types/thicknesses from top down)	0.15 m Topsoil 0.85 m Nominally compacted clayey soil	
D.4	Percentage of Approved Fill Area Currently Capped with Final Cover (%)	5%	
D.5	Type(s) of Daily Cover (e.g., soil, C&D waste, tarps etc.)	Soil, tarps, auto shredder fluff	
D.6	Waste: Daily Cover Ratio	4 to 1	

PART E - LEACHATE QUALITY/MANAGEMENT

	Required Information	Data				Comments/Notes/References
E.1	Raw leachate Quality (approx. representative peak concentration-mg/L based on available monitoring data, except where noted)					Note that peak concentrations may not have been reached yet.
		Max	**Min**	**Average**	**Representative Peak**	
	pH (give range of values)	9.3	6.8	7.4	7.4	
	Conductivity (µS/cm)	33600	1800	11723	30,000	
	Total Dissolved Solids	26900	1760	9194	25,000	
	Alkalinity	14400	956	68	14,000	
	Ammonia-N	292	14.5	151	300	
	Total Kjeldahl Nitrogen	373	44.36	180	350	
	Biological Oxygen Demand	2770	93	685	2,000	
	Chemical Oxygen Demand	4030	165	1552	2,800	
	Dissolved Organic Carbon	983	70.2	401	1,000	
	Phenols	1.12	0.016	0.363	1.0	
	Arsenic	1.25	0.003	0.279	1.0	
	Barium	0.51	0.06	0.22	0.5	
	Boron	20.8	1.38	6.56	15	
	Cadmium	0.004	0.0005	0.002*	<0.001	
	Calcium	282	13	136	250	
	Chloride	3380	118	805	1,500	
	Chromium	0.256	0.016	0.072	0.2	
	Copper	0.08	0.006	0.03*	<0.01	
	Iron	9.3	0.07	1.32	10	
	Lead	0.005	0.002	0.004*	<0.01	
	Magnesium	163	18	79	120	
	Mercury	0.0006	0.0006	0.0006*	0.0006	
	Nitrate	6.75	0.36	2.59*	5	
	Nitrite	0	0	0*	<1	
	Phosphorous	112	0.31	19	25	
	Potassium	283	44	153	280	
	Sodium	13000	246	3439	5,000	
	Sulphate	9440	13	1443	5,000	
	Zinc	0.4	0.005	0.129*	<0.1	

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

	Required Information	Data	Comments/Notes/References
	Benzene (µg/L) 1,4-Dichlorobenzene (µg/L) Dichloromethane (µg/L) Toluene (µg/L) Vinyl Chloride (µg/L)	1.4 1 1.2* 1.0 1.2 0.5 0.83* 0.8 204 148 176* 180 64 1.2 30 30 263 11.4 56.3 60 **Note:** * = most or all are ND	
E.2	Typical Current Leachate Collection Rate (m^3/year)	45,157m^3 in 2005	Leachate Generation Rate: = $\frac{45{,}157\ m^3/year}{13\ Ha}$ = 347 mm/yr (~37% total precip.) Total precip. = 945 mm/yr
E.3	Is Collected Leachate Recirculated Through Waste Fill? (if yes, give percentage that is recirculated)	No, although C of A allows.	
E.4	Is Collected Leachate Discharged to Sanitary Sewer System? (If you give percentage that is discharged to sewer)	No	
E.5	Is Collected Leachate Treated or Pre-Treated On Site? (indicate type of treatment/pre-treatment system and the receptor of the treatment system effluent)	Yes	Pilot Treatment Facility – Peat filter and a series of subsurface (SSF) and surface free-flow (SF) constructed wetlands. Sent to dry ditches that flow into Fraser Drain to Moose Creek or spray irrigated to future landfill areas on-site currently forrested.

PART F - LANDFILL GAS CHARACTERISTICS/MANAGEMENT

	Required Information	Data	Comments/Notes/References
F.1	Method(s) of Landfill Gas Management (e.g., passive venting through cover soils, landfill gas collection/utilization system)	Passive venting through cover soils; future plans for active landfill gas collection / utilization.	
F.2	Landfill Gas Composition (% by volume) (give ranges) Methane (CH_4) Carbon Dioxide (CO_2) Mercaptans (CHS) Hydrogen Sulphide (H_2S)	Unknown	
F.3	Are there Complaints of Of-site Odour Impacts? (indicate approximate frequency of complaints)	Yes; odours associated with start-up of new raw leachate holding pond.	
F.4	Are odour suppresents (other than cover soils) used? (specify types)	Yes; Hydrologic Systems Inc. Airstreme Misting System around raw leachate holding pond.	
F.5	Estimated or Measured Maximum Landfill Gas Generation Rate (m^3/dry kg of waste /year)	Unknown	

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

PART A - GENERAL SITE INFORMATION

	Required Information	Data	Comments/Notes/References
A.1	Location (City/Province)	Ottawa, Ontario	
A.2	Start Date of Landfilling	1980	
A.3	Estimated Closure Date	2018 or 2048 Most likely range 2028 to 2040	Based on ten to forty years of site life from "Trail Waste Facility Landfill Optimization/Expansion Project; Appendix B – Hydrogeological and Geotechnical Studies and Assessment of Leachate Containment Requirements" March 2002. Variation depends on the amount of diversion and the disposal rate.
A.4	Current Waste Placement Rate (tonnes/year)	203,000 tonnes/year	"Trail and Nepean Landfill Sites, Report for the 2000 Monitoring and Operating Program" May 2001 proposed planning placement rate.
A.5	Approved Total Waste Fill Capacity (tonnes or m^3 of waste fill, not including cover soils)	16,988,422 m^3 (excludes composite liner and leachate collection system but includes final cover) 13,002,738 m^3 (approximate without cover soils)	CofA # A461303 dated May 16, 2006 16,988,422 – 588,000 final cover = 16,400,422 m^3 16,400,422 – 3,397,684 daily cover = 13,002,738 m^3
A.6	Existing Quantity of Waste Fill in Place (tonnes or m^3 of waste fill-not including cover soils)	As of 2000, approximately 6,740,000 m^3 of airspace consumed	"Trail Waste Facility Landfill Optimization/Expansion Project; EA/EPA Document" March 2002.
A.7	Approved Waste Fill Area (Ha)	87.9 ha	
A.8	Existing Waste Fill Area (Ha)	67.7 ha	
A.9	Total Site Area Including Buffer Zone (Ha) and Site Facilities	150 ha	Ratio: $\frac{\text{Total Site Area}}{\text{Approved Fill Area}} = \frac{150\text{ Ha}}{88\text{ Ha}} = 1.7$
A.10	Typical Cell Excavation Depth (average depth of cell below original ground surface)	3.7 m	Average based on cell excavation depth for each Stage weighted by the Stage area.
A.11	Approved Maximum Height of Waste Fill Relative to Perimeter Ground Surface (m)	28 m	Relation to north (low) perimeter.
A.12	Surrounding Land Use (existing)	General Rural Area Sand and Gravel Resource Area	
A.13	Distance to Nearest Populated Area (km)	Currently 2.6 km	Figure 1.3 "Trail Waste Facility Landfill Optimization/Expansion Project; EA/EPA Document" March 2002.
A.14	Distance to Nearest Residence (km)	1.5 km	Figure 3.1 "Trail Waste Facility Landfill Optimization/ Expansion Project; EA/EPA Document" March 2002.

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

	Required Information	Data	Comments/Notes/References
A.15	Currently Proposed Post-Closure Land Use	Unknown	
A.16	Applicable Regulations (list titles)	O.Reg. 232/98 O.Reg. 347 Certificate of Approval for a Waste Disposal Site under the EPA Section 27 Certificate of Approval (Air) under the EPA Section 6 Certificate of Approval for sewage discharge under the OWRA	

PART B - GEOLOGICAL/HYDORGEOLOGICAL SETTING

	Required Information	Data	Comments/Notes/References
B.8	Typical Depth to Bedrock Relative to Base of Landfill Cells (m)	28 m	
B.9	Type/Thickness/Hydraulic Conductivity of Overburden Layers Beneath Base of Landfill Cells (list layers and corresponding thickness/hydraulic conductivity, starting from the base of landfill)	-upper fine to medium sand / 0 (if no silt and clay deposit present) to 6 m / 2.0×10^{-4} to 2.0×10^{-8} m/s -silt and clay deposit / 0 (if not present) to 22 m / 3.0×10^{-7} to 8.1×10^{-10} m/s -coarse sand and gravel deposit interlayered with fine to medium sand / 2 to 28 m /1.0×10^{-4} to 2.3×10^{-7} m/s (6×10^{-4} m/s based on MODFLOW) -discontinuous silty glacial till / 0 to 6 m -dolostone bedrock	Interpretation and mapping of the surface topography of the clay layer suggests that the clay layer once covered all of a ridge and was eroded in some areas, followed by redeposition of sand and gravel, which was subsequently reworked by wave action. Due to this erosion, the clay is not present beneath large parts of the Trail Landfill site. In areas where windows in the clay are present, it is interpreted that the shallow aquifer is continuous (hydraulically connected) with the deep aquifer.
B.10	Bedrock Type(s) (uppermost 10m of bedrock for landfills founded in overburden or to a maximum of 30m depth below the base of landfill for landfills cells founded in rock)	Dolostone bedrock of the Oxford formation.	Regional studies (Velderman, 1993) suggest that water bearing zones for water supply are typically encountered between 10 to 25 m below the bedrock surface.
B.11	Typical Depth to Groundwater Surface Below Base of Landfill Cells (m)	1.5 m	
B.12	Primary Aquifer Unit (e.g., a specific overburden layer and/or upper fractured bedrock)	The deep aquifer as described in B.4.	
B.13	Does Existing Natural (unimpacted) Groundwater in Aquifer Unit Meet Regulatory Requirements for Drinking Water Quality? (Yes or No)	Yes.	
B.14	What are the Current Uses (if any) of Groundwater Within 5km of the Landfill (e.g., drinking water, agricultural watering, livestock water)?	Drinking water (bedrock aquifer)	

PART C - WASTE CHARACTERISTICS

	Required Information	Data	Comments/Notes/References
C.9	Waste Pre-Treatment Processes (e.g., source separation, shredding, composting, anaerobic digestion, etc.)	Composting of source separated leaf and yard waste currently completed on-site.	
C.10	Organic Matter Content of As-Received Waste (% dry weight basis)		
C.11	Primary Components of As-Received Waste (e.g., C&D wastes, plastics, glass, metal, wood, soil, textiles-indicate measured or estimated percentages by dry weight for each)	MSW and I C & I Waste	
C.12	Particle Size Range of As-Received Waste (mm)		
C.13	Elemental Composition of As-Received Waste C_{total} (g/kg dry wt. basis) $C_{organic}$ N_{total} $N_{organic}$ S Fe Cl Ca Na Pb Cd Zn Moisture		
C.14	Maximum Leachable BOD (g/kg dry wt. basis)		
C.15	Maximum Leachable COD (g/kg dry wt. basis)		
C.16	In-place Apparent Waste Density (tonnes of in-place waste per m^3 of landfill air space volume)	0.75 tonnes / m^3	

PART D - WASTE CONTAINMENT

	Required Information	Data	Comments/Notes/References
D.7	Base Liner Profile (indicate layer types/thickness from top down)	Stage 1 – none Stage 2 – none Stage 3 – 400 g/m^2 non-woven geotextile, 80 mil HDPE geomembrane; 0.6 m compacted clay liner (existing) Stage 4 – 1200 g/m^2 non-woven geotextile, 80 mil HDPE geomembrane; 0.6 m compacted clay liner (existing) Stage 5 – 80 mil HDPE geomembrane; GCL (proposed)	
D.8	Components of Leachate Collection System (indicate layer types/thicknesses from top down, perforated pipe diameter/spacing)	Stages 3 and 4 existing – contoured subgrade with 200 mm diameter leachate collection piping on 30 m centres within a granular drainage blanket; base sloped at a 2% lateral cross-fall towards the piping; the entire Stage drains northerly at a 0.5% longitudinal gradient. In Stage 3 the collection header is external, north of the containment cell. In Stage 4 the leachate collection lines enter sumps inside the cell from which leachate is removed by pumping. In Stage 3, the drainage blanket consists of 600 mm of 19 mm clean stone; the leachate collection pipes are within a 1.5 m width of 62 mm clear stone drainage envelope	

	Required Information	Data	Comments/Notes/References
		whose thickness is 0.9 m. In Stage 4, the drainage blanket consists of 600 mm of 25 mm clear stone, with the leachate collection pipes within a drainage envelope as described above. Stage 5 – proposed similar to Stages 3 and 4	
D.9	Components of Final Cover System (indicate material types/thicknesses from top down)	Stage 1 – low permeability (0.1m vegetated sandy silt, 0.31m sandy silt, 0.3m sand drain, 40 mil HDPE geomembrane, 0.15m sand bedding, non-woven geotextile separator) to be removed for expansion – 750 mm of cover material which incorporates a low-permeability barrier after expansion Stage 2 - low permeability (0.1m vegetated sandy silt, 0.31m sandy silt, 0.3m sand drain, 40 mil VLDPE geomembrane, 0.15m sand bedding, non-woven textile) to be removed for expansion – 750 mm of cover material which incorporates a low-permeability barrier after expansion (not yet designed) Stage 3 – 750 mm of cover material which incorporates a low-permeability barrier (not yet designed) Stage 4 – 750 mm of cover material which incorporates a low-permeability barrier (not yet designed)	CofA # A461303 dated May 16, 2006

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

Required Information		Data	Comments/Notes/References
		Stage 5 – permeable soil cover (0.15m vegetated sandy silt, 0.6m general soil cover)	
D.10	Percentage of Approved Fill Area Currently Capped with Final Cover (%)	Stage 1 (26 ha) and Stage 2 (14.7 ha) have a final cover, however approval for a vertical expansion of Stages 1 through 4 and a horizontal expansion known as Stage 5 was received in 2006. Technically no Stages have the "final" cover at this time.	
D.11	Type(s) of Daily Cover (e.g., soil, C&D waste, tarps etc.)	150 mm soil or automobile shredder residue	
D.12	Waste: Daily Cover Ratio	4:1	"Trail Waste Facility Landfill Optimization/Expansion Project; Appendix M – Design and Operations Report" March 2002.

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

PART E - LEACHATE QUALITY/MANAGEMENT

	Required Information	Data				Comments/Notes/References
E.6	Raw leachate Quality (approx. representative peak concentration-mg/L based on available monitoring data, except where noted)					Data provided from 1996 to 2002.
	PARAMETER (all mg/L)	**Min.**	**Max.**	**Ave.**	**Representative Peak**	
	pH (give range of values)	5.92	8.40	7.07		
	Conductivity (µS/cm)	374	15,200	8,349	15,000	
	Total Dissolved Solids	No Data				
	Alkalinity	584	8,800	4,083	7,000	
	Ammonia-N	7.75	1,830	381	800	
	Total Kjeldahl Nitrogen	0.60	1,250	583	1,000	
	Biological Oxygen Demand (excl. BOD21)	3.00	13,000	3,120	12,000	
	Chemical Oxygen Demand	100	18,000	2,580	10,000	
	Dissolved Organic Carbon	70	7,660	1,873	5,000	
	Phenols (omitted data with unclear units)	0.016	1.020	0.277	5	
	Arsenic	0.001	0.200	0.023	0.1	
	Barium	0.01	1.44	0.58	1.0	
	Boron	0.01	8.80	4.73	7.0	
	Cadmium	0.0002	0.0200	0.0048	0.01	
	Calcium	11.3	12,700	607	1,500	
	Chloride	5	9,700	1,412	2,000	
	Chromium	0.01	0.31	0.08	0.2	
	Copper	0.002	0.450	0.085	0.3	
	Iron	0.23	249	34.35	50	
	Lead	0.0012	1.73	0.0476	0.05	
	Magnesium	2	395	201	350	
	Mercury	0.0001	0.04	0.004	0.004	
	Nitrate	0.10	0.75	0.19	0.2	
	Nitrite	0.10	0.10	0.10	0.1	
	Phosphorous (total)	0.19	17.00	3.17	10	
	Potassium	4	1,330	493	1,000	
	Sodium	5	1,730	896	1,500	
	Sulphate	0.7	680.0	98.3	600	
	Zinc	0.01	6.50	0.98	2	

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

	Required Information	Data	Comments/Notes/References
	PARAMETER (all µg/L) Benzene 1,4-Dichlorobenzene (p-dichlorobenzene) Dichloromethane (methylene chloride) Toluene (methylbenzene) Vinyl Chloride	**Min. Max. Ave. Representative Peak** 0.20 81.00 10.28 35 0.20 33.00 7.10 20 3.00 666.00 53.16 100 0.50 1,940 209.5 1,000 0.50 1,000 37.6 100	
E.7	Typical Current Leachate Collection Rate (m^3/year)	74,000 m^3/year in 2002	Leachate Collection Rate: = 74,000 m^3/yr = 275 mm/year 270,000 m^2 (stg 3&4) (30% total precip.) Total precip. = 945 mm/year
E.8	Is Collected Leachate Recirculated Through Waste Fill? (if yes, give percentage that is recirculated)	Stage 3 – recirculation was facilitated by the use of relocatable polyethylene forcemain piping. The leachate was pumped to open lagoons situated on the surface of the landfill. The lagoon locations were moved periodically to ensure uniform distribution of the leachate. Recirculation of the lechate into the landfilled refuse was practiced from 1991 until 1996.	
E.9	Is Collected Leachate Discharged to Sanitary Sewer System? (If you give percentage that is discharged to sewer)	Leachate collected currently from Stages 3 and 4 and in the future from Stage 5, trucked off-site and 100% discharged to sewage treatment plant.	
E.10	Is Collected Leachate Treated or Pre-Treated On Site? (indicate type of treatment/pre-treatment system and the receptor of the treatment system effluent)	No, not at present, but possibly in the future depending on various factors.	

PART F - LANDFILL GAS CHARACTERISTICS/MANAGEMENT

	Required Information	Data	Comments/Notes/References
F.6	Method(s) of Landfill Gas Management (e.g., passive venting through cover soils, landfill gas collection/utilization system)	A sub-cover grid of horizontal perforated piping initially provided passive gas venting through this low permeability final cover in Stage 1. For Stage 2, a series of existing full refuse depth, gas extraction wells were connected via transmission piping and controls to a gas extraction/flaring facility. The Stage 1 passive vents were capped and the piping system connected to the flare. The facility has a 1200 CFM total design capacity. Stage 3 – existing gas collection at mid-point cleanouts and the south-end manhole access points to the leachate collection piping. A number of temporary gas extraction wells were also installed in both Stages 3 and 4 and connected to the flaring facility. The vertical expansion of Stages 1 to 4, as well as proposed future Stage 5 have been planned on the basis of horizontal gas collection piping placed within the waste as landfilling proceeds. This may be modified to utilize vertical wells. A 5MW generating station is currently under construction at the site and to be commissioned in late 2006/early 2007.	

CONVENTIONAL WASTE LANDFILL DATA
SITE: Trail Road Waste Facility Landfill, Ottawa
November 2006

	Required Information	Data	Comments/Notes/References
F.7	Landfill Gas Composition (% by volume) (give ranges) Methane (CH_4) Carbon Dioxide (CO_2) Mercaptans (CHS) Hydrogen Sulphide (H_2S)	 27.0% 15.5% <0.1 ppm (note hydrogen sulphide/carbonyl sulphide)	Data collected from Stage 1 sample "Trail Waste Facility Landfill Optimization/Expansion Project; Appendix B – Design and Operations Report" March 2002.
F.8	Are there Complaints of Off-site Odour Impacts? (indicate approximate frequency of complaints)	Infrequent.	
F.9	Are odour suppressants (other than cover soils) used? (specify types)	No	
F.10	Estimated or Measured Maximum Landfill Gas Generation Rate (m^3/dry kg of waste /year)	~ 33 cfm per Hectare [~6 $L/m^2/hr$]	Stages 1 to 4 + Stage 5 peak in 2037 = 2,823 + 97 standard cubic feet per minute [Total fill area = 87.9 Ha]

Appendix C

Copy of European Union Directive 1999/31/EC, dated April 26, 1999 on the Landfill of Waste

I

(Acts whose publication is obligatory)

COUNCIL DIRECTIVE 1999/31/EC

of 26 April 1999

on the landfill of waste

THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 130s(1) thereof,

Having regard to the proposal from the Commission [1],

Having regard to the opinion of the Economic and Social Committee [2],

Acting in accordance with the procedure laid down in Article 189c of the Treaty [3],

(1) Whereas the Council resolution of 7 May 1990 [4] on waste policy welcomes and supports the Community strategy document and invites the Commission to propose criteria and standards for the disposal of waste by landfill;

(2) Whereas the Council resolution of 9 December 1996 on waste policy considers that, in the future, only safe and controlled landfill activities should be carried out throughout the Community;

(3) Whereas the prevention, recycling and recovery of waste should be encouraged as should the use of recovered materials and energy so as to safeguard natural resources and obviate wasteful use of land;

(4) Whereas further consideration should be given to the issues of incineration of municipal and non-hazardous waste, composting, biomethanisation, and the processing of dredging sludges;

(5) Whereas under the polluter pays principle it is necessary, *inter alia*, to take into account any damage to the environment produced by a landfill;

(6) Whereas, like any other type of waste treatment, landfill should be adequately monitored and managed to prevent or reduce potential adverse effects on the environment and risks to human health;

(7) Whereas it is necessary to take appropriate measures to avoid the abandonment, dumping or uncontrolled disposal of waste; whereas, accordingly, it must be possible to monitor landfill sites with respect to the substances contained in the waste deposited there, whereas such substances should, as far as possible, react only in foreseeable ways;

(8) Whereas both the quantity and hazardous nature of waste intended for landfill should be reduced where appropriate; whereas the handling of waste should be facilitated and its recovery enhanced; whereas the use of treatment processes should therefore be encouraged to ensure that landfill is compatible with the objectives of this Directive; whereas sorting is included in the definition of treatment;

(9) Whereas Member States should be able to apply the principles of proximity and self-sufficiency for the elimination of their waste at Community and national level, in accordance with Council Directive 75/442/EEC of 15 July 1975 on waste [5] whereas the objectives of this Directive must be pursued and clarified through the establishment of an adequate, integrated network of disposal plants based on a high level of environmental protection;

(10) Whereas disparities between technical standards for the disposal of waste by landfill and the lower costs associated with it might give rise to increased disposal of waste in facilities with low standards of

(1) OJ C 156, 24.5.1997, p. 10.
(2) OJ C 355, 21.11.1997, p. 4.
(3) Opinion of the European Parliament of 19 February 1998 (OJ C 80, 16.3.1998, p. 196), Council common position of 4 June 1998 (OJ C 333, 30.10.1998, p. 15) and Decision of the European Parliament of 3 February 1999 (OJ C 150, 28.5.1999, p. 78)
(4) OJ C 122, 18.5.1990, p. 2.

(5) OJ L 194, 25.7.1975, p. 39. Directive as last amended by Commission Decision 96/350/EC (OJ L 135, 6.6.1996, p. 32).

environmental protection and thus create a potentially serious threat to the environment, owing to transport of waste over unnecessarily long distances as well as to inappropriate disposal practices;

(11) Whereas it is therefore necessary to lay down technical standards for the landfill of waste at Community level in order to protect, preserve and improve the quality of the environment in the Community;

(12) Whereas it is necessary to indicate clearly the requirements with which landfill sites must comply as regards location, conditioning, management, control, closure and preventive and protective measures to be taken against any threat to the environment in the short as well as in the long-term perspective, and more especially against the pollution of groundwater by leachate infiltration into the soil;

(13) Whereas in view of the foregoing it is necessary to define clearly the classes of landfill to be considered and the types of waste to be accepted in the various classes of landfill;

(14) Whereas sites for temporary storage of waste should comply with the relevant requirements of Directive 75/442/EEC;

(15) Whereas the recovery, in accordance with Directive 75/442/EEC, of inert or non-hazardous waste which is suitable, through their use in redevelopment/restoration and filling-in work, or for construction purposes may not constitute a landfilling activity;

(16) Whereas measures should be taken to reduce the production of methane gas from landfills, *inter alia*, in order to reduce global warming, through the reduction of the landfill of biodegradable waste and the requirements to introduce landfill gas control;

(17) Whereas the measures taken to reduce the landfill of biodegradable waste should also aim at encouraging the separate collection of biodegradable waste, sorting in general, recovery and recycling;

(18) Whereeas, because of the particular features of the landfill method of waste disposal, it is necessary to introduce a specific permit procedure for all classes of landfill in accordance with the general licensing requirements already set down in Directive 75/442/EEC and the general requirements of Directive 96/61/EC concerning integrated pollution prevention and control [1] whereas the landfill site's compliance with such a permit must be verified in the course of an inspection by the competent authority before the start of disposal operations;

(19) Whereas, in each case, checks should be made to establish whether the waste may be placed in the landfill for which it is intended, in particular as regards hazardous waste;

(20) Whereas, in order to prevent threats to the environment, it is necessary to introduce a uniform waste acceptance procedure on the basis of a classification procedure for waste acceptable in the different categories of landfill, including in particular standardised limit values; whereas to that end a consistent and standardised system of waste characterisation, sampling and analysis must be established in time to facilitate implementation of this Directive; whereas the acceptance criteria must be particularly specific with regard to inert waste;

(21) Whereas, pending the establishment of such methods of analysis or of the limit values necessary for characterisation, Member States may for the purposes of this Directive maintain or draw up national lists of waste which is acceptable or unacceptable for landfill, or define criteria, including limit values, similar to those laid down in this Directive for the uniform acceptance procedure;

(22) Whereas for certain hazardous waste to be accepted in landfills for non-hazardous waste acceptance criteria should be developed by the technical committee;

(23) Whereas it is necessary to establish common monitoring procedures during the operation and after-care phases of a landfill in order to indentify any possible adverse environmental effect of the landfill and take the appropriate corrective measures;

(24) Whereas it is necessary to define when and how a landfill should be closed and the obligations and responsibility of the operator on the site during the after-care period;

(25) Whereas landfill sites that have been closed prior to the date of transposition of this Directive should not be suject to its provisions on closure procedure;

(26) Whereas the future conditions of operation of existing landfills should be regulated in order to take the necessary measures, within a specified period of time, for their adaptation to this Directive on the basis of a site-conditioning plan;

[1] OJ L 257, 10.10.1996, p. 26.

(27) Whereas for operators of existing landfills having, in compliance with binding national rules equivalent to those of Article 14 of this Directive, already submitted the documentation referred to in Article 14(a) of this Directive prior to its entry into force and for which the competent authority authorised the continuation of their operation, there is no need to resubmit this documentation nor for the competent authority to deliver a new authorisation;

(28) Whereas the operator should make adequate provision by way of a financial security or any other equivalent to ensure that all the obligations flowing from the permit are fulfilled, including those relating to the closure procedure and after-care of the site;

(29) Whereas measures should be taken to ensure that the price charged for waste disposal in a landfill cover all the costs involved in the setting up and operation of the facility, including as far as possible the financial security or its equivalent which the site operator must provide, and the estimated cost of closing the site including the necessary after-care;

(30) Whereas, when a competent authority considers that a landfill is unlikely to cause a hazard to the environment for longer than a certain period, the estimated costs to be included in the price to be charged by an operator may be limited to that period;

(31) Whereas it is necessary to ensure the proper application of the provisions implementing this Directive throughout the Community, and to ensure that the training and knowledge acquired by landfill operators and staff afford them the necessary skills;

(32) Whereas the Commission must establish a standard procedure for the acceptance of waste and set up a standard classification of waste acceptable in a landfill in accordance with the committee procedure laid down in Article 18 of Directive 75/442/EEC;

(33) Whereas adaptation of the Annexes to this Directive to scientific and technical progress and the standardisation of the monitoring, sampling and analysis methods must be adopted under the same committee procedure;

(34) Whereas the Member States must send regular reports to the Commission on the implementation of this Directive paying particular attention to the national strategies to be set up in pursuance of Article 5; whereas on the basis of these reports the Commission shall report to the European Parliament and the Council;

HAS ADOPTED THIS DIRECTIVE

Article 1

Overall objective

1. With a view to meeting the requirements of Directive 75/442/EEC, and in particular Articles 3 and 4 thereof, the aim of this Directive is, by way of stringent operational and technical requirements on the waste and landfills, to provide for measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, from landfilling of waste, during the whole life-cycle of the landfill.

2. In respect of the technical characteristics of landfills, this Directive contains, for those landfills to which Directive 96/61/EC is applicable, the relevant technical requirements in order to elaborate in concrete terms the general requirements of that Directive. The relevant requirements of Directive 96/61/EC shall be deemed to be fulfilled if the requirements of this Directive are complied with.

Article 2

Definitions

For the purposes of this Directive:

(a) '*waste*' means any substance or object which is covered by Directive 75/442/EEC;

(b) '*municipal waste*' means waste from households, as well as other waste which, because of its nature or composition, is similar to waste from household;

(c) '*hazardous waste*' means any waste which is covered by Article 1(4) of Council Directive 91/689/EEC of 12 December 1991 on hazardous waste [1]

(d) '*non-hazardous waste*' means waste which is not covered by paragraph (c);

(e) '*inert waste*' means waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the ecotoxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and/or groundwater;

[1] OJ L 377, 31.12.1991, p. 20. Directive as last amended by Directive 94/31/EC (OJ L 168, 2.7.1994, p. 28);

(f) '*underground storage*' means a permanent waste storage facility in a deep geological cavity such as a salt or potassium mine;

(g) '*landfill*' means a waste disposal site for the deposit of the waste onto or into land (i.e. underground), including:

— internal waste disposal sites (i.e. landfill where a producer of waste is carrying out its own waste disposal at the place of production), and

— a permanent site (i.e. more than one year) which is used for temporary storage of waste,

but excluding:

— facilities where waste is unloaded in order to permit its preparation for further transport for recovery, treatment or dispsal elsewhere, and

— stoarage of waste prior to recovery or treatment for a period less than three years as a general rule, or

— storage of waste prior to disposal for a period less than one year;

(h) '*treatment*' means the physical, thermal, chemical or biological processes, including sorting, that change the characteristics of the waste in order to reduce its volume or hazardous nature, facilitate its handling or enhance recovery;

(i) '*leachate*' means any liquid percolating through the deposited waste and emitted from or contained within a landfill;

(j) '*landfill gas*' means all the gases generated from the landfilled waste;

(k) '*eluate*' means the solution obtained by a laboratory leaching test;

(l) '*operator*' means the natural or legal person responsible for a landfill in accordance with the internal legislation of the Member State where the landfill is located; this person may change from the preparation to the after-care phase;

(m) '*biodegradable waste*' means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard;

(n) '*holder*' means the producer of the waste or the natural or legal person who is in possession of it;

(o) '*applicant*' means any person who applies for a landfill permit under this Directive;

(p) '*competent authority*' means that authority which the Member States designate as responsible for performing the duties arising from this Directive;

(q) '*liquid waste*' means any waste in liquid form including waste waters but excluding sludge;

(r) '*isolated settlement*' means a settlement:

— with no more than 500 inhabitants per municipality or settlement and no more than five inhabitants per square kilometre and,

— where the distance to the nearest urban agglomeration with at least 250 inhabitants per square kilometre is not less than 50 km, or with difficult access by road to those nearest agglomerations, due to harsh meteorological conditions during a significant part of the year.

Article 3

Scope

1. Member States shall apply this Directive to any landfill as defined in Article 2(g).

2. Without prejudice to existing Community legislation, the following shall be excluded from the scope of this Directive:

— the spreading of sludges, including sewage sludges, and sludges resulting from dredging operations, and similar matter on the soil for the purposes of fertilisation or improvement,

— the use of inert waste which is suitable, in redevelopment/restoration and filling-in work, or for construction purposes, in landfills,

— the deposit of non-hazardous dredging sludges alongside small waterways from where they have been dredged out and of non-hazardous sludges in surface water including the bed and its sub soil,

— the deposit of unpolluted soil or of non-hazardous inert waste resulting from prospecting and extraction, treatment, and storage of mineral resources as well as from the operation of quarries.

3. Without prejudice to Directive 75/442/EEC Member States may declare at their own option, that the deposit of non-hazardous waste, to be defined by the committee established under Article 17 of this Directive, other than inert waste, resulting from prospecting and extraction, treatment and storage of mineral resources as well as from the operation of quarries and which are deposited in a manner preventing environmental pollution or harm to human health, can be exempted from the provisions in Annex I, points 2, 3.1, 3.2 and 3.3 of this Directive.

4. Without prejudice to Directive 75/442/EEC Member States may declare, at their own option, parts or all of Articles 6(d), 7(i), 8(a)(iv), 10, 11(1)(a), (b) and (c), 12(a) and (c), Annex I, points 3 and 4, Annex II (except point 3, level 3, and point 4) and Annex III, points 3 to 5 to this Directive not applicable to:

(a) landfill sites for non-hazardous or inert wastes with a total capacity not exceeding 15 000 tonnes or with an annual intake not exceeding 1 000 tonnes serving islands, where this is the only landfill on the island and where this is exclusively destined for the disposal of waste generated on that island. Once the total capacity of that landfill has been used, any new landfill site established on the island shall comply with the requirements of this Directive;

(b) landfill sites for non-hazardous or inert waste in isolated settlements if the landfill site is destined for the disposal of waste generated only by that isolated settlement.

Not later than two years after the date laid down in Article 18(1), Member States shall notify the Commission of the list of islands and isolated settlements that are exempted. The Commission shall publish the list of islands and isolated settlements.

5. Without prejudice to Directive 75/442/EEC Member States may declare, at their own option, that underground storage as defined in Article 2(f) of this Directive can be exempted from the provisions in Article 13(d) and in Annex I, point 2, except first indent, points 3 to 5 and in Annex III, points 2, 3 and 5 to this Directive.

Article 4

Classes of landfill

Each landfill shall be classified in one of the following classes:

— landfill for hazardous waste,

— landfill for non-hazardous waste,

— landfill for inert waste.

Article 5

Waste and treatment not acceptable in landfills

1. Member States shall set up a national strategy for the implementation of the reduction of biodegradable waste going to landfills, not later than two years after the date laid down in Article 18(1) and notify the Commission of this strategy. This strategy should include measures to achieve the targets set out in paragraph 2 by means of in particular, recycling, composting, biogas production or materials/energy recovery. Within 30 months of the date laid down in Article 18(1) the Commission shall provide the European Parliament and the Council with a report drawing together the national strategies.

2. This strategy shall ensure that:

(a) not later than five years after the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 75 % of the total amount (by weight) of biodegradable municipal waste produced in 1995 or the latest year before 1995 for which standardised Eurostat data is available

(b) not later than eight years afte the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 50 % of the total amount (by weight) of biodegradable municipal waste produced in 1995 or the latest year before 1995 for which stadardised Eurostat data is available;

(c) not later than 15 years after the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 35 % of the total amount (by weight) of biodegradable municipal waste produced in 1995 or the lates year before 1995 for which standardised Eurostat data is available.

Two years before the date referred to in paragraph (c) the Council shall reexamine the above target, on the basis of a report from the Commission on the practical experience gained by Member States in the pursuance of the targets laid down in paragraphs (a) and (b) accompanied, if appropriate, by a proposal with a view to confirming or amending this target in order to ensure a high level of environmental protection.

Member States which in 1995 or the latest year before 1995 for which standardised EUROSTAT data is available put more than 80 % of their collected municipal waste to landfill may postpone the attainment of the targets set out in paragraphs (a), (b), or (c) by a period not exceeding four years. Member States intending to make use of this provision shall inform in advance the Commission of their decision. The Commission shall inform other Member States and the European Parliament of these decisions.

The implementation of the provisions set out in the preceding subparagraph may in no circumstances lead to the attainment of the target set out in paragraph (c) at a date later than four years after the date set out in paragraph (c).

3. Member States shall take measures in order that the following wastes are not accepted in a landfill:

(a) liquid waste;

(b) waste which, in the conditions of landfill, is explosive, corrosive, oxidising, highly flammable or flammable, as defined in Annex III to Directive 91/689/EEC;

(c) hospital and other clinical wastes arising from medical or veterinary establishments, which are infectious as defined (property H9 in Annex III) by Directive 91/689/EEC and waste falling within category 14 (Annex I.A) of that Directive.

(d) whole used tyres from two years from the date laid down in Article 18(1), excluding tyres used as engineering material, and shredded used tyres five years from the date laid down in Article 18(1) (excluding in both instances bicylce tyres and tyres with an outside diameter above 1 400 mm);

(e) any other type of waste which does not fulfil the acceptance criteria determined in accordance with Annex II.

4. The dilution of mixture of waste solely in order to meet the waste acceptance criteria is prohibited.

Article 6

Waste to be accepted in the different classes of landfill

Member States shall take measures in order that:

(a) only waste that has been subject to treatment is landfilled. This provision may not apply to inert waste for which treatment is not technically feasible, nor to any other waste for which such treatment does not contribute to the objectives of this Directive, as set out in Article 1, by reducing the quantity of the waste or the hazards to human health or the environment;

(b) only hazardous waste that fulfils the criteria set out in accordance with Annex II is assigned to a hazardous landfill;

(c) landfill for non-hazardous waste may be used for:

(i) municipal waste;

(ii) non-hazardous waste of any other origin, which fulfil the criteria for the acceptance of waste at landfill for non-hazardous waste set out in accordance with Annex II;

(iii) stable, non-reactive hazardous wastes (e.g. solidified, vitrified), with leaching behaviour equivalent to those of the non-hazardous wastes referred to in point (ii), which fulfil the relevant acceptance criteria set out in accordance with Annex II. These hazarouds wastes shall not be deposited in cells destined for biodegradable non-hazardous waste,

(d) inert waste landfill sites shall be used only for inert waste.

Article 7

Application for a permit

Member States shall take measures in order that the application for a landfill permit must contain at least particulars of the following:

(a) the identity of the applicant and of the operator when they are different entities;

(b) the description of the types and total quantity of waste to be deposited;

(c) the proposed capacity of the disposal site;

(d) the description of the site, including its hydrogeological and geological characteristics;

(e) the proposed methods for pollution prevention and abatement;

(f) the proposed operation, monitoring and control plan;

(g) the proposed plan for the closure and after-care procedures;

(h) where an impact assessment is required under Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment ([1]), the information provided by the developer in accordance with Article 5 of that Directive;

(i) the financial security by the applicant, or any other equivalent provision, as required under Article 8(a)(iv) of this Directive.

Following a successful application for a permit, this information shall be made available to the competent national and Community statistical authorities when requested for statistical purposes.

Article 8

Conditions of the permit

Member States shall take measures in order that:

(a) the competent authority does not issue a landfill permit unless it is satisfied that:

(i) without prejudice to Article 3(4) and (5), the landfill project complies with all the relevant requirements of this Directive, including the Annexes;

([1]) OJ L 175, 5.7.1985, p. 40. Directive as amended by Directive 97/11/EC (OJ L 73, 14.3.1997, p. 5).

(ii) the management of the landfill site will be in the hands of a natural person who is technically competent to manage the site; professional and technical development and training of landfill operators and staff are provided;

(iii) the landfill shall be operated in such a manner that the necessary measures are taken to prevent accidents and limit their consequences;

(iv) adequate provisions, by way of a financial security or any other equivalent, on the basis of modalities to be decided by Member States, has been or will be made by the applicant prior to the commencement of disposal operations to ensure that the obligations (including after-care provisions) arising under the permit issued under the provisions of this Directive are discharged and that the closure procedures required by Article 13 are followed. This security or its equivalent shall be kept as long as required by maintenance and after-care operation of the site in accordance with Article 13(d). Member States may declare, at their own option, that this point does not apply to landfills for inert waste;

(b) the landfill project is in line with the relevant waste management plan or plans referred to in Article 7 of Directive 75/442/EEC;

(c) prior to the commencement of disposal operations, the competent authority shall inspect the site in order to ensure that it complies with the relevant conditions of the permit. This will not reduce in any way the responsibility of the operator under the conditions of the permit.

Article 9

Content of the permit

Specifying and supplementing the provisions set out in Article 9 of Directive 75/442/EEC and Article 9 of Directive 96/61/EC, the landfill permit shall state at least the following:

(a) the class of the landfill;

(b) the list of defined types and the total quantity of waste which are authorised to be deposited in the landfill;

(c) requirements for the landfill preparations, landfilling operations and monitoring and control procedures, including contingency plans (Annex III, point 4.B), as well as provisional requirements for the closure and after-care operations;

(d) the obligation on the applicant to report at least annually to the competent authority on the types and quantities of waste disposed of and on the results of the monitoring programme as required in Articles 12 and 13 and Annex III.

Article 10

Cost of the landfill of waste

Member States shall take measures to ensure that all of the costs involved in the setting up and operation of a landfill site, including as far as possible the cost of the financial security or its equivalent referred to in Article 8(a)(iv), and the estimated costs of the closure and after-care of the site for a period of at least 30 years shall be covered by the price to be charged by the operator for the disposal of any type of waste in that site. Subject to the requirements of Council Directive 90/313/EEC of 7 June 1990 on the freedom of access to information on the environment [1]Member States shall ensure transparency in the collection and use of any necessary cost information.

Article 11

Waste acceptance procedures

1. Member States shall take measures in order that prior to accepting the waste at the landfill site:

(a) before or at the time of delivery, or of the first in a series of deliveries, provided the type of waste remains unchanged, the holder or the operator can show, by means of the approprate documentation, that the waste in question can be accepted at that site according to the conditions set in the permit, and that it fulfils the acceptance criteria set out in Annex II;

(b) the following reception procedures are respected by the operator:

— checking of the waste documentation, including those documents required by Article 5(3) of Directive 91/689/EEC and, where they apply, those required by Council Regulation (EEC) No 259/93 of 1 February 1993 on the supervision and control of shipments of waste within, into and out of the European Community [2];

— visual inspection of the waste at the entrance and at the point of deposit and, as appropriate, verification of conformity with the description provided in the documentation submitted by the holder. If representative samples have to be taken in order to implement Annex II, point 3, level 3, the results of the analyses shall be kept and the sampling shall be made in conformity with Annex II, point 5. These samples shall be kept at least one month;

— keeping a register of the quantities and characteristics of the waste deposited, indicating origin, date of delivery, identity of the producer or collector in the case of municipal waste, and, in the case of hazardous

(1) OJ L 158, 23.6.1990, p. 56.

(2) OJ L 30, 6.2.1993, p. 1. Regulation as amended by Regulation (EC) No 120/97 (OJ L 22, 24.1.1997, p. 14).

waste, the precise location on the site. This information shall be made available to the competent national and Community statistical authorities when requested for statistical purposes;

(c) the operator of the landfill shall always provide written acknowledgement of receipt of each delivery acepted on the site;

(d) without prejudice to the provisions of Regulation (EEC) No 259/93, if waste is not accepted at a landfill the operator shall notify without delay the competent authority of the non-acceptance of the waste.

2. For landfill sites which have been exempted from provisions of this Directive by virtue of Article 3(4) and (5), Member States shall take the necessary measures to provide for:

— regular visual inspection of the waste at the point of deposit in order to ensure that only non-hazardous waste from the island or the isolated settlement is accepted at the site; and

— a register on the quantities of waste that are deposited at the site be kept.

Member States shall ensure that information on the quantities and, where possible, the type of waste going to such exempted sites forms part of the regular reports to the Commission on the implementation of the Directive.

Article 12

Control and monitoring procedures in the operational phase

Member States shall take measures in order that control and monitoring procedures in the operational phase meet at least the following requirements:

(a) the operator of a landfill shall carry out during the operational phase a control and monitoring programme as specified in Annex III;

(b) the operator shall notify the competent authority of any significant adverse environmental effects revealed by the control and monitoring procedures and follow the decision of the competent authority on the nature and timing of the corrective measures to be taken. These measures shall be undertaken at the expense of the operator.

At a frequency to be determined by the competent authority, and in any event at least once a year, the operator shall report, on the basis of aggregated data, all monitoring results to the competent authorities for the purpose of demonstrating compliance with permit conditions and increasing the knowledge on waste behaviour in the landfills;

(c) the quality control of the analytical operations of the control and monitoring procedures and/or of the analyses referred to in Article 11(1)(b) are carried out by competent laboratories.

Article 13

Closure and after-care procedures

Member States shall take measures in order that, in accordance, where appropriate, with the permit:

(a) a landfill or part of it shall start the closure procedure:

(i) when the relevant conditions stated in the permit are met; or

(ii) under the authorisation of the competent authority, at the request of the operator; or

(iii) by reasoned decision of the competent authority;

(b) a landfill or part of it may only be considered as definitely closed after the competent authority has carried out a final on-site inspection, has assessed all the reports submitted by the operator and has communicated to the operator its approval for the closure. This shall not in any way reduce the responsibility of the operator under the conditions of the permit;

(c) after a landfill has been definitely closed, the operator shall be responsible for its maintenance, monitoring and control in the after-care phase for as long as may be required by the competent authority, taking into account the time during which the landfill could present hazards.

The operator shall notify the competent authority of any significant adverse environmental effects revealed by the control procedures and shall follow the decision of the competent authority on the nature and timing of the corrective measures to be taken;

(d) for as long as the competent authority considers that a landfill is likely to cause a hazard to the environment and without prejudice to any Community or national legislation as regards liability of the waste holder, the operator of the site shall be responsible for monitoring and analysing landfill gas and leachate from the site and the groundwater regime in the vicinity of the site in accordance with Annex III.

Article 14

Existing landfill sites

Member States shall take measures in order that landfills which have been granted a permit, or which are already in operation at the time of transposition of this Directive, may not continue to operate unless the steps outlined below are accomplished as soon as possible and within eight years after the date laid down in Article 18(1) at the latest:

(a) with a period of one year after the date laid down in Article 18(1), the operator of a landfill shall prepare and present to the competent authorities, for their approval, a conditioning plan for the site including the particulars listed in Article 8 and any corrective measures which the operator considers will be needed in order to comply with the requirements of this Directive with the exception of the requirements in Annex I, point 1;

(b) following the presentation of the conditioning plan, the competent authorities shall take a definite decision on whether operations may continue on the basis of the said conditioning plan and this Directive. Member States shall take the necessary measures to close down as soon as possible, in accordance with Article 7(g) and 13, sites which have not been granted, in accordance with Article 8, a permit to continue to operate;

(c) on the basis of the approved site-conditioning plan, the competent authority shall authorise the necessary work and shall lay down a transitional period for the completion of the plan. Any existing landfill shall comply with the requirements of this Directive with the exception of the requirements in Annex I, point 1 within eight years after the date laid down in Article 18(1);

(d) (i) within one year after the date laid down in Article 18(1), Articles 4, 5, and 11 and Annex II shall apply to landfills for hazardous waste;

(ii) within three years after the date laid down in Article 18(1), Article 6 shall apply to landfills for hazardous waste.

Article 15

Obligation to report

At intervals of three years Member States shall send to the Commission a report on the implementation of this Directive, paying particular attention to the national strategies to be set up in pursuance of Article 5. The report shall be drawn up on the basis of a questionnaire or outline drafted by the Commission in accordance with the procedure laid down in Article 6 of Directive 91/692/EEC ([1]) The questionnaire or outline shall be sent to Member States six months before the start of the period covered by the report. The report shall be sent to the Commission within nine months of the end of the three-year period covered by it.

The Commission shall publish a Community report on the implementation of this Directive within nine months of receiving the reports from the Member States.

Article 16

Committee

Any amendments necessary for adapting the Annexes to this Directive to scientific and technical progress and any proposals for the standardisation of control, sampling and analysis methods in relation to the landfill of waste shall be adopted by the Commission, assisted by the Committee established by Article 18 of Directive 75/442/EEC and in accordance with the procedure set out in Article 17 of this Directive. Any amendments to the Annexes shall only be made in line with the principles laid down in this Directive as expressed in the Annexes. To this end, as regards Annex II, the following shall be observed by the Committee: taking into account the general principles and general procedures for testing and acceptance criteria as set out in Annex II, specific criteria and/or test methods and associated limit values should be set for each class of landfill, including if necessary specific types of landfill within each class, including underground storage. Proposals for the standardisation of control, sampling and analysis methods in relation to the Annexes of this Directive shall be adopted by the Commission, assisted by the Committee, within two years after the entry into force of this Directive.

The Commission, assisted by the Committee, will adopt provisions for the harmonisation and regular transmission of the statistical date referred to in Articles 5, 7 and 11 of this Directive, within two years after the entry into force of this Directive, and for the amendments of such provisions when necessary.

Article 17

Committee procedure

The Commission shall be assisted by a Committee composed of the representatives of the Member States and chaired by the representative of the Commission.

The representative of the Commission shall submit to the Committee a draft of the measures to be taken. The Committee shall deliver its opinion on the draft within a time limit which the chairman may lay down according to the urgency of the matter. The opinion shall be delivered by the majority laid down in Article 148(2) of the Treaty in the case of decisions which the Council is required to adopt on a proposal from the Commission. The votes of the representatives of the Member States within the Committee shall be weighted in the manner set out in that Article. The chairman shall not vote.

The Commission shall adopt the measures envisaged if they are in accordance with the opinion of the Committee.

If the measures envisaged are not in accordance with the opinion of the Committee, or if no opinion is delivered, the Commission shall, without delay, submit to the Council a proposal relating to the measures to be taken. The Council shall act by a qualified majority.

If on the expiry of a period of three months from the date of referral to the Council, the Council has not acted, the proposed measures shall be adopted by the Commission.

([1]) OJ L 377, 31.12.1991, p. 48.

Article 18

Transposition

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive not later than two years after its entry into force. They shall forthwith inform the Commission thereof.

When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such a reference shall be laid down by Member States.

2. Member States shall communicate the texts of the provisions of national law which they adopt in the field covered by this Directive to the Commission.

Article 19

Entry into force

This Directive will enter into force on the day of its publication in the *Official Journal of the European Communities*.

Article 20

Addressees

This Directive is addressed to the Member States.

Done at Luxembourg, 26 April 1999.

For the Council

The President

J. FISCHER

ANNEX I

GENERAL REGUIREMENTS FOR ALL CLASSES OF LANDFILLS

1. **Location**

1.1. The location of a landfill must take into consideration requirements relating to:

(a) the distances from the boundary of the site to residential and recreation areas, waterways, water bodies and other agricultural or urban sites;

(b) the existence of groundwater, coastal water or nature protection zones in the area;

(c) the geological and hydrogeological conditions in the area;

(d) the risk of flooding, subsidence, landslides or avalanches on the site;

(e) the protection of the nature or cultural patrimony in the area.

1.2. The landfill can be authorised only if the characteristics of the site with respect to the abovementioned requirements, or the corrective measures to be taken, indicate that the landfill does not pose a serious environmental risk.

2. **Water control and leachate management**

Appropriate measures shall be taken, with respect to the characteristics of the landfill and the meteorological conditions, in order to:

— control water from precipitations entering into the landfill body,

— prevent surface water and/or groundwater from entering into the landfilled waste,

— collect contaminated water and leachate. If an assessment based on consideration of the location of the landfill and the waste to be accepted shows that the landfill poses no potential hazard to the environment, the competent authority may decide that this provision does not apply,

— treat contaminated water and leachate collected from the landfill to the appropriate standard required for their discharge.

The above provisions may not apply to landfills for inert waste.

3. **Protection of soil and water**

3.1. A landfill must be situated and designed so as to meet the necessary conditions for preventing pollution of the soil, groundwater or surface water and ensuring efficient collection of leachate as and when required according to Section 2. Protection of soil, groundwater and surface water is to be achieved by the combination of a geological barrier and a bottom liner during the operational/active phase and by the combination of a geological barrier and a bottom liner during the operational/active phase and by the combination of a geological barrier and a top liner during the passive phase/post closure.

3.2. The geological barrier is determined by geological and hydrogeological conditions below and in the vicinity of a landfill site providing sufficient attenuation capacity to prevent a potential risk to soil and groundwater.

The landfill base and sides shall consist of a mineral layer which satisfies permeability and thickness requirements with a combined effect in terms of protection of soil, groundwater and surface water at least equivalent to the one resulting from the following requirements:

— landfill for hazardous waste: $K \leq 1,0 \times 10^{-9}$ m/s; thickness ≥ 5 m,

— landfill for non-hazardous waste: $K \leq 1,0 \times 10^{-9}$ m/s; thickness ≥ 1 m,

— landfill for inert waste: $K \leq 1,0 \times 10^{-7}$ m/s; thickness ≥ 1 m,

m/s: meter/second.

Where the geological barrier does not naturally meet the above conditions it can be completed artificially and reinforced by other means giving equivalent protection. An artificially established geological barrier should be no less than 0,5 metres thick.

3.3. In addition to the geological barrier described above a leachate collection and sealing system must be added in accordance with the following principles so as to ensure that leachate accumulation at the base of the landfill is kept to a minimum:

Leachate collection and bottom sealing

Landfill category	non hazardous	hazardous
Artificial sealing liner	required	required
Drainage layer ≥ 0,5 m	required	required

Member States may set general or specific requirements for inert waste landfills and for the characteristics of the abovementioned technical means.

If the competent authority after a consideration of the potential hazards to the environment finds that the prevention of leachate formation is necessary, a surface sealing may be prescribed. Recommendations for the surface sealing are as follows:

Landfill category	non hazardous	hazardous
Gas drainage layer	required	not required
Artificial sealing liner	not required	required
Impermeable mineral layer	required	required
Drainage layer > 0,5 m	required	required
Top soil cover > 1 m	required	required.

3.4. If, on the basis of an assessment of environmental risks taking into account, in particular, Directive 80/68/EEC [1], the competent authority has decided, in accordance with Section 2 ('Water control and leachate management'), that collection and treatment of leachate is not necessary or it has been established that the landfill poses no potential hazard to soil, groundwater or surface water, the requirements in paragraphs 3.2 and 3.3 above may be reduced accordingly. In the case of landfills for inert waste these requirements may be adapted by national legislation.

3.5. The method to be used for the determination of the permeability coefficient for landfills, in the field and for the whole extension of the site, is to be developed and approved by the Committee set up under Article 17 of this Directive.

4. **Gas control**

4.1. Appropriate measures shall be taken in order to control the accumulation and migration of landfill gas (Annex III).

4.2. Landfill gas shall be collected from all landfills receiving biodegradable waste and the landfill gas must be treated and used. If the gas collected cannot be used to produce energy, it must be flared.

4.3. The collection, treatment and use of landfill gas under paragraph 4.2 shall be carried on in a manner which minimises damage to or deterioration of the environment and risk to human health.

[1] OJ L 20, 26.1.1980, p. 43. Directive as last amended by Directive 91/692/EEC (OJ L 377, 31.12.1991, p. 48).

5. **Nuisances and hazards**

Measures shall be taken to minimise nuisances and hazards arising from the landfill through:

— emissions of odours and dust,

— wind-blown materials,

— noise and traffic,

— birds, vermin and insects,

— formation and aerosols,

— fires.

The landfill shall be equipped so that dirt originating from the site is not dispersed onto public roads and the surrounding land.

6. **Stability**

The emplacement of waste on the site shall take place in such a way as to ensure stability of the mass of waste and associated structures, particularly in respect of avoidance of slippages. Where an artificial barrier is established it must be ascertained that the geological substratum, considering the morphology of the landfill, is sufficiently stable to prevent settlement that may cause damage to the barrier.

7. **Barriers**

The landfill shall be secured to prevent free access to the site. The gates shall be locked outside operating hours. The system of control and access to each facility should contain a programme of measures to detect and discourage illegal dumping in the facility.

ANNEX II

WASTE ACCEPTANCE CRITERIA AND PROCEDURES

1. Introduction

This Annex describes:

— general principles for acceptance of waste at the various classes of landfills. The future waste classification procedure should be based on these principles,

— guidelines outlining preliminary waste acceptance procedures to be followed until a uniform waste classification and acceptance procedure has been developed. This procedure will, together with the relevant sampling procedures, be developed by the technical Committee referred to in Article 16 of this Directive. The technical Committee shall develop criteria which have to be fulfilled for certain hazardous waste to be accepted in landfills for non-hazardous waste. These criteria should, in particular, take into account the short, medium and long term leaching behaviour of such waste. These criteria shall be developed within two years of the entry into force of this Directive. The technical Committee shall also develop criteria which have to be fulfilled for waste to be accepted in underground storage. These criteria must take into account, in particular, that the waste is not to be expected to react with each other and with the rock.

This work by the technical Committee, with the exception of proposals for the standardisation of control, sampling and analysis methods in relation to the Annexes of this Directive which shall be adopted within two years after the entry into force of this Directive, shall be completed within three years from the entry into force of this Directive and must be carried out having regard to the objectives set forth in Article 1 of this Directive.

2. General principles

The composition, leachability, long-term behaviour and general properties of a waste to be landfilled must be known as precisely as possible. Waste acceptance at a landfill can be based either on lists of accepted or refused waste, defined by nature and origin, and on waste analysis methods and limit values for the properties of the waste to be accepted. The future waste acceptance procedures described in this Directive shall as far as possible be based on standardised waste analysis methods and limit values for the properties of waste to be accepted.

Before the definition of such analysis methods and limit values, Member States should at least set national lists of waste to be accepted or refuses at each class of landfill, or defined the criteria required to be on the lists. In order to be accepted at a particular class of landfill, a type of waste must be on the relevant national list or fulfil criteria similar to those required to be on the list. These lists, or the equivalent criteria, and the analysis methods and limit values shall be sent to the Commission within six months of the transposition of this Directive or whenever they are adopted at national level.

These lists or acceptance criteria should be used to establish site specific lists, i.e. the list of accepted waste specified in the permit in accordance with Article 9 of this Directive.

The criteria for acceptance of waste on the reference lists or at a class of landfill may be based on other legislation and/or on waste properties.

Criteria for acceptance at a specific class of landfill must be derived from considerations pertaining to:

— protection of the surrounding environment (in particular groundwater and surface water),

— protection of the environmental protection systems (e.g. liners and leachate treatment systems),

— protection of the desired waste-stabilisation processes within the landfill,

— protection against human-health hazards.

Examples of waste property-based criteria are:

— requirements on knowledge of total composition,

— limitations on the amount of organic matter in the waste,

— requirements or limitations on the biodegradability of the organic waste components,

— limitations on the amount of specified, potentially harmful/hazardous components (in relation to the abovementioned protection criteria),

— limitations on the potential and expected leachability of specified, potentially harmful/hazardous components (in relation to the abovementioned protection criteria),

— ecotoxicological properties of the waste and the resulting leachate.

The property-based criteria for acceptance of waste must generally be most extensive for inert waste landfills and can be less extensive for non-hazardous waste landfills and least extensive for hazardous waste landfills owing to the higher environmental protection level of the latter two.

3. **General procedures for testing and acceptance of waste**

The general characterisation and testing of waste must be based on the following three-level hierarchy:

Level 1: *Basic characterisation*. This constitutes a thorough determination, according to standardised analysis and behaviour-testing methods, of the short and long-term leaching behaviour and/or characteristic properties of the waste.

Level 2: *Compliance testing*. This constitutes periodical testing by simpler standardised analysis and behaviour-testing methods to determine whether a waste complies with permit conditions and/or specific reference criteria. The tests focus on key variables and behaviour identified by basic characterisation.

Level 3: *On-site verification*. This constitutes rapid check methods to confirm that a waste is the same as that which has been subjected to compliance testing and that which is described in the accompanying documents. It may merely consist of a visual inspection of a load of waste before and after unloading at the landfill site.

A particular type of waste must normally be characterised at Level 1 and pass the appropriate criteria in order to be accepted on a reference list. In order to remain on a site-specific list, a particular type of waste must a regular intervals (e.g. annually) be tested at Level 2 and pass the appropriate criteria. Each waste load arriving at the gate of a landfill must be subjected to Level 3 verification.

Certain waste types may be exempted permanently to temporarily from testing at Level 1. This may be due to impracticability to testing, to unavailability of appropriate testing procedures and acceptance criteria or to overriding legislation.

4. **Guidelines for preliminary waste acceptance procedures**

Until this Annex is fully completed only Level 3 testing is mandatory and Level 1 and Level 2 applied to the extent possible. At this preliminary stage waste to be accepted at a particular class of landfill must either be on a restrictive national or site-specific list for that class of landfill or fulfil criteria similar to those required to get on the list.

The following general guidelines may be used to set preliminary criteria for acceptance of waste at the three major classes of landfill or the corresponding lists.

Inert waste landfills: only inert waste as defined in Article 2(e) can be accepted on the list.

Non-hazardous waste landfills: in order to be accepted on the list a waste type must not be covered by Directive 91/689/EEC.

Hazardous waste landfills: a preliminary rough list for hazardous waste landfills would consist of only those waste types covered by Directive 91/689/EEC. Such waste types should, however not be accepted on the list without prior treatment if they exhibit total contents or leachability of potentially hazardous components that are high enough to constitute a short-term occupational or environmental risk or to prevent sufficient waste stabilisation within the projected lifetime of the landfill.

5. **Sampling of waste**

Sampling of waste may pose serious problems with respect to representation and techniques owing to the heterogeneous nature of many wastes. A European standard for sampling of waste will be developed. Until this standard is approved by Member States in accordance with Article 17 of this Directive, the Member States may apply national standards and procedures.

ANNEX III

CONTROL AND MONITORING PROCEDURES IN OPERATION AND AFTER-CARE PHASES

1. Introduction

The purpose of this Annex is to provide the minimum procedures for monitoring to be carried out to check:

— that waste has been accepted to disposal in accordance with the criteria set for the category of landfill in question,

— that the processes within the landfill proceed as desired,

— that the environmental protection systems are functioning fully as intended,

— that the permit conditions for the landfill are fulfilled.

2. Meteorological data

Under their reporting obligation (Article 15), Member States should supply data on the collection method for meteorological data. It us up to Member States to decide how the data should be collected (*in situ*, national meteorological network, etc.).

Should Member States decide that water balances are an effective tool for evaluating whether leachate is building up in the landfill body or whether the site is leaking, it is recommended that the following data are collected from monitoring at the landfill or from the nearest meteorological station, as long as required by the competent authority in accordance with Article 13(c) of this Directive:

	Operation phase	After-care phase
1.1. Volume of precipitation	daily	daily, added to monthly values
1.2. Temperature (min., max., 14.00 h CET)	daily	monthly average
1.3. Direction and force of prevailing wind	daily	not required
1.4. Evaporation (lysimeter) [1]	daily	daily, added to monthly values
1.5. Atmospheric humidity (14.00 h CET)	daily	monthly average

[1] Or through other suitable methods.

3. Emission data: water, leachate and gas control

Sampling of leachate and surface water if present must be collected at representative points. Sampling and measuring (volume and composition) of leachate must be performed separately at each point at which leachate is discharged from the site. Reference: general guidelines on sampling technology, ISO 5667-2 (1991).

Monitoring of surface water is present shall be carried out at not less than two points, one upstream from the landfill and one downstream.

Gas monitoring must be representative for each section of the landfill. The frequency of sampling and analysis is listed in the following table. For leachate and water, a sample, representative of the average composition, shall be taken for monitoring.

The frequency of sampling could be adapted on the basis of the morphology of the landfill waste (in tumulus, buried, etc). This has to be specified in the permit.

	Operating phase	After-care phase (3)
2.1. Leachate volume	monthly (1) (3)	every six months
2.2. Leachate composition (2)	quarterly (3)	every six months
2.3. Volume and composition of surface water (7)	quarterly (3)	every six months
2.4. Potential gas emissions and atmospheric pressure (4) (CH_4, CO_2, O_2, H_2S, H_2 etc.)	monthly (3) (5)	every six months (6)

(1) The frequency of sampling could be adapted on the basis of the morphology of the landfill waste (in tumulus, buried, etc.). This has to be specified in the permit.
(2) The parameters to be measured and the substances to be analysed vary according to the composition of the waste deposited; they must be laid down in the permit document and reflect the leaching characteristics of the wastes.
(3) If the evaluation of data indicates that longer intervals are equally effective, they may be adapted. For leachates, conductivity must always be measured at least once a year.
(4) Thease measurements are related mainly to the content of organic material in the waste.
(5) CH_4, CO_2, O_2, regularly, other gases as required, according to the composition of the waste deposited, with a view to reflecting its leaching properties.
(6) Efficiency of the gas extraction system must be checked regularly.
(7) On the basis of the characteristics of the landfill site, the competent authority may determine that these measurements are not required, and will report accordingly in the way laid down in Article 15 of the Directive.

2.1 and 2.2 apply only where leachate collection takes place (see Annex I(2)).

4. **Protection of groundwater**

A. *Sampling*

The measurements must be such as to provide information on groundwater likely to be affected by the discharging of waste, with at least one measuring point in the groundwater inflow region and two in the outflow region. This number can be increased on the basis of a specific hydrogeological survey and the need for an early identification of accidental leachate release in the groundwater.

Sampling must be carried out in at least three locations before the filling operations in order to establish reference values for future sampling. Reference: Sampling Groundwaters, ISO 5667, Part 11, 1993.

B. *Monitoring*

The parameters to be analysed in the samples taken must be derived from the expected composition of the leachate and the groundwater quality in the area. In selecting the parameters for analysis account should be taken of mobility in the groundwater zone. Parameters could include indicator parameters in order to ensure an early recognition of change in water quality (1).

	Operation phase	After-care phase
Level of groundwater	every six months (1)	every six months (1)
Groundwater composition	site-specific frequency (2) (3)	site-specific frequency (2) (3)

(1) If there are fluctuating groundwater levels, the frequency must be increased.
(2) The frequency must be based on possibility for remedial actions between two samplings if a trigger level is reached, i.e. the frequency must be determined on the basis of knowledge and the evaluation of the velocity of groundwater flow.
(3) When a trigger level is reached (see C), verification is necessary by repeating the sampling. When the level has been confirmed, a contingency plan (laid down in the permit) must be followed.

(1) Recommended parameters: ph, TOC, phenols, heavy metals, fluoride, AS, oil/hydrocarbons.

C. *Trigger levels*

Significant adverse environmental effects, as referred to in Articles 12 and 13 of this Directive, should be considered to have occurred in the case of groundwater, when an analysis of a groundwater sample shows a significant change in water quality. A trigger level must be determined taking account of the specific hydrogeological formations in the location of the landfill and groundwater quality. The trigger level must be laid down in the permit whenever possible.

The observations must be evaluated by means of control charts with established control rules and levels for each downgradient well. The control levels must be determined from local variations in groundwater quality.

5. **Topography of the site: data on the landfill body**

	Operating phase	After-care phase
5.1. Structure and composition of landfill body ([1])	yearly	
5.2. Settling behaviour of the level of the landfill body	yearly	yearly reading

([1]) Data for the status plan of the concerned landfill: surface occupied by waste, volume and composition of waste, methods of depositing, time and duration of depositing, calculation of the remaining capacity still available at the landfill.